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University of Wisconsin-Madison, College of Agricultural and Life Sciences,  
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# Introduction

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

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

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

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



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

Please visit the Nutrient and Pest Management program's website at [ipcm.wisc.edu](http://ipcm.wisc.edu) for more IPM and nutrient management publications.

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# Soil Sampling

## Preplant



Soil sampling is a valuable management tool for proper and efficient soil management. Soil samples should be collected and analyzed before planting vine crops into a field for the first time. Soil sampling should continue annually or as needed. Soil sampling as part of a management plan will help you determine how much fertilizer and soil amendments are needed to ensure crop productivity and environmental sustainability.



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

- ☐ **A. Soil samples are taken to determine soil nutrient, pH, and organic matter levels.**
- ☐ **B. Soil samples are taken in a manner recommended by UWEX.**
- ☐ **C. Soil test results are reviewed, and fertilizer needs are calculated.**
- ☐ **D. Organic matter levels are monitored, and practices that increase the organic matter content are implemented.**

## A. How to sample soil

Taking accurate soil samples is the first step in determining nutrient needs, soil pH, and organic matter levels. The following is detailed information on how to sample soil and submit the soil for testing.

## When to sample

Soil samples may be collected in the fall or in the spring before planting, whichever is most convenient. For early-planted vine crops, a fall sampling time may be necessary to ensure soil test results and fertilizer recommendations are received well before the planting date. Whichever sampling time you choose, you should attempt to be consistent from year to year.

## Sampling equipment

Use a stainless steel soil-sampling probe if you have one. These insert easily into the soil, bringing up a soil “core”. You may be able to borrow a soil sampling probe from your county extension office. You can also use a shovel and trowel. Dig into the soil with the shovel and carefully bring out a vertical slice of the soil, then use the trowel to take a slice of the first 0-6 inches.



Be sure the tools are clean and free from rust. Do not use galvanized steel or brass equipment because they may contaminate the soil samples with metals.

## How to take soil samples

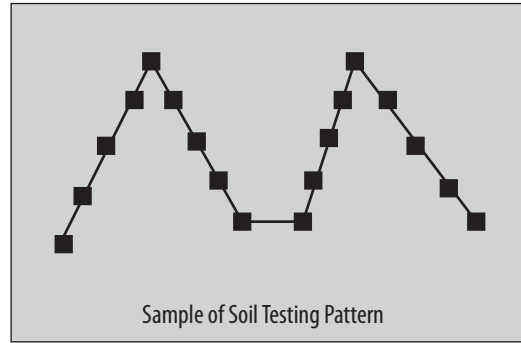
One composite soil sample should be taken for every five acres within the field. A composite sample is a collection of 10-20 soil cores that are mixed together in a plastic or stainless steel bucket. The more soil cores you collect, the more representative the soil sample will be. Walking in a W-shaped sampling pattern is a good technique to use



***Stainless steel soil probe***



### ***Stainless steel soil probe***



to ensure that you are collecting samples that represent the entire field.

If manure or crop residues are on the surface, push them aside. Insert the probe or trowel to plow depth, which is generally considered the top 6 to 8 inches of soil. Sample at the same depth from year to year so that soil test values can be compared accurately over time. Sampling deeper than the tillage layer can result in an underestimation of organic matter, phosphorus, and zinc.

After all of the cores for a field have been collected, mix the soil thoroughly to obtain a composite soil sample. Collect at least two cups of soil into a clean plastic bag (zip-lock bags work well) and discard the remaining soil. Identify the bag with your name, field identification number, and sample number.



### ***Making a composite sample***

If you are growing many different crops in an area of five acres or less, you may want to consider altering your sampling protocol and dividing your fields into smaller management zones. Each management zone would represent an area of the field that is managed differently than other parts of the field in any year. One composite sample would be collected for each management zone. This type of soil sampling protocol is especially beneficial if the management zones differ with respect to the type and intensity of tillage and use of manure or cover crops.

## What to do with the soil samples

Routine soil analysis includes soil pH, soil test

phosphorus, soil test potassium, and soil organic matter content. It should be noted that soil test P and K are not a measure of the total amount of P and K in the soil but instead a measure of the plant available P and exchangeable K in the soil. Soil tests can be requested for calcium, magnesium, and micronutrients as well. Other soil measures such as texture analysis, cation exchange capacity, and total nitrogen can be requested to learn more about your soil system. It is also important to note that nitrogen fertilizer recommendations for vine crops are not based on any soil tests for nitrogen.

which utilizes soil test S and OM%, as well as other estimated S components. For a detailed description of soil test levels see *Optimum Soil Test Levels for Wisconsin* (UW-Extension A3030) and *Nutrient application guidelines for field, vegetable, and fruit crops* (UW-Extension A2809).



### Quick Note

Send your samples to a Wisconsin DATCP certified soil and manure testing laboratory. There are currently seven laboratories that are certified. Certification guarantees that analytical procedures used and nutrient recommendations are based on procedures and guidelines approved by the University of Wisconsin.



### Quick Note

Use the information provided in your soil test to plan your fertility program. Soil test reports from WI DATCP certified labs will provide all nutrient recommendations.

## B. Interpreting the soil test

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 or fertilizer recommendations.

Nitrogen recommendations are based on results of field trials in Wisconsin and bordering states and the OM percentage of the soil. Soils with lower OM will have less natural supply of N and require larger fertilizer inputs compared to soils with greater OM. Soil test P and K values are converted into fertilizer recommendations by placing each value into a soil test category. The soil test category (low, medium, optimum, high, very high, extremely high) along with the crop demand level are used to determine the fertilizer recommendation. Vine crops are in the demand level 5 category of high demand vegetable crops. Soil test categories have also been developed for calcium, magnesium, boron, zinc, and manganese. Sulfur requirements are determined from a Sulfur Availability Index (SAI),

Finally, the soil test report will include nutrient or fertilizer recommendations. The recommendations are based on the crop demand for nutrients in a single season and are calculated to tell you how mu (if any) of a particular nutrient is needed for optimum crop growth. Nutrient recommendations for vine crops are in the section **Soil Fertility and Plant Nutrition**.

### Soil Names

Some soils and subsoils are naturally higher in nutrients than others. The University of Wisconsin fertilizer recommendations account for the contribution of nutrients from the subsoil, so it's important that the soil lab knows the name of the soil type in your field.

If you don't know the name of your soil, you will find it on county soil survey reports or your farm conservation plan. If you need help finding this information, contact your county Extension agent or the district conservationist at the Natural Resource Conservation Service (NRCS).





## Quick Note

UW fertilizer guidelines are based on a build and maintain approach. When soils are in the optimum soil test category, then P and K recommendations are equivalent to the amount of P and K removed with the crop at harvest. Fertilizer recommendations for soil in the high and very high categories represent 50% and 25% of crop removal, respectively. No fertilizer is required for soils testing in the extremely high category. For soils testing in the low or very low categories, fertilizer guidelines represent application of the amount that the crop needs and is able to remove plus amounts needed to build soil test levels toward the optimum range over a 4-6 year period.

## C. Recommended fertilizers

It is usually best to use a combination of both organic and inorganic fertilizers. Inorganic fertilizers are sometimes called chemical or commercial fertilizers because they are produced in an industrial manufacturing process. Examples of inorganic fertilizers include: urea, ammonium sulfate, ammonium nitrate, triple super phosphate, potassium chloride (muriate of potash), and potassium sulfate (sulfate of potash). An advantage of using inorganic fertilizers is that they are concentrated in nutrients, and the nutrients are water-soluble and thus immediately available for plant uptake. However, if inorganic fertilizers are not applied in synchrony with plant demand or applied in excess of plant demand, nutrients can be lost to the environment and become a water quality contaminant.

Organic fertilizers are fertilizer sources that originate from animal waste or plant material, such as animal manures, compost, or green manures (legume cover crops). An advantage of organic fertilizers is that nutrients are not all immediately available and thus are released throughout the growing season. An additional advantage is that they provide soil quality benefits as well; additions of organic material can improve soil structure, water holding capacity, and biological activity of the soil. A disadvantage of organic fertilizers is they are not as nutrient-rich as inorganic fertilizers

and greater amounts of material will need to be applied.

There is a third category of fertilizers, which are OMRI-approved for certified organic production systems. Examples of OMRI-approved fertilizers are blood meal, composted animal manure, fish emulsion, feather meal, cottonseed meal, and alfalfa meal. Rock phosphate and bone meal are common organic fertilizers used to supply additional phosphorus. Amending soil with compost, legume cover crops, or crop residues also supplies significant plant nutrients in organic form.

Organic products must be decomposed by soil microorganisms before the nutrients become available to plants. Because it is a microbial process, decomposition depends on the type of material, the texture of the material, the temperature, and the moisture level. Sometimes the decomposition process isn't fast enough to provide enough nitrogen for a rapidly growing vine crop. It's a good idea to keep records of the organic materials you use and how the crop responds to them.

## D. Building the organic matter content of the soil

A soil which receives regular additions of organic materials will have good nutrient- and water-holding capacity, will have good aeration for root development, will require less chemical fertilizer and water, and is easier to cultivate. Organic matter stabilizes soil particles, helping soil to resist compaction. It supports an active soil biota that competes with and suppresses soil-borne pathogens.

Implement practices in your IPM program that maintain or increase the organic matter content of the soil. Regular additions of manures and composts, planting and incorporating cover crops and green manures, reducing tillage, and practicing crop rotation are all practices that will achieve this. Even small increases in organic matter can have a beneficial effect.



*Red clover as a cover crop*



## Soil Information Sheet For Field, Vegetable and Fruit Crops

Date Rec'd

Lab No. (Lab Use Only)		County <b>Washington</b>		FSA No.		Method of Payment									
		Name <b>The Progressive Farm</b>				<b>The "FERTILIZER CREDIT INFORMATION" section is very important for obtaining accurate recommendations. A previous legume crop such as alfalfa or soybean will reduce the amount of N needed for the next crop. If you apply manure, it will reduce the final N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O fertilizer recommendations.</b>									
		Address													
		City		Zip											
County Code		Email add													
TOTAL NUMBER OF SAMPLES } <b>7</b>		CROP DEPTH } <b>8"</b>		Credit Card No.		Exp. Date ____/____/____ VISA ____ MC ____									
		4-YEAR CROP ROTATION		FERTILIZER CREDIT INFORMATION											
				Previous Legume Crop											
				Manure Applied to Field Since Last Crop											
FIELD ID	SAMPLE NO (S)	Check if irrigated	SOIL NAME (if known)	Acres in Field	Slope %	Sequence to be Grown (crop code)	Yield Goal	Legume Crop (crop code)	Legume Forage % stand (circle)	Check if more than 8" regrowth in fall	Manure Code (see below)	Application Rate T/a or galls	Application Method (circle one)	Consecutive Years of Application (circle)	
<b>1</b>	<b>1-3</b>		<b>Sisson</b>	<b>15</b>	<b>1</b>	17	160		<30			<b>1</b>	<b>20</b>	Surface	1
						29	3		30-70			Incorporated	2		
						1	6		>70			Injected	3+		
						1	6								
<b>2</b>	<b>4-7</b>		<b>Sisson</b>	<b>20</b>	<b>5</b>	17	160		<30			<b>1</b>	<b>20</b>	Surface	1
						29	3		30-70			Incorporated	2		
						1	6		>70			Injected	3+		
						1	6								
									<30				Surface	1	
									30-70				Incorporated	2	
									>70				Injected	3+	
									<30				Surface	1	
									30-70				Incorporated	2	
									>70				Injected	3+	
									<30				Surface	1	
									30-70				Incorporated	2	
									>70				Injected	3+	
									<30				Surface	1	
									30-70				Incorporated	2	
									>70				Injected	3+	
									<30				Surface	1	
									30-70				Incorporated	2	
									>70				Injected	3+	

**Soil name is important to know because fertilizer recommendations vary with soil type. One way to find soil type is to look at your farm's conservation plan – it will have the name of the soil or an abbreviation on each field. If you don't know what the abbreviation stands for, call your Land Conservation Department or the Natural Resources Conservation Service. Percent slope should also be indicated on the conservation plan.**

**A list of crop codes with yield goal units can be found on the back of the soil information sheet. In this example, 17 indicates corn for grain in bushels/acre, 29 indicates small grain silage, underseeded with alfalfa in tons/acre, and 1 indicates established alfalfa in tons/acre.**

**Use realistic yield goals. This is important for getting the right P and K recommendations.**

**In this section you can request analysis for soil nutrients beyond those included with a routine soil test. You must indicate the specific soil sample(s) and the type of analysis for each.**

Special Soil Tests (additional fee) (List field or sample identification)		Manure Code List	
Calcium-Magnesium	Zinc	Solid	Liquid
Boron	Sulfate <b>1-3</b>	1 Dairy	11 Dairy
Manganese	Other	2 Beef	12 Veal Calf
Soil tests recommended if : growing corn (field or sweet) Zn and SO <sub>4</sub> -S growing legume forage B and SO <sub>4</sub> -S growing small grain or soybean (with pH>7.0) Mn growing potato or apple (with pH<5.5) Ca/Mg growing specialty or vegetable crop B, Zn, and Mn acid of sandy soil with high amounts of applied K Ca/Mg		3 Swine	13 Beef
		4 Duck	14 Swine, indoor pit
		5 Chicken	15 Swine, outdoor pit
		6 Turkey	16 Swine, farrow-nursery indoor pit
		7 Sheep	17 Duck
		8 Horse	18 Poultry

**This is the most important information on the entire report!**

The "Nutrients to Apply" section tells you the actual pounds per acre of N,  $P_2O_5$  and  $K_2O$  to apply. This recommendation has been adjusted to reflect any fertilizer credits you indicated.

UW Soil & Plant Analysis Lab  
8452 Mineral Point Road  
Verona, WI 53593  
(608) 262-4364

**The "Crop Nutrient Need" section is the field's nutrient recommendations based on your soil test results and crop to be grown. These recommendations have NOT been adjusted for any fertilizer credits.**

The "Fertilizer Credit" section is based on the numbers entered on your soil test information form. If you didn't put them on the form but do have credits, you can subtract them from the "Crop Nutrient Need" to get the "Nutrients to Apply."

**This is the most important information on the entire report!**

**The "Nutrients to Apply" section tells you the actual pounds per acre of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O to apply. This recommendation has been adjusted to reflect any fertilizer credits you indicated.**

LAB #:	
County:	Account No.
Washington	000000
Date Received	Date Processed
6/26/2007	6/26/2007
Slope	Plow Depth
1% Acres	8"
Soil Name	
Sisson	
Field Name	
1	
Previous Crop	
Corn	

		NUTRIENT RECOMMENDATIONS									
Cropping Sequence	Yield Goal	Crop Nutrient Need			Legume N	Fertilizer Credit			Nutrients to Apply		
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O		Manure N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
	per acre	lbs/a			lbs/a	lbs/a			lbs/a		
Corn, grain	151-170 bu	see below	0	0	0	60	60	144	see below	0	0
Sm grain silage, w/alf sdg	2-3.5 ton	20	0	0	0	20	10	115	0	0	0
Alfalfa, established	5.6-6.5 ton	0	0	90	0	10	5	9	0	0	90
Alfalfa, established	5.6-6.5 ton	0	0	90	0	0	0	0	0	0	90

There is no lime recommendation.

SUGGESTED N APPLICATION RATES FOR CORN (GRAIN) AT DIFFERENT N: CORN PRICE RATIOS								
Previous Crop	N: Corn Price Ratio (\$lb/N: \$/bu)							
	0.05		0.10		0.15		0.20	
High / Very High Yield Potential Soils	Rate <sup>1</sup>	Range	Rate <sup>1</sup>	Range	Rate <sup>1</sup>	Range	Rate <sup>1</sup>	Range
Corn, Forage legumes, Leguminous vegetables, Green manures <sup>3</sup>	lb N/a (Total to Apply) <sup>2</sup>							
	165	135-190	135	120-155	120	100-135	105	90-120
Soybean, Small grains <sup>4</sup>	140	110-160	115	100-130	100	85-115	90	70-100

<sup>1</sup> Rate is the N rate that provides the maximum return to N (MRTN). Range is the range of profitable N rates that provide an economic return to N within \$1/a of the MRTN.

<sup>2</sup> These rates are for total N applied including N in starter fertilizer and N used in herbicide applications.

<sup>3</sup> Subtract N credits for forage legumes, leguminous vegetables, green manures, and animal manures.

Subtract N credits for ridge legumes, leguminous vegetables, green manures, and animal manures. This includes 1st, 2nd, and 3rd year credits where applicable. Do not subtract N credits for leguminous vegetables on sand and loamy sand soils.

<sup>4</sup> Subtract N credits for animal manures and 2nd year forage legumes.

### Guidelines for choosing an appropriate N application rate for corn (grain)

1) If there is > 50% residue cover at planting, use the upper end of the range.

2) For small grains on medium and fine textured soils, the mid-to-low end of the profitable range is most appropriate.

3) If 100% of the N will come from organic sources, use the top end of the range. In addition, up to 20 lb N/a in starter fertilizer may be applied in this situation.

4) For medium and fine textured soils with: > 10% organic matter, use the low end of the range; < 2% organic matter, use the high end of the range.

5) If there is a likelihood of residual N (carry-over N), then use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.

6) For corn following small grain on medium and fine textured soils, the middle to low end of the range is appropriate.

The N recommendations for corn are listed in this section. These rates are adjusted according to your cost of N fertilizer and your anticipated price for corn - expressed as one of four N:corn price ratios. Each price ratio suggests an N rate for maximum economic return and also a range of profitable N rates that are within \$1.00/acre of the maximum return rate. The guidelines below the table provide advice for selecting an N rate within the range.

### ADDITIONAL INFORMATION

Fertilizer credit based on 1 year(s) of 20 tons/acre of surface dairy manure.

Recommended rates are the total amount of nutrients to apply (N-P-K), including starter fertilizer.

Starter fertilizer (e.g. 10+20+20 lbs N+P<sub>2</sub>O<sub>5</sub>+K<sub>2</sub>O/a) is advisable for row crops on soils slow to warm in the spring.

Because of excessively high P levels, no  $P_2O_5$  fertilizer or manure is recommended on this field.

If alfalfa will be maintained for more than three years, increase recommended K<sub>2</sub>O by 20% each year.

N.B. = Not required for calculation of lime requirement when soil pH is 6.6 or higher.

This section will have comments and suggestions for modifying the nutrient recommendations based on crop management practices.

	TEST INTERPRETATION					
Cropping Sequence	Very Low	Low	Optimum	High	Very High	Excessive
Corn, grain	P K	P K	P K	P K	P K	P K
Sm grain silage, w/alf sdg	P K	P K	P K	P K	P K	P K
Alfalfa, established	P K	P K	P K	P K	P K	P K
Alfalfa, established	P K	P K	P K	P K	P K	P K
Rotation pH	X	X	X	X	X	X

LABORATORY ANALYSIS																
Sample Identification	Soil pH	O.M. %	Phosphorus ppm	Potassium ppm	60-69 Lime Req (T/a)	Calcium ppm	Magnesium ppm	Estimated CEC	Boron ppm	Manganese ppm	Zinc ppm	Sulfate-Sulfur ppm	Sulfur Avail. Index	Texture Code	Sample Density	Buffer pH
1	7.6	3.2	106	205	0							1.0	49	2	1.06	N.R.
2	7.4	2.9	96	195	0							1.0	48	2	1.04	N.R.
3	7.5	2.7	102	210	0							1.1	48	2	1.08	N.R.
Adjusted Averages	7.5	2.9	101	203								1.0	48			

**Don't be misled by this section. The micronutrients that are listed are not analyzed unless you specify that they should be.**

## SECONDARY AND MICRONUTRIENTS RECOMMENDATIONS

Interpretations -----  
Response to sulfur unlikely

In this example, the only micronutrient tested was sulfur. The sulfur result (Sulfur Available Index or SAI) is shown and interpreted as H (high). The others are left blank because they were not tested.

SAI-H

# Seed Selection

Preplant



Seed selection is an important decision that affects the health, vigor, and yield of your crop. Choosing well-adapted, disease-resistant varieties is an economical way to avoid problems later in the season.



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

- ☐ **A. Varieties are chosen that are well-adapted to the region and have good quality and marketing attributes.**
- ☐ **B. Certified, disease-free seed is purchased.**
- ☐ **C. Varieties are selected with resistance to one or more key cucurbit disease.**
- ☐ **D. If the crop will start with transplants, care is taken that they are grown insect- and disease-free and hardened off properly.**

## A. Variety selection

When making your variety choices, consider what the market demands in terms of size, keeping qualities, cooking qualities, and flavor. Consider the length of the growing season, your soil, past pest and disease problems, and your own personal tastes. Choose varieties that will mature by the targeted delivery dates. When trying a new cultivar, do not use it exclusively. Grow new trials next to old standbys so you can compare the characteristics objectively.

Get to know the varieties that perform well in your growing area. Ask other growers which varieties have worked well for them and why. Experiment with bush and vine types to determine the most desirable fruit size for your conditions.

### **Cucumbers** *Cucumis sativa*

Cucumbers grown in Wisconsin are generally classified as slicing, greenhouse, pickling, and gherkin types. Slicing cucumbers are long and tapered, with smooth, glossy skin. Some slicers are burpless types. Greenhouse cucumbers are smooth, seedless slicing cucumbers that don't need insect pollination. Pickling cucumbers are smaller, blunt, spiny cucumbers that are eaten fresh or are pickled. The gherkin is a type of pickling cucumber.

Choose cucumber varieties for their disease resistance as well as horticultural characteristics. Look for varieties with resistance to angular leaf spot, anthracnose, powdery mildew, downy mildew, and viruses. Most cucumber varieties are now considered resistant to scab.



**Pickling cucumber**

### **Melons** *Citrullus lanatus* (watermelon) and *Cucumis melo* (muskmelon)

Watermelon and muskmelon are the melons most commonly grown in Wisconsin. Muskmelons have a wide range of size and flesh qualities. The most

popular type of muskmelon is the small, oval, heavily netted kind commonly called a cantaloupe. All cantaloupes are muskmelons, but not all muskmelons are cantaloupes. Honeydew melons are also a type of muskmelon.

Watermelons and muskmelons need a relatively long, warm growing season to produce and develop sweet fruit. Choose melon varieties that flower early and produce smaller fruit for earliest yield. These varieties tend to have compact foliage, and their vines and the distance between leaves (nodes) are shorter than larger, long-season melons. The main culinary qualities desired in small melons are sweetness, crunchiness, and flavor.



**Watermelon**

### **Summer squash**

*Cucurbita pepo*

Zucchini is probably the most well-known summer squash, as well as the yellow crookneck and the patty pan or scallop types. The selection of summer squash varieties has greatly expanded in the past few years as the result of new interest, hybridization, and introduction of disease resistance. Many beautiful and flavorful varieties are available.

Summer squash differs from winter squash in that they are relatively smaller fruit that are harvested before the rind hardens while still immature. Summer squash grows on bush-type plants that do not spread as much as winter squash and have a shorter growing season. Many more disease-resistant varieties are now available.



**Summer squash**

### **Winter squash**

Winter squash matures late in the season. Winter squash includes several species of cucurbits, each having unique characteristics. Within each species are many different varieties, with a wide range of



shapes, sizes, colors, and flavors. Winter squash is grown for cooking and baking, and as a winter storage vegetable.

*Cucurbita pepo* includes the popular Acorn and Delicata types of squash and pie pumpkins. *C. pepo* is the same species as summer squash, and immature fruit can be eaten right off the vine. The winter kinds of *C. pepo* can be quite flavorful, such as the Sweet Dumpling variety. They don't store as well as other winter squash.



**Winter squash**

*Cucurbita moschata* is most known as the tan-skinned butternut squash, but there are other lesser known varieties of moschata squash. Some require a long growing season. Moschatas have moist flesh and can be flavorful. These squash have the longest storage potential.

*Cucurbita maxima* are the larger squash varieties such as the Hubbard and Kabocha types. A popular maxima squash is the Buttercup, but there are many excellent varieties available. This group is considered to have excellent flavor, especially when "cured" for several weeks after harvest. Good storage potential.

### **Pumpkin** *Cucurbita pepo*

Pumpkins are a type of winter squash. Most varieties that are called pumpkin have bright orange fruit, very long vines, and stems that are firmer, more rigid, and more square than those of other squashes. Pumpkins are grown for traditional autumn decorating, pie-making, and seed roasting.



**Pumpkins**

The most common pumpkins are varieties of *Cucurbita pepo*. The large-fruited pumpkins that have been known to weigh hundreds of pounds belong to the species *Cucurbita maxima*. *Cucurbita mos-*

*chata* is a related variety with a tan skin color that is used for commercially canned pumpkin.

Pumpkins come in a wide range of sizes. Miniature pumpkins are all varieties of *C. pepo* and will weigh up to a pound. Most miniature varieties are grown for decoration and are not usually used in pies or other products.

Small pumpkin varieties, with fruit from 2-8 pounds, are grown for baking, decoration, and carving. If you want edible seeds, choose one of the naked-seeded varieties. Medium (8-15 pounds) and large pumpkin (15-25 pounds) varieties are grown for cooking or for Jack O'Lanterns.

## **B. Plant clean seed**

Several key pathogens of vine crops survive on seed and are spread from field to field when infected seed is planted. For example, the bacteria that cause angular leaf spot is spread on seed. Even a few seeds in a seed lot can start disease problems in a field when environmental conditions are favorable.

Planting clean seed is an effective disease management strategy for vine crops. Always buy certified, disease-free seed from a reputable supplier. Seed lots should be entirely free from viruses, angular leaf spot bacteria, and the fungi that cause anthracnose, Alternaria, and scab. A reputable seed supplier will test seed lots for these pathogens and certify the lot as disease-free.

### **Choosing resistant varieties**

Consider varieties with some resistance to the most challenging problems, such as powdery mildew, angular leaf spot, anthracnose, cucumber mosaic virus, downy mildew, and scab. Over time your own experiences in the field will help you decide which varieties to grow in the future and which ones to avoid because they are too susceptible to specific insect pests or diseases.

## C. Disease resistance

Selecting a plant variety that has resistance to insects and diseases is the foundation of a successful IPM program. It is one of the most economical and effective ways to prevent some disease problems. Varietal selection is also an important way to avoid physiological disorders, such as cracking. Fortunately, varieties are available that have good horticultural characteristics as well as disease resistance.

Disease resistance can be defined as the ability of a plant to keep pathogen growth in check, as compared to a more susceptible plant. Some varieties are more tolerant to a disease than others, which means that the plants are less damaged or can maintain yield, even if they are infected by the pathogen.

Increasing numbers of varieties are available with some resistance to the most important diseases of vine crops. Look for varieties with resistance to angular leaf spot, anthracnose, powdery mildew, cucumber mosaic virus, downy mildew, and scab. Most cucumber varieties are now considered resistant to scab. No variety is resistant or tolerant to all insects and diseases, so it's important to identify the pests and diseases that are the most damaging in your fields and select varieties with some resistance to those problems.

Find resistant varieties by checking seed catalogues, cooperative extension publications, and with other farmers. Over time your own experiences in the field will help you decide which varieties to grow in the future and which ones to avoid because they are too susceptible to specific insect pests or diseases.

## D. Handling seed and transplants

All vine crops can either be direct-seeded or transplanted. Cucumbers and summer squash are commonly direct-seeded. When direct-seeding, it's important to wait for warmer soils (60-75 degrees F), or warm soils first with plastic mulch. Melons, pumpkins and winter squash can also be direct-seeded, but many growers start them as transplants in order to extend the growing season.

### Breeding for disease resistance

Plants are generally resistant to most pathogens. The ability of a pathogen to cause disease in a host plant is usually the exception, not the rule. This is because a well-growing plant has a genetically-based ability to recognize potential invading pathogens and to mount successful defenses, similar to what our immune systems do for us. Successful pathogens cause disease because they are able to evade the plant's defense mechanisms. Breeding for disease resistance in plants has been the major method for controlling plant diseases for many decades.

Other advantages to using transplants is the efficient use of seed, reduced weeding costs, shortened cropping period in the field, uniform stand and quality, and less exposure to pests.

The disadvantage of using transplants is that cucurbits have a taproot that does not like to be disturbed. If the container is too small or if they are kept in a pot too long, growth can be stunted. Furthermore, it takes time for the plant to get adjusted once transplanted. If the plants don't harden off well, the vines tend to get sunburned and stunted and lose several days' growth.

If you grow your own early crop, start transplants 3-4 weeks before transplanting into the field, which should occur late May to early June in Wisconsin. To minimize transplant shock, use fiber containers that can be easily peeled away from the roots or tapered pots so that plants can be easily slipped out. Use one container for each seedling. You can also start your plants in peat pots that can be planted pot and all. Be sure pots are clean, and use disease-free soil.

Transplant when the plants are about three weeks old, with one to two true leaves at transplanting time. Older transplants that have begun to run are difficult to handle and suffer greater transplant shock. Harden off the seedlings before planting to the field. Be sure to dig a deep transplant hole to help minimize transplant shock.

# Field Selection

## Preplant



A healthy vine crop begins with selecting a favorable planting site. The best vine crops are grown in fields with full sun, well-drained soil, and excellent air circulation. Choosing a site where vine crops have not been grown for several years is one of the most effective ways to avoid pest and disease problems later in the season.



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

- ☐ **A. Vine crops have not been grown in the field for at least three years.**
- ☐ **B. Rotation crops are used that prevent the build-up of diseases, insects, and weeds.**
- ☐ **C. Soil qualities and field characteristics are considered in the selection process.**
- ☐ **D. This year's crop was preceded by a winter cover crop.**

## A. Crop rotation

Crop rotation is one of the most important pest control strategies for vine crops. Several key pests and diseases such as squash bugs, squash vine borers, anthracnose, and angular leaf survive in the residues of vine crops. Crop rotation allows enough time for the residue to decompose completely, and for the pest population to die out, before the next susceptible crop is grown.

If you have the land available, do not plant a crop in the cucurbit family more often than every three years in a field. Cucurbit, or vine crops, include cucumber, muskmelon, cantaloupe and honeydew melons, watermelon, summer squash such as zucchini, winter squash, pumpkin, and gourds.



### Quick Note

Crop rotation combined with field sanitation to remove crop residues and destroy overwintering sites has been shown to be an effective strategy to suppress squash bugs.

The distance between this year's vine crop and last season's vine crop can affect pest pressure, too. Squash bugs, squash vine borers, and cucumber beetles will move from old fields to new plantings. This is particularly true for cucumber beetles. Crop rotation to a distant field ( $> \frac{1}{2}$  mile away) can help minimize the size of the beetle population. Simply rotating to new ground within a field, or to an adjacent field, is not effective due to the mobility of the beetle. By increasing the distance between the overwintering sites and newly planted fields, their arrival may be delayed or reduced. Several studies have shown that planting vine crops in greater distances from each other enhances the effectiveness of insecticides. This is called spatial rotation.

Avoid planting corn near vine crops because the spotted cucumber beetle larvae also feeds on corn.



Field corn

## B. Choosing rotational crops

A good rotation plan will prevent the build-up of pests, weeds, and diseases. Crop rotation is also a good way to improve soil quality. There are many good rotation choices for vine crops that do not include members of the Cucurbitaceae family. These include beans and other legume vegetables, lettuce and spinach crops, members of the onion family (onions, garlic, leeks, scallions), carrots, cole crops (broccoli, cabbage), and beets and other root crops.

Rotate between crop families to avoid the build-up of soil diseases. In particular, plan at least three years between peppers, tomatoes, and eggplants and cucurbits to avoid build-up of the root pathogen *Phytophthora*. Rotating between crops with early and late planting dates can help prevent weed problems by providing windows for cultivation. Keep a record of the cropping history in each field.

Grain crops such as barley, rye, wheat, oats, and other grasses grown either as hay or as a cover crop are particularly valuable in breaking pest cycles and building soil structure.



### Quick Note

**Temporal rotation:** refers to the number of years since vine crops were planted. A rotation of vine crops-snap beans-sweet corn-grains is a three year rotation.

**Spatial rotation:** refers to the distance from the current vine crop field to last year's vine crop field.

### Plant Family

Cucurbits, or vine crops, are a diverse group of plant species that form the plant family Cucurbitaceae. Cucurbits include cucumber, muskmelon, cantaloupe and honeydew melons, watermelon, summer squash such as zucchini, winter squash, pumpkin, and gourds.



## C. Characteristics of a good planting site

Choosing a planting site with conditions favorable for vine crops can go a long way in establishing a vigorous crop. Choose a location with full sun and good air circulation. Vine crops can grow in a wide range of soils as long as they are fertile, moist, and relatively high in organic matter and nitrogen. Muskmelon in particular should be grown on well-drained soil with good water-holding capacity for best quality.

Leaf diseases can be a challenge with vine crops. Minimize this problem by choosing fields in a sunny, well-drained location where the air circulation is excellent and the morning dew dries quickly. Avoid low, shady spots or locations where air flow is blocked—these are the conditions in which leaf diseases can thrive.



**Leaf diseases (downy mildew shown above) can be minimized by choosing a good planting site.**

Know the pest history of the field. For example, avoid fields with heavy infestations of perennial weeds such as nutsedge or quackgrass that are difficult to control. Consult your field maps, rotation history, and the pest history of the field. Note the presence of perennial broadleaf weeds such as burdock, pokeweed, and other perennial broadleaf weeds that may host viruses of cucurbits. Similarly, avoid fields with a history of persistent soil-borne diseases such as Fusarium wilt, white mold, or nematodes.

Most vine crops require a long growing season. Avoid fields with low spots and frost pockets where cold air tends to settle on cold nights, as this will shorten the growing season. In areas of relatively low elevation, a higher-elevation site such as on the brow of a hill can have a growing season several weeks longer.

## D. Cover crops as rotation crops

Consider cover crops in the rotation plan. In addition to breaking pest cycles, rotating with a cover crop has the benefits of adding organic matter and nutrients and suppressing weeds. A regular addition of a cover crop in the rotation plan can result in better health and higher yields of subsequent vine crops and other vegetable crops.

When choosing a cover crop, have one or more particular goals in mind, for example, weed control or adding organic matter to the soil. Decide if the cover crop can remain in place for the entire season, perhaps grown as hay, or if it will be incorporated into the soil for the purpose of soil improvement, a practice called green manuring.

Both legume and non-legume cover crops offer benefits in the rotation plan. Vine crops thrive in soil high in nitrogen that a legume crop can provide. Depending on several factors, a legume crop can release a significant amount of plant-available nitrogen in the first and also in the second year after it is incorporated into the soil. Non-legume grass crops are excellent soil builders.

Consider the cover crop as valuable as the vegetable crop, with attention to when and how to plant, plant establishment and weed control, and how the crop will be harvested or incorporated into the soil.

### Seedcorn Maggots (SCM)

Seedcorn maggot flies are attracted to decaying organic matter. They are attracted to rye or other cover crop that has been recently disked (less than three weeks). Melons or cucumbers planted in fields of disked-down rye or other cover crop are at greatest risk. If needed, you can delay planting or other cultural methods to reduce SCM infestations (see insect management). However, using a cover crop is encouraged as a good field practice and should not be abandoned for fear of SCM damage.

**Notes:**

# Field Preparation



Fields should be prepared properly for planting. This includes weed control, incorporation of organic amendments, and preparing the soil in a way that maintains soil moisture and allows for root penetration and water infiltration.



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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. Pre-plant tillage is adequate for planting and weed control but not excessive.**
- ☐ **B. Soil moisture levels are monitored. Tillage and planting occur at appropriate moisture levels.**
- ☐ **C. A pre-emergence weed management plan is in place, and weeds are controlled before planting. The stale seedbed technique is considered.**
- ☐ **D. Cover crops and other organic amendments are incorporated three weeks before planting to improve the soil and to avoid attracting the seedcorn maggot.**

## A. Tillage

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



*Incorporating residue*

© Howard F. Schwarz

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 penetration, root growth, and the amount of soil oxygen.

Many vegetable farmers use chisel plows in their operations. Plowing with a chisel implement is a form of mulch tillage, in which residues are mixed in the upper layers of the soil and a significant percentage remains on the soil surface to reduce erosion.

Follow these general guidelines for pre-plant tillage:

- ▶ Do not till if soil moisture is greater than 80%.
- ▶ 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.

## 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. Then consult the **Feel Chart for Estimating Soil Moisture Percent (%)** in this section.



*Estimating soil moisture*

## C. Pre-plant weed control

Proper bed preparation is important for successful weed cultivation after the crop is planted. Prepare a straight, well-made bed, as well as straight seeding and transplant lines, so that cultivating implements can work closely and accurately in the plant row. Poorly-leveled land will cause water to collect in low areas of the field, favoring growth of root pathogens and water-loving weeds. Avoid fields that are heavily infested with hard-to-control perennial weeds.

Weeds in cucurbits are difficult to control once the crop vines out into the row. Pre-planting is therefore an important window for weed management in vine crops. 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 and is particularly suitable for late-planted crops such as squash, cucumbers, and other vine crops.

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, or 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 vine crop is then direct-seeded or transplanted without additional tillage into a seedbed that has been depleted of a good proportion of germinable weed seeds.



## Feel Chart for Estimating Soil Moisture Percent (%)

	Sand or loamy sand soil texture	Loam, silt loam, clay loam soil texture
<b>Below 20%</b>	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.
<b>35-40%</b>	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.
<b>50%</b>	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.	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>60-65%</b>	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.
<b>70-80%</b>	Forms weak ball. Distinct fingerprint outline on ball. Soil particles will stick to palm. <b>Optimum for planting.</b>	Damp and heavy; slightly sticky when squeezed. Forms tight plastic ball. Shatters with a burst into large particles when broken. Hand is moist. <b>Optimum for planting.</b>
<b>100%</b>	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.

## D. Incorporating cover crops and amendments

Vine crops require soils with good organic matter content that provide a steady supply of nutrients and water. Tilling in plant residues, planting and incorporating a cover crop or green manure, or amending the soil with composts or animal manures are productive strategies for building the organic matter content of soil.

Adding cover crops to the rotation can result in increased yields in the subsequent vine crop. Have a goal in mind when choosing a cover crop, for ex-

ample, to add nitrogen, suppress weeds, improve soil structure, or break pest cycles. Legumes are the best cover crops for adding nitrogen to the soil because of the symbiotic bacteria on their roots that fix atmospheric nitrogen. When the legume is incorporated into the soil, about 50% of the fixed nitrogen will be available for the subsequent vine crop. Grass or grain crops planted in the fall and tilled into the soil as green manures before planting are good soil improvers and can capture nitrogen that might have been leached from the soil

Wait about three weeks, depending on soil temperatures and moisture, between incorporating a cover crop or organic amendments and planting direct-seeded cucurbits. This will allow time for the cover crop to sufficiently decompose to improve the seedbed and to avoid attracting the adult seedcorn maggot, which prefers to lay eggs in decomposing residues.



### 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.

# Planting Process

## Planting



Careful planting and attention to environmental conditions at planting time will contribute to the quality and health of the final stand. Rapid, steady early-season growth of the vine crop will greatly improve resistance to pests and diseases.



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

- ☐ **A. Planting occurs at proper soil and air temperature.**
- ☐ **B. Planting occurs at optimal row and plant spacing.**
- ☐ **C. Planting is timed to avoid peak emergence of the seedcorn maggot, if possible.**
- ☐ **D. Mechanical pest controls such as row covers, reflective mulches, or trap crops are considered.**

## A. Optimal planting conditions

Cucurbits are warm-season crops that do best in temperatures of 75-85 degrees F during the day. The seeds germinate most rapidly when the soil temperature is above 70 degrees F, but they can be direct-seeded as soon as the soil temperature reaches 60 degrees F.

When direct-seeding, it's important that the seed is in good contact with moist soil. Planting generally begins in mid-May in southern Wisconsin and early June in northern Wisconsin.



*Emerging seedlings*

Wind can be damaging to vine crop plantings, especially if temperatures are also low. In some growing seasons, wilting can occur after periods of cloudy or rainy weather. Without sunshine, soil temperatures drop to below 55-60 degrees F and water uptake by the roots is slowed. When the sun reappears, the roots can't supply enough water until the soil temperatures warm again.

### Using plastic mulches to warm soil

Cucurbits need 90-120 frost-free days to reach maturity. Plastic mulches of various kinds can be used to increase the soil temperature and speed early-season plant growth. Many growers find that muskmelons, watermelons, cucumbers, squash, and pumpkins will all ripen earlier and produce better yields and fruit quality when grown on plastic mulch. Costs and management time will both increase with the use of "plasticulture", but if it's done well, the higher productivity should compensate. The most serious disadvantage of using plastic mulch is the removal from the field and disposal.

Black plastic mulch is most commonly used. It suppresses weed growth, reduces soil water loss, and increases soil temperature. Soil temperatures under black plastic mulch during the day are generally 5 degrees F higher at a depth of 2 inches and 3 degrees F higher at a depth of 4 inches compared with bare soil. For plastic mulch to be most effective, it is important that it be in contact with the soil that it covers.

Clear plastic mulch has an even greater effect on soil temperatures than colored plastic. Clear plastic increases soil temperatures by 8-14 degrees F at a depth of two inches and by 6-9 degrees F at a depth of four inches. A disadvantage is that weeds can grow under the clear mulch, while black mulch shades them out. You may want to experiment with clear plastic to find out whether weeds become a real problem. The mulch's benefit to the crop may outweigh the competition from weeds.

## B. Optimal row & plant spacing

Proper plant spacing optimizes yield and also allows plants enough space to thrive. Spacing that is too narrow can create conditions of poor air circulation that favor disease development. Consider increasing air circulation by planting rows parallel to prevailing winds and not planting too close to hedgerows. Growing the crop in smaller parcels can also help slow the spread of powdery mildew. Plant a straight, well-made bed that will be easy to cultivate.

Some general planting guidelines for vine crops are in the table below. Bush-type varieties require less space between the plants and rows than vine-type varieties.

Plant spacing	Between rows	Between plants
Cucumber		
Pickling	3-5 feet	1-2 feet
Slicing	4-6 feet	1-2 feet
Zucchini/ summer squash	4-5 feet	2-4 feet
Melon		
Muskmelon	5-7 feet	8-12 inches
Watermelon	5-8 feet	3-8 feet
Winter squash		
Bush	6-8 feet	2-4 feet
Vine	3-8 feet	3-5 feet
Pumpkin		
Bush	2-4 feet	3-5 feet
Vine	3-8 feet	3-5 feet
Miniature	6-8 feet	2 feet



## C. Time planting to avoid key pests

Vine crops are most susceptible to damage by seed corn maggots if they are just germinating or in the seedling stage when the first generation of adults (small flies) are laying eggs. Schedule planting to avoid the peak fly emergence and egg-laying periods. In this way the crop will be protected from the largest population of the pest.

You can predict the peak fly emergence and egg-laying. It will be at different calendar dates each year but will always occur at the same time that redbud is in early flowering. Another way to determine this date is by monitoring cabbage maggot development using the degree day (DD) system. Entomologists use this system routinely to predict the presence of damaging stages of insect pests or of stages susceptible to control measures. Begin recording degree day accumulations for Wisconsin on March 1<sup>st</sup>.

The first generation maggots develop from eggs laid when 200<sub>DD</sub> have accumulated, which also corresponds to the late bloom of Norway maple and early bloom of redbud. Subsequent peak egg-laying will occur when 600<sub>DD</sub> and 1000<sub>DD</sub> have been reached. Keep a running total of degree days, and plant during fly-free periods that occur between generations.

### Time Planting to Avoid the Seedcorn Maggot

Seedcorn maggots are favored by cool, wet weather and conditions with high organic matter. Delay planting until soil temperatures are thoroughly warm and newly-incorporated cover crops or manure are well-decomposed. The adult seedcorn maggot will not lay eggs in soils with temperatures greater than 70 degree F. Assure rapid seed germination by planting in moist soil and not too deep. The longer the germination, the greater the risk of infestation.

## D. Using mechanical pest controls

### Row Covers

Floating row covers are made of spun-bonded polyester and spun-bonded polypropylene and are so lightweight that they “float” over most crops without support. The fabric is permeable to sunlight, water, and air and provides a microclimate similar to the interior



**Row covers provide an effective barrier to insect pests.**

of a greenhouse. The fabric creates a horizontal windbreak that protects the plants from drying winds. In addition to their season-extending function, row covers also provide an effective barrier that excludes insect pests. Consider row covers to keep out squash bugs, squash vine borers, cucumber beetles, early infestations of aphids, and virus transmission by aphids.

Medium-weight covers are the most commonly available. Apply the covers at the time of planting and leave them on until bloom, when the flowers must be available for pollination by bees. Heat-loving cucurbit crops can withstand high temperatures under the covers. Remember to temporarily remove the covers periodically to weed early.

### Reflective Mulches

Use row covers or reflective plastic mulch to prevent early aphid infestation and virus transmission (direct seeding is recommended in reflective mulch for maximum effectiveness). It will also discourage cucumber beetles.

### Perimeter trap cropping

Trap cropping is a pest management technique that involves planting a plant species or plant variety that is more attractive to the pest than the main crop. Perimeter trap cropping involves planting one or two rows of the attractive plant species so that it completely encircles the main crop. It can be easily incorporated into a pest management program and is most worthwhile for pests that are abundant and destructive in most years. In vine crops it can be an effective control strategy for cucumber

beetles. It does not work well for insect pests such as aphids, which are passively dispersed by wind. Understanding how the pest moves in its environment is crucial in creating a successful trap crop system.

Cucurbit varieties vary considerably in their attractiveness to cucumber beetles, so the trap crop system can work well for this pest. Dark green zucchini, blue hubbard squash, buttercup squash or another *Cucurbita maxima* crop planted in one or two rows to create an unbroken perimeter around the field can concentrate cucumber beetles away from the main crop. Be sure the trap crop completely encircles the main crop to gain the most benefit and discourage entry to the main crop. Two rows of the trap crop may be necessary along field edges that border woods or last year's fields. The perimeter trap crops should then be monitored and treated with an insecticide as needed, treated with a systemic insecticide at planting, or flamed on a cool morning. At low populations, sprays may not be needed. This can reduce or even eliminate the need for pesticides in the main crop.

Perimeter trap cropping may be more effective for squash than for pumpkins. Note that many giant pumpkin varieties are *Cucurbita maxima*. Do not use a crop that is highly susceptible to bacterial wilt in the border.



### Quick Notes

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**Seedcorn maggot generations:** (base temperature = 50 degrees F) 200<sub>DD</sub> (norway maple late bloom, redbud early bloom), 600<sub>DD</sub> (black locust early bloom), 1000<sub>DD</sub> (chicory full bloom)

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**Squash vine borer:** (base temperature = 50 degrees F) Egg laying at 900-1000<sub>DD</sub> (chicory full bloom)

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## Calculating Degree Days

Temperature affects the rate of development of plants and insects. Cold weather slows development and warm weather speeds it up. For this reason, you can more accurately monitor crop development, and predict pest behavior by using a system that measures the accumulation of heat with the passing of time. This system is called degree day accumulation (DD).

A degree day is a unit of measure that occurs for each degree above a certain base temperature during a 24-hour period. The base temperature is the temperature below which there is no plant or insect development. Specific insects have their specific base temperature. Most plants use a base temperature of 50 degrees F.

To calculate degree days you'll need a maximum/minimum thermometer to obtain the daily high and low temperatures. Calculate the degree days using the following equation:

$$(\text{Daily high temp} + \text{Daily low temp}) \div 2 = \text{Daily average temperature}$$

$$\text{Daily average temperature} - \text{Base temperature} = \text{Degree day accumulation (DD)}$$

Keep adding together the accumulated degree days to predict the peak emergence of each generation of pests you are monitoring. For example, the cabbage maggot has a developmental base temperature of 43 degrees F; if the temperature remains at 44 degrees F (or one degree above the developmental base temperature) for 24 hours, one degree day is accumulated.

The Wisconsin Department of Agriculture also keeps track of degree days and posts them on their website at <http://www.doa.state.wi.us/degreedays>

# 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. Life cycles and ecology of insects, weeds, and diseases and economic thresholds of vine crops 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 pest problems that can occur in a crop and considers all available pest management strategies. These will include cultural practices, physical and mechanical controls, host resistance based on genetics, biological control, and chemical control.

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

This section outlines general IPM principles. Specific IPM strategies for snap beans are given throughout the workbook.

## 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 check for the presence or signs and symptoms of insect pests, beneficial insects, diseases, and weeds. Accurate and timely scouting helps you to identify potential problems before they become less manageable and will probably prevent unnecessary pesticide treatments.

The information recorded during scouting is useful in several ways. It aids in the day-to-day decision-making process, especially when combined with knowledge of pest life cycles and crop development. The field data obtained during scouting is

also extremely useful when planning for the next growing season. For example, if bacterial wilt is noted this season, a wilt-resistant variety can be chosen for the next crop rotation to prevent this disease from reoccurring.

How you scout depends on the crop growth stage and the insects, diseases, and weeds likely to be present. Scouting calendars and scouting guidelines for specific pests are given in the **Scouting** section of this workbook.

## C. Common pests, diseases and weeds of vine crops

The more you know about the common pests, diseases, and weeds of a crop, the more effective you will be in preventing pest problems and managing those that do occur. It helps you to anticipate which ones are likely to be a problem in your field and to recognize them quickly. Being familiar with the common pests helps you to be more effective with the control measures you use because you can target them to the pest's most vulnerable stages. You will be able to use multiple control strategies throughout the season.

Accurate pest identification is a crucial first step for effective pest management. Misidentification of insects, diseases, and weeds is a common cause of poor pest control. On the next page is brief description of the major pests and diseases of vine crops that you and your scouts should be able to recognize. Learn as much as you can about each of them.

### 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 two 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



Both annual and perennial broadleaf weeds affect cole crop 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 resprout when their top growth has been removed mechanically or by other means, as long as the underground storage organ is intact.

- ▶ 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.



A diagram of a grass leaf cross-section. The central part is the **blade**. It is surrounded by a **sheath**. At the junction of the blade and sheath is the **ligule**. Below the ligule, the sheath splits into two parts called **collar and auricles**.

## 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.

## Key Insect Pests of Vine Crops in Wisconsin

These are the main pests and diseases of vine crops that you and your scout should be able to recognize. Detailed information on the life cycle, scouting, and integrated management of each pest and disease can be found in the pest profiles located in the **Appendix**.

### Aphids



Aphids generally do not cause serious direct injury to cucurbits, but many species of aphids can transmit virus diseases. If aphids are present in adequate number, infested leaves will curl downward, turn brown, and die. Aphids typically do not cause significant direct damage until plants have started to produce runners. Cucumbers and muskmelon are generally most affected by aphids. Natural enemies (parasitoids, predators, and fungal diseases) are frequently associated with aphid colonies. Aphid feeding may cause the leaves to become distorted. Honeydew (aphid secretions) may also serve as a growing medium for sooty mold, a fungus that can disfigure the fruit with black blotches. Ants are also attracted to honeydew.

### Cucumber beetles



The striped cucumber beetle is a frequent pest of cucurbits. They are difficult to control with insecticides and require an integrated strategy. A major concern with striped cucumber beetle on cucumbers and some melons is the ability of the adult to vector bacterial wilt, as well as viruses. The adult striped cucumber beetle has yellow wings with three longitudinal black stripes. Feeding causes extensive damage particularly when the plant is young, or not yet growing vigorously. Beetles can kill young seedlings when populations are high. Beetles can feed on fruit of watermelon and muskmelon later in the season, causing cosmetic damage and loss of fruit quality. The striped cucumber beetle overwinters in protected areas near buildings, fence rows, and woodlots and can be present as plants emerge from the soil or shortly after transplanting. The bacterium causes plants to wilt, and once the infection is established control is not possible.



The spotted cucumber beetle is an occasional pest of cucurbits and is recognized by the twelve prominent black spots on its body. Spotted cucumber beetles have a much wider host range than the striped cucumber beetle, which restricts its feeding to cucurbits.

### Seed corn maggot

#### *Delia platura*



Seed corn maggot (SCM) is an occasional pest in cucurbits. SCM overwinter as pupae in the soil, and adults emerge and mate before laying eggs in field areas. Resulting larvae feed on seeds below ground. This cycle is repeated 3-5 times during the year. Infestations can be detected by checking plants for scars left behind after egg-laying. Plowing in crop debris post-harvest can remove their overwintering sites and prevent further infestations, and insecticides and natural parasites can control or destroy eggs and adults. The seedcorn maggot feeds on germinating seeds or young transplants. It is generally only a pest early in the season before the soil is thoroughly warm. Seedcorn maggots are particularly damaging when residues of the previous crop or other soil amendments have not thoroughly decayed before planting cucurbits. Direct-seeded cucumber and melons are generally most affected by seedcorn maggots.

## Squash bug

*Anasa tristis*



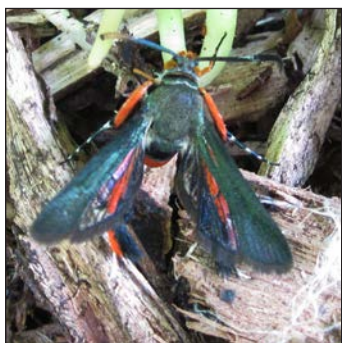
© Whitney Cranshaw, Colorado State Univ.

The squash bug is a flattened dark brown to gray insect that looks similar to the stinkbug. It will feed on all members of the cucurbit family, but pumpkins and squash are preferred. Immature squash bugs go through five molts before reaching maturity in July and August. There is one generation per year in Wisconsin.

Adults and nymphs feed on leaves and stems, as well as developing fruit. They feed with piercing/sucking mouthparts that disrupt the flow of water and nutrients, causing leaves to wilt. If the infestation is severe, leaves on mature plants will appear blackened as if burned.

## Squash vine borer

*Melittia cucurbitae*

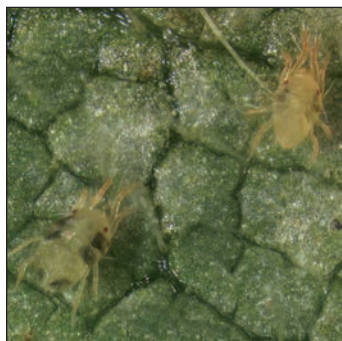


The squash vine borer is an occasional pest of cucurbits, particularly in smaller plantings. Thick-stemmed winter squash, particularly Hubbard squash, pumpkins, and zucchini, are the most susceptible to borer damage, while thin-stemmed squash, melons, and cucumbers are less preferred.

Adults emerge mid-June through July and lay eggs on stems or leaf stalks towards the base of the plant. Upon hatching, the small, white caterpillar larvae immediately bore into the stem, leaving large entrance holes covered with frass. Several larvae boring into the main stem can kill the plant, while the loss of a runner or two when the plant is larger will not cause economic damage.

## Two-spotted spider mite

*Tetranychus urticae*



Two-spotted spider mites can be a serious problem on cucurbits during hot, dry weather and can kill or seriously stunt the growth of plants. Watermelons and cantaloupes are especially susceptible. The tiny mites feed on the contents of individual cells of the leaves, and damage can develop very quickly. Because of their small size, spider mites are hard to detect until vines are damaged with hundreds of mites on each leaf.

Broad-spectrum insecticides applied at planting or as a foliar spray for other insect control can contribute to severe outbreaks of mites on melons by killing their natural enemies. Infestations of two-spotted spider mites can often signify irrigation or nutrient stress.



## Key Diseases of Vine Crops in Wisconsin

These are the main diseases of vine crops that you and your scout should be able to recognize. Detailed information on scouting, disease cycles, and management are in the following chapters and in the Pest Profiles section of the **Appendix**.

### Alternaria leaf blight

*Alternaria cucumerina*



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Alternaria is a fungal leaf spot disease similar to anthracnose that develops during the middle of the season as the canopy closes. Small lesions begin on the upper surface of crown leaves. The lesions enlarge with a target-like pattern. Weak and senescing plants are more susceptible to Alternaria leaf spot than are vigorous plants.

All cucurbits can be affected, especially muskmelon, cucumber, summer squash, and watermelon.

### Angular leaf spot

*Pseudomonas lachrymans*



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Angular leaf spot is caused by a bacterium that infects leaves, stems, and fruit during all stages of crop growth. The angular shape of the lesions gives this disease its name. Fruit lesions are usually superficial.

Angular leaf spot can be a destructive disease when environmental conditions are favorable. Resistant varieties of most vine crops are available and should be planted.

### Anthracnose

*Colletotrichum lagenarium*



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Anthracnose is a destructive fungal disease of leaves, stems, and fruit. Cucumber, muskmelon, and watermelon are most affected by anthracnose. It can also be a postharvest problem for all cucurbits. Fruits affected by anthracnose will not be suitable for long-distance shipping or farmers market sales.

Large, irregular tan to black lesions are signs of anthracnose on leaves and stems. On fruit the lesions are circular, sunken, and water-soaked, with a black center. They serve as entry points for secondary rots.



## Bacterial wilt

*Erwinia tracheiphilia*



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

Bacterial wilt is a serious infectious disease of vine crops. The bacterial pathogen is transmitted by the cucumber beetle when it feeds on plant tissue. After vine crops begin to run, scouts may notice individual leaves with severe wilt symptoms on sunny days. Within a week or two the condition spreads to entire vines, which do not recover from the wilt. Bacterial wilt is especially common with cantaloupes and cucumbers. Squash and pumpkins may not wilt as rapidly but may be stunted by the disease. Once infection has occurred, however, no control is possible and wilting plants should be removed from the field to prevent further spread.

## Downy mildew

*Pseudoperonospora cubensis*



© Dr. Amanda Gevens, UW-Madison

Downy mildew is caused by a fungus-like pathogen that affects only the leaves of all cucurbit varieties when weather is wet and cool-moderate in temperature. Depending upon the strain of downy mildew, some cucurbits may be more susceptible in a given year. In Wisconsin, we have had few years with problematic downy mildew, and it has been primarily found on cucumbers.

The appearance of downy mildew can come as early as late June or as late as August depending upon temperature, moisture, and levels of infection in surrounding production regions. Cotyledons to most mature leaves can become infected. While there are no direct fruit infections, loss of foliage can result in sunscald and reduction in yield and quality. Little varietal tolerance is currently commercially available.

## Fusarium wilt

*Fusarium oxysporum*



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Fusarium wilt is caused by a soil fungus that infects young or older plants through the roots. Once in the plant, the fungus is transported in the water-conducting tissue of the plant, causing wilt. Cucumber, muskmelon, and watermelon are most affected by Fusarium wilt. Resistant varieties are available and should be planted if the fungus is present.

Once the fungus is established in a field, it can survive in soil for over 20 years. Therefore, exclusion is key. Rotate crops to prevent build-up of the fungus in the soil. Scout for the presence of Fusarium, and be sure not to move soil from infested fields into uninfested fields on machinery or boots.

## Phytophthora crown and fruit rot

*Phytophthora capsici*

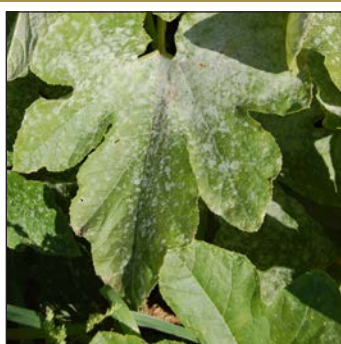


Phytophthora crown and fruit rot is a potentially devastating disease of cucurbits, solanaceous, and legume crops, affecting all plant parts.

Phytophthora is favored by warm to hot and wet conditions. Low-lying or flood prone areas of fields are often first to show symptoms, which include water-soaking at the crown or stem, wilting, and fruit rot (watersoaking and white, talcum-like pathogen sporulation). This is a sporadic yet potentially aggressive soilborne disease when conditions are wet. No complete resistance is available in cucurbits. Alteration of cultural conditions to promote dry canopies and soil drainage can aid in control along with fungicides, where applicable.

## Powdery mildew

*Golovinomyces cichoracearum*, *Podosphaera xanthii*



Powdery mildew is a common foliar disease of cucurbits that occurs mid- to late in the season, depending on the weather conditions. A white powdery growth covers infected leaves, reducing photosynthesis, plant vigor and yield. On susceptible crops, powdery mildew is often severe enough to significantly reduce the number and size of fruit. Although the fruit is rarely infected, the quality of the fruit is indirectly affected by powdery mildew due to sunscald, incomplete ripening, and low sugar content. Main hosts of powdery mildew are cucumber, muskmelon, pumpkins, and squash, sometimes watermelon. Increasing numbers of varieties are available with resistance to powdery mildew.

## Viruses



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All cucurbits are susceptible to several types of viruses. Some common viruses are cucumber mosaic virus, zucchini yellow mosaic virus, watermelon mosaic virus, and squash mosaic virus. Most often, actively growing and mature plants are affected. It rarely infects plants in the seedling stage. Virus infection reduces yield by affecting the vigor of the plant and the number and the quality of the fruit.

Cucumber and muskmelon are most susceptible to cucumber mosaic virus. Vines of virus-infected plants are often stunted and new leaves are dwarfed, mottled, and sometimes distorted. Severely affected plants may have fruit with mosaic symptoms.

## D. Biologically-based IPM (BioIPM)

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, host resistance, and biological controls that help prevent 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 (BioIPM).

- ▶ Cultural controls are decisions made in the production system that will avoid or suppress the build-up of pests and diseases. 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, limiting weed competition, using disease-free seed and transplants, cleaning machinery to prevent spread of pathogens and weeds from field to field, and many more. Overhead irrigation can be limited to reduce the amount of time leaves remain wet and reduce foliar disease risk.
- ▶ 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, treating seeds with hot water to remove seed-borne pathogens, cultivation to smother weeds and bury over-wintering pathogens, and maintaining proper temperatures and air flow in greenhouses and storage facilities to prevent the growth of disease organisms.
- ▶ 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 the use of naturally-occurring or introduced beneficial organisms to control or suppress pest populations. Common examples are parasitic wasps and predacious bugs, beetles, and spiders. Natural enemies of pests are common in the field and should be preserved.



*Green lacewing adult*

© Joseph Berger

- ▶ Chemical control by applying pesticides should be used together with preventative control measures and only when pest populations will cause economic damage. When possible, choose a selective pesticide that is specific for the pest you are trying to control with little or no detrimental effects on beneficial insects. Another category of pesticides is called biorational products, which have other attributes that make them less harmful to the user and the environment.
- ▶ Pesticides are formulations that kill many different kinds of pests as well as beneficial organisms. Pesticides can lead to a resurgence of pest populations due to a lack of natural controls or to secondary pest outbreaks and additional applications. For this reason, they should be used only if there are no other options to manage the pest. Proper pesticide application and resistance management techniques should be used to preserve the usefulness of available products.

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 you determine which pest control strategies are working and where improvements can be made each year.

## **IPM Components** (Reprinted with permission from the Lodi-Woodbridge Winegrape Commission)

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

**1. Understanding the ecology and dynamics of the crop.** It is important to gather all of the available knowledge about the crop we are growing. Most, if not all, pest problems can be directly related to the condition of the crop. The more we know about the ecology of the crop, the better pest management decisions we can make.

**2. Understanding the ecology and dynamics of the pest(s) and their natural enemies.** It is not only important to know what pests are present but also to know the details of their life cycles, what makes their populations change, whether any natural controls are present, and what effects these may have on the pests. By knowing as much about the pest as possible, we may find some weak point that we can exploit.

**3. Instituting a monitoring program to assess levels of pests and their natural enemies.** It is vitally important to continually monitor the pest levels in the field. This is a crucial aspect of the IPM approach. By knowing how many pests are present, we can make the best decision about how much damage they might cause to the crop. If natural enemies are present, we need to know how many are present as well because they may take care of the pest problem for us.

**4. Establishing an economic threshold for each pest.** Effective monitoring and use of economic thresholds make up the core of any IPM program. What is an economic threshold? It is the level of a pest population above which, if a control action is not taken, the amount of damage caused by the pest will exceed the amount it costs to control that pest. In other words, it is the level of the pest population at which the control measure used pays for itself.

**5. Considering available control techniques and determining which are most appropriate.** A wide range of control techniques are available for crop pests. They can be divided into five broad categories: chemical controls, such as pesticides; cultural controls, such as controlling plant vigor or rotations; biological controls, such as natural enemy releases or conserving natural enemies; behavioral control, such as the use of insect pheromones; and genetic control, such as the use of resistant varieties.

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

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

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

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



# Scouting

## In-Season



Effective scouting during the growing season will ensure that pests are treated only when they reach economically damaging levels and ensures the efficacy of the treatment. Scouting provides information on changes in pest populations over space and time and helps with decision-making.



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. Proper 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. The University of Wisconsin IPM program offers a Vegetable Crop Scouting class. Contact the IPM Coordinator, Bryan Jensen, at 608-263-4073 for more information.

## B. Scouting calendar

### Emergence to four-leaf stage

Monitor the crop twice a week as soon as the plants emerge or directly after transplanting. Overwintered striped cucumber beetle adults can colonize a field very quickly and cause direct damage to emerging or newly-transplanted plants, in addition to possibly transmitting bacterial wilt. Overwintered squash bugs can also be active at this time. Pay particular attention to field edges where beetles are entering from overwintering sites.

Be aware of areas in the field where seedling emergence is poor and inspect for seed maggot injury or damping off. Make notes for future rotational and management strategies. Scout for and identify emerg-



*Emergence stage*

ing weeds. In general, smaller annual weeds will be much easier to control than larger, established weeds.

### Runner formation to harvest

As runners begin to form, scout the crop at least once a week. Aphids,

squash vine borers, squash bugs, and leaf diseases can start building at this time.

Aphid and two-spotted spidermite populations can build quickly if weather becomes hot and dry. During wet

weather, be alert for the development of fungal and bacterial leaf and fruit diseases such as anthracnose.



*Runner stage*

Pay particular attention to symptoms of wilting. Wilting in cucurbits can occur from a number of causes, including serious diseases such as bacterial wilt, Fusarium wilt, and Phytophthora. Wilting can be caused by squash vine borers, early infestations of squash bugs, as well as droughty soils. Do your best to diagnose the cause, as this will determine the necessary treatment as well as future preventative strategies.

Scout the oldest, most susceptible cucurbit plantings for powdery mildew once a week as soon as the first fruit start to enlarge, and continue until harvest. This disease builds quickly on susceptible crops. Powdery

mildew will appear first on lower, older leaves or shaded leaves.

Examine 50 leaves by looking closely at the top and underside of five old crown leaves in 10 different locations in a field. Once you can easily see signs of powdery mildew when walking through a field,

it is too late to apply any treatments. Keep an eye out for annual grasses at this time. These grasses may appear harmless at first but establish quickly and can reduce yields and hinder harvest.



*Harvest stage*

## Harvest

Numerous bacteria and fungi are capable of causing fruit decay in the field, and later in storage. Inspect fruit at harvest for lesions or any signs of decay and discard suspect fruit.

This is a good time to scout for weeds and record the specific locations where weeds are producing seed. Use this information to guide spot treatments before next season's crop.

## C. Scouting methods

In general, scout cucurbits by walking the field in a systematic manner, such as a W-shaped pattern, that adequately covers the field. However, once the rows close, it may become difficult to walk through a thick vine crop such as pumpkin. Do the best you can, keeping in mind that you want to sample representative sections of the whole field.



*Scouting with a sweep net*

In the early season, before the plants begin to vine, choose five representative sites throughout the field. Inspect at least two leaves on five different plants at each site. After the plants vine and individual plants are indistinguishable (vine types), or fruits begin to enlarge (bush type), inspect 10 leaves and five fruit at each of five plant areas (about 10 square feet) in the field.

Look for the presence and signs of insect pests, diseases, and beneficial insects. Note the general plant condition. Examine the upper and lower leaf surfaces, the growing point, and the stem at the soil line. 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.

As you walk from site to site, remain alert for signs of insect or disease problems that may be sporadic in the field. Be aware of yellowing or wilting plants,

## Scouting for cucumber beetle

The striped cucumber beetle can be present on cucurbits when plants emerge from the soil or shortly after transplanting. Populations will continue to increase for about two weeks. Inspect the crop twice a week, if possible during this time, because this is when plants are most susceptible to feeding damage and transmission of bacterial wilt and viruses.

poor seedling emergence, or heavy insect feeding, and examine these plants more closely. Do your best to accurately diagnose the cause. Don't hesitate to seek help if needed. Check the field edges as well as low-lying areas of the field where pests or diseases have been a problem in the past.

Consult **Scouting Guidelines for the Key Insect Pests of Vine Crops in Wisconsin** and **Scouting Methods for Key Diseases of Vine crops** on the following pages for descriptions of specific pests and diseases to look for. Record your findings on a scouting form. See an example of a scouting form on the next page.

## D. Field records and maps

In general, 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. Organic growers also need detailed records to show compliance with the National Organic Program.

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 things 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.

Harvest records can be invaluable in planning for the future, especially to determine which crops or varieties were most affected by pests or diseases, when to plant specific crops, or how much to grow in the future.

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".

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

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

Procedure:

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



# Pest Scouting Form

Date / Time\_\_\_\_\_

Field #\_\_\_\_\_

Crop\_\_\_\_\_

Grower\_\_\_\_\_

Field Location\_\_\_\_\_

Plant Height\_\_\_\_\_

Scout \_\_\_\_\_

Field Size\_\_\_\_\_

Growth Stage\_\_\_\_\_

Field Map: Draw a rough map of the field, noting the orientation, pattern in which you scouted, and any special field features.

Insects: Walk a W pattern in field, inspecting random plants (25 plants per field, 50 if the field is large). Note the name, size/growth stage and tally how many you find. Then calculate the percentage of infestation (total number of pests/number of plants x 100).

Weeds: Count the number of weeds per 10 feet of row for large infestations or every 100 feet of row for smaller infestations. Identify the weed and mark what you find on the map.

Disease: Note whether there are any disease symptoms present, determine the extent of the symptoms, location and how many plants are affected. If plants appear stunted, inspect roots.

Scouting Calendar	April	May	June	July	August	September	October
<b>Insects</b>							
Aphids							
Cucumber beetles							
Seedcorn maggot							
Squash bug							
Squash vine borer							
Two-spotted spider mite							
<b>Diseases</b>							
Alternaria leaf blight							
Angular leaf spot							
Anthracnose							
Bacterial wilt							
Downy mildew							
Fusarium							
Phytophthora blight							
Powdery mildew							
Viruses							

## Scouting Guidelines for the Key Insect Pests of Vine Crops in Wisconsin

These are the scouting methods for main pests of vine crops that you and your scout should be able to recognize. Detailed information on the life cycle, scouting, and integrated management of each pest can be found in the **Appendix**.

### Aphids



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Department of Entomology, Bugwood.org

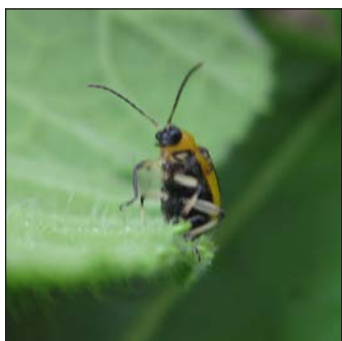
Aphids do not generally cause significant feeding damage to cucurbits but are the main vectors of cucumber mosaic virus and other viruses. Specifically the melon aphid transmit viruses more than other species. They are quite variable in color, but all stages are small soft-bodied insects with black cornicles (“tail pipes”), eyes, and leg joints.

Aphid populations usually start to build around the time when the vines form runners. Aphid populations will increase rapidly in hot weather, so check plants more frequently then. Check lower leaf surfaces and growing points. Cover the field thoroughly as initial infestations will occur as isolated “hot spots”. Aphids feed mainly on the underside of the leaves, where they suck the sap from the plants. Infested leaves curl downward and may turn brown and die. Cucumber, muskmelon, and watermelon are most affected by aphids. Other signs that indicate an aphid infestation are cast skins, honeydew, sooty mold, and ants. Natural enemies (parasitoids, predators, and fungal diseases) are frequently associated with aphid colonies.

**Threshold:** Insecticides are not an effective control of viruses transmitted by aphids. Use resistant varieties. If scouting indicates localized infestations, spot spraying can be considered to prevent direct damage from aphid feeding. Use selective insecticides to conserve natural enemies.

## Cucumber beetles

*Acalymma vittatum*



**Striped cucumber beetles have a black abdomen**

Cucumber beetles can colonize emerging seedlings and transplants quickly. It is important to scout carefully at least twice a week early in the season because this is when plants are most susceptible to feeding damage and disease transmission. Pay particular attention to field edges where beetles are entering from overwintering sites. There is not yet reliable degree day information to predict peak activity, but beetle activity can occur very early in the season. A second generation of beetles occurs in mid-summer in Wisconsin.

A major concern with striped cucumber beetles is their ability to transmit the bacterium *Erwinia tracheiphilia*, which causes bacterial wilt, a serious infectious disease. Cucumbers and melons are the most susceptible to bacterial wilt. Striped cucumber beetles are yellow-green, about one-quarter of an inch long, with three long stripes along the length of the body. Beetles feed on the leaf surface of young leaves, sometimes leaving holes. Heavy feeding on older leaves results in leaves appearing net-like, with only the veins remaining. Once feeding begins, beetles use an aggregation pheromone to call others to the food source.

Be aware that adult striped cucumber beetles look very similar to the western corn rootworm adult. It's important to distinguish between the two because the western corn rootworm does not transmit bacterial wilt and does no real damage to cucurbit plants. Turn the beetle over, and examine the underside of the abdomen. The striped cucumber beetle has a black abdomen, and the western corn rootworm has a yellow abdomen.

**Threshold:** A total of 50 plants should be inspected for the field. Calculate the average number of beetles per plant. Treat when there are more than four or five adults per 50 plants. Second generation beetles can cause serious injury to squash if plants are not yet touching within the row. Threshold at this stage is less than 5 beetles per plant.

## Seed corn maggot

*Delia platura*



Areas in the field where seedling emergence is poor may indicate seed maggot injury. Examine 5-10 seedlings in these areas and note if heavy root feeding is apparent. Seed corn maggots are typical fly larvae, pale yellow, legless, about one quarter inch long, and look like a grain of rice. They bore into the seeds or young seedlings.

Peak adult emergence from overwintering pupae occurs from early to mid-May when degree day accumulations reach 200<sub>DD</sub> using a base temperature of 39 degrees F. The next generations occur when 600<sub>DD</sub> and 1000<sub>DD</sub> have been reached. Keep a running total of degree days to determine when peak egg-laying occurs. Flies will not lay eggs when the soil temperature is greater than 70 degrees F. Adult flies lay eggs in soil with high organic matter or near seeds and seedlings. They are particularly attracted to decaying animal or green manure in recently tilled fields.

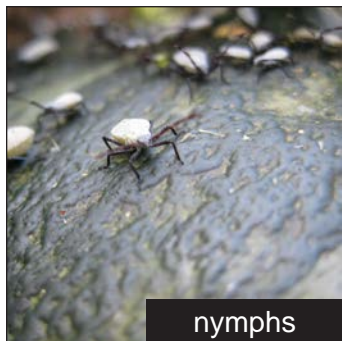
**Threshold:** Damage is generally not detected until it is too late to take control actions, meaning that there is no economic threshold for this pest and management is preventative. Control is often achieved with preventative seed treatments.

## Squash bug

*Anasa tristis*



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The squash bug is most common on pumpkins and squash. Seedlings, new transplants, and flowering plants are the most critical growth stages to monitor, as these are the stages when the most damage can occur. The adult squash bug and older nymphs are difficult to kill, so early detection of eggs and young nymphs is important.

The squash bug can be misidentified as a stinkbug. Both insects look similar and emit a disagreeable odor when crushed; however, the stinkbug is not a pest of cucurbits. Squash bug adults are flattened insects about 5/8 of an inch long, brownish-gray with orange and brown stripes along the edge of the abdomen. Nymphs are pale green but become dark, greenish gray or brown as they mature. Check the undersides of leaves for clusters of yellowish-brown to red eggs laid in neat rows from spring to midsummer.

Young nymphs tend to aggregate at the base of the plant. Adults and nymphs feed on leaves and stems as well as developing fruit. They will disperse quickly when disturbed. Squash bugs feed by sucking nutrients from leaves and disrupting the flow of water and nutrients, which can cause wilting. Before wilting, yellow specks will develop on the foliage that eventually turn brown and dry. If the infestation is severe, leaves on mature plants will appear blackened as if burned.

**Threshold:** Threshold is reached when the average number of egg masses (groups of eggs) is greater than one egg mass per plant before flowering.

## Squash vine borer

*Melittia cucurbitae*



Begin scouting fields for the squash vine borer in mid-June when the adult moth emerges from cocoons in the soil. The adult is a clear-winged, fast-flying moth that can be mistaken for a wasp. Adults lay eggs on stems or leaf stalks towards the base of the plant. Peak egg-laying occurs when 900-1000<sub>DD50</sub> have accumulated or when chicory is in full bloom. Upon hatching, the larvae immediately bore into the plant stem. Look for sawdust-like excrement coming from entry holes just above where the vine breaks the soil. If caught early, it is often possible to save the plant by carefully splitting the vine lengthwise and removing borers. Place a little moist soil over the split vine.



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Thick-stemmed winter squash, pumpkins, and zucchini are particularly susceptible. Butternut squash (*C. moschata*) is resistant. Cucumbers and melons are less preferred. Squash vine borer is more likely to be a problem where infestations were heavy the previous year. There is one generation per year in the upper Midwest.

**Threshold:** Treat when adults are observed (900<sub>DD50</sub> accumulated), especially when runners are less than two feet long. There are currently no treatment thresholds. Several larvae boring into the main stem can kill the entire plant, while the loss of a runner or two when the plant is larger will not cause economic damage. Focus treatments on the basal 14-16 inches of vines.



## Two-spotted spider mite

*Tetranychus urticae*



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Mites are small arthropods about the size of a dot at the end of a sentence. Hot, dry weather will favor mite populations. Rains can reduce infestations. The two-spotted spider mite is greenish-yellow with two black spots on its back. Use a hand lens to confirm identification.

Check field edges, as this is where mites will appear first. Examine the crown leaves of 10 plants in 10 locations along the field edge. Heavily infested leaves will appear yellow and crusty. Look at the lower leaf surface near where the major veins join the petiole, as mites and their webbing tend to appear here first. Heavy infestations often signify irrigation deficits.

**Threshold:** No thresholds have been established for spider mites on cucurbits.

## Scouting Methods for Key Diseases of Vine crops

These are the scouting methods for main pests and diseases of vine crops that you and your scout should be able to recognize. Detailed information on the life cycle, scouting, and integrated management of each disease can be found in the Appendix.

## Alternaria leaf blight

*Alternaria cucumerina*



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Alternaria is a fungal leaf spot disease that develops during the middle of the season. It occurs primarily on muskmelons, but other cucurbits can be affected.

Begin scouting when plants begin to run (vine types) or flower (bush types). Look for small, circular, water-soaked lesions on the upper surface of crown leaves. Lesions enlarge with a target-like pattern of dark concentric rings within the spots. Spots coalesce to affect large areas of leaves and can cause defoliation that begins on crown leaves.

**Threshold:** Begin fungicide treatment symptoms found on one leaf per 50 leaves inspected. Rotating fungicides is important as Alternaria fungi have developed resistance to some systemic fungicides.

## Angular leaf spot

*Pseudomonas lachrymans*



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Angular leaf spot is a bacterial disease that infects leaves, stems, and fruit during all stages of crop growth. Scout closely for the disease in the early to mid-season as immature fruit appear. Many varieties of cucurbits have good resistance to angular leaf spot.

Initial symptoms will be small water-soaked spots that later turn brown, often with a yellow halo. As the lesion dries, the affected tissue may fall out, causing a shot-hole appearance. Leaf lesions are delimited by veins, giving them an angular shape. The sunken lesions on fruit are generally superficial and may have a white crust.

Bacterial leaf spot is caused by a different bacterial species. Bacterial leaf spot looks similar in size and color to angular leaf spot, but the spots are circular. When moist, small droplets of exudates may come from the lesions and dry as a white crust. Fruit may have sunken spots with white crust.

**Threshold:** Treat when symptoms are found on one leaf per 25-50 leaves sampled. See A3422 for current recommendations.

## Anthracnose

*Colletotrichum lagenarium*



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Anthracnose is a destructive fungal disease of leaves, stems, and fruit. Cucumbers, muskmelons, and watermelons are most affected. Anthracnose usually becomes established in mid-season after the plant canopy has developed. The fungus requires leaf wetness and fairly high temperatures between 70-80 degrees F to develop. Scout for signs of anthracnose during warm, moist weather from midseason through harvest.

Symptoms of anthracnose vary among the three principal cucurbits infected. On cucumber and muskmelon, symptoms usually begin as small, yellowish, water-soaked lesions which can enlarge considerably. Stem lesions on muskmelon can girdle the stem and cause vines to wilt. Stem cankers are less obvious on cucumbers. On watermelon, anthracnose lesions are irregular and turn dark brown or black, rather than tan.

Fruit lesions are circular, sunken, and water-soaked, with a black center. When moisture is present, the black center of the lesion is covered with salmon-colored spores. Use a 10X lens to inspect. Fruit lesions are generally superficial, but they serve as entry points for secondary rots.

**Threshold:** There is no treatment for Anthracnose once infection has occurred. Protectant fungicides can aid in limiting initial infection. See A3422 for current recommendations.

## Bacterial wilt

*Erwinia tracheiphila*



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Bacterial wilt is a serious infectious disease of cucumber and muskmelon, and occasionally pumpkins and squash, caused by the bacterium *Erwinia tracheiphila*. It is spread from plant to plant by the cucumber beetle. It is not spread by contaminated seed. Watermelon is not affected by bacterial wilt.

Signs of bacterial wilt are wilting and drying of individual leaves, which may also have cucumber beetle injury. In a week or two, one or more vines or the entire plants wilt. Wilted parts may appear to recover at night, but they continue to wilt on sunny days and finally die. Once infection has occurred, no control is possible, and wilting plants should be removed, if possible, to prevent further spread.

Several other pathogens, as well as insects, can cause wilt in cucurbits, including the soil fungus *Fusarium*, *Phytophthora*, squash vine borer, and squash bug. Sometimes, if an affected stem is cut off near the ground, the sap may be milky in appearance or sticky. This is an indication of bacterial wilt, but identification should be confirmed.

**Threshold:** Prevention of bacterial wilt is dependent on resistant varieties and cucumber beetle control. To prevent bacterial wilt in susceptible crops, beetles should not be allowed to exceed 4-5 beetles for every 50 plants.

## Downy mildew

*Pseudoperonospora cubensis*



© Dr. Amanda Gevens, UW-Madison

Downy mildew can be a serious leaf disease when rain or heavy dew allow leaves to remain wet and temperatures are between 60-70 degrees F. Scout crops from mid-July to the end of the season when conditions favor development.

Downy mildew will not affect fruit. Leaves of pumpkins, winter squash, cucumbers, watermelon, and mature summer squash look pale green to yellow and are angular (held between veins) on leaf surfaces. On the undersides of leaves, you may see the diagnostic gray to black fuzzy pathogen sporulation. A 10X hand lens can aid the visualization of the sporulation.

As lesions progress, affected areas of the leaf turn brown and die, and sporulation on leaf undersides becomes limited and hard to detect.

**Threshold:** If weather conditions are favorable and a susceptible crop is grown, begin fungicide treatments before symptoms are severe. Rotating fungicides is important as downy mildew fungi have developed resistance to some systemic fungicides.



## Fusarium wilt

*Fusarium oxysporum f.sp. melonis*, *Fusarium solani f. sp. cucurbitae*



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Fusarium wilt is caused by a soil fungus that infects young or older plants through the roots and disease develops rapidly when soil temperatures are warm. Once in the plant, the fungus is transported in the water-conducting tissue of the plant, causing wilt. The pathogen infects only varieties of *Cucumis melo* (i.e., melons, muskmelons, and some squash), and weeds are not known to be hosts.

Scout for signs of fusarium wilt in mid-season to harvest. Record the occurrence and severity of wilt symptoms. Symptoms are commonly expressed after fruit set and consist of yellowing of a runner on one side of the plant followed by rapid wilting. Runner lesions develop externally and extend from the crown to the yellowed tips. Other runners collapse in a similar manner, and whole plant collapse occurs rapidly. External lesions may develop on roots accompanied by red gumming at or just below the soil surface. Internally, a dark red-brown vascular discoloration extends from roots to runners.

**Threshold:** There is no treatment for Fusarium once it is established. However, note the presence of the disease so that preventative measures can be taken in the following season.

## Phytophthora crown and fruit rot

*Phytophthora capsici*



Phytophthora crown and fruit rot can be a very destructive disease. All cucurbits are susceptible. It can infect plants from the seedling stage through harvest. The fungus is highly dependent on saturated soil for infection, and the disease is most likely to be found in wet or poorly-drained areas of fields. *Phytophthora capsici* can also infect tomatoes, peppers, eggplants, and succulent beans. Be sure to rotate away from all of these susceptible crops if this disease has occurred. The pathogen is soilborne and can survive in the soil for 10 years or more. Do not land spread culls to limit accumulation of the pathogen in soil.

Disease symptoms occur suddenly, and plants wilt and die within a few days of infection. Symptoms usually start as a wilting and browning of the growing tip. Infected fruit rot quickly in the field and post-harvest. The roots and stems are soft, water-soaked, and brown.

**Threshold:** There is no treatment for Phytophthora once infection and wilting has occurred. Fungicides can aid in limiting spread of this disease from fruit to fruit in a smaller fruiting cucurbit crop such as pickling cucumber. See A 3422 for current fungicides.



## Powdery mildew

*Golovinomyces cichoracearum*, *Podosphaera xanthii*



Powdery mildew is a common and often severe foliar disease of cucurbits that occurs later in the season. Scout for powdery mildew from fruit set to harvest. Lesions are light yellow at first, then become white or tan with powdery growth that is easy to recognize. Start by scouting the oldest cucurbit plantings once a week as soon as the first fruit start to enlarge. Lesions usually appear first on lower, older leaves or shaded leaves. Examine 50 leaves by looking closely at the top and underside of five old crown leaves in 10 different locations in a field.



Favorable conditions for the disease are dense plant growth and low light intensity. Warm, dry weather of 68-80 degrees F is ideal.

All cucurbit species are susceptible, although resistant varieties of cucumber, melon, summer squash, winter squash, and pumpkin are available and should be planted where powdery mildew tends to be a problem.

**Threshold:** If fungicide treatment is considered, begin when infection is seen on one crown leaf in 50 inspected. Rotating fungicides is important, as powdery mildew fungi have developed resistance to some systemic fungicides.

## Viruses



Viruses are generally introduced into new plantings by infected seed and transmitted from plant to plant by aphid or cucumber beetle feeding. Weeds are also a source of some viruses. Viruses can spread quickly in a field when aphid activity is high. Like aphid infestations, initial virus infection is often localized in hot spots within the field.

Look for signs of virus infection when scouting for insects mid-June to harvest. Symptoms vary. New leaves can be dwarfed, mottled, and sometimes distorted. Mosaic patterns of irregularly shaped, dark green areas alternating with light green or yellow areas is a recognizable virus symptom. New leaves of muskmelons and cucumbers infected with cucumber mosaic virus sometimes wilt and die, while old crown leaves turn yellow and dry up. Plants decline slowly.



Watermelon mosaic virus tends to cause raised, blister-like areas on leaves and affect leaf size. Zucchini yellow mosaic virus typically causes the leaf lobes to become long and narrow. Some viruses can cause malformations of the fruit.

Several viruses are found in wild and volunteer cucurbits, as well as weeds such as goosefoot, lambsquarters, Russian thistle, and various legumes.

**Threshold:** There is no control for viruses once the disease is established. Plant resistant varieties, use virus-free seed, and manage insect vectors. Rogue virus-infected plants.

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# Disease Management

## In-Season



Vine crop diseases are more effectively prevented than cured. Planting resistant varieties, sanitation, and excluding pathogens from non-infested fields are important IPM strategies for vine crop diseases.



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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. *Good growing practices are maintained 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. *Vine crop 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 and disease resistance

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 cucurbit diseases.

There are things you can do to make the environment less favorable for disease. Many vine crop pathogens need long periods of leaf wetness to cause disease, so a key strategy to prevent leaf disease is to maximize air movement and leaf drying in the crop canopy. You can do this by selecting fields with good air circulation, planting with wide row spacing, planting in rows parallel to prevailing winds, and not planting too close to hedgerows.

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 warm, well-drained soil ready to support vigorous seedling growth. Be sure soil has adequate, balanced fertility, and continue to improve soil structure and tilth each year.

## B. Scouting for diseases

Scouting is particularly important in managing cucurbit diseases. As you become familiar with vine crops, learn to anticipate which diseases are likely to be a problem, and scout weekly for them. Be ready to take action. Leaf diseases such as powdery mildew can develop quickly, and there are no control options possible once the disease is past threshold levels. Fungicides, especially organic alternatives, are protectants and need to be applied before the disease develops.

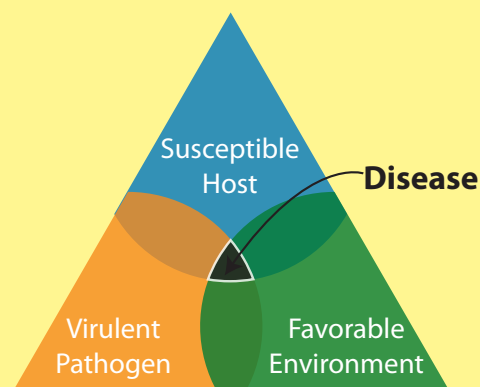
Accurate identification of disease symptoms, especially recognizing if the problem is caused by bacteria or fungi, is essential for choosing effective control strategies. Sometimes environmental conditions can cause symptoms that look like diseases or insect damage. Don't hesitate to seek help if you are not sure what is causing a problem. Consult with a knowledgeable grower, a crop consultant, or your county agricultural Extension agent. You can find your local county Extension office in the county government listings of your local phone book or at [www.uwex.edu/ces/cty](http://www.uwex.edu/ces/cty).

### Conducive crop growth stages

Seeds, seedlings, and transplants are vulnerable stages for disease development in vine crops. Seeds can harbor bacterial and fungal pathogens, and infected seed is a common way for *Alternaria* leaf spot, viruses, anthracnose, angular leaf spot, and other pathogens to spread from field to field. Buy certified, disease-free seed from a reputable seed dealer. Grow transplants under the best possible conditions, and scout them often for symp-

### 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.



toms of disease. Inspect the seedlings before they are transplanted, and scout fields at least weekly for several weeks after planting. Remove any plants with signs of bacterial wilt. Scouting carefully at this stage will help prevent serious problems later in the season.

Many pathogens take advantage of wounds created by insect feeding, or by mechanical injury to gain entry into the plant. Be aware of those periods when insects may be feeding and look closely for signs of secondary infection by bacterial wilt or soft rot pathogens.

### Conducive weather conditions

The conditions most favorable for leaf diseases such as Septoria leaf spot, downy mildew, anthracnose, and bacterial leaf spot are periods of high humidity, fog, drizzling rains, and heavy dew, when leaves remain wet for many hours or days. Scout carefully during and after these periods. Seedlings are particularly susceptible, although plants can be infected at any growth stage. Use weather-based forecasting programs when available. These track the movement of pathogens that do not overwinter in the north, such as downy mildew.



### Quick Note

**Where to get help diagnosing plant diseases:** (1) Knowledgeable growers in your area, (2) Crop consultants, (3) 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/), (4) UW-Madison Plant Diagnostic Clinic—samples may take two weeks to process

## C. IPM strategies to manage vine crop diseases

Vine crops pathogens can affect the fruit as well as plant leaves and stems, especially at harvest or in storage. Therefore, disease management in cucurbits is an important crop quality issue. The following pages summarize general IPM strategies to manage vine crop diseases, as strategies to control specific diseases.

### Crop rotation and residue management

Crop rotation is an effective strategy to control pathogens that overwinter in crop debris. This includes Septoria leaf spot, Alternaria leaf spot, anthracnose, and the angular leaf spot pathogen. Crop rotation allows enough time for the residue to decompose completely and the pathogen to die out before the next susceptible crop is grown. If you have the land available, do not plant a cucurbit crop more often than every three years in a field. Plow under debris soon after harvest to allow for rapid and thorough decomposition.

### Host resistance

Choose resistant cultivars as much as possible, especially if you have had a specific disease problem in the past. Host resistance is an important way to manage angular leaf spot, anthracnose, Fusarium wilt, powdery mildew, downy mildew, and scab that are otherwise difficult to control. Consult your seed catalogs, seed company representatives, and extension specialists and other farmers about recommended and available resistant cultivars.

### Sanitation/Exclusion

Sanitation is the removal of a pathogen from seed, plants, or equipment. Excluding a pathogen from a field, or preventing it from spreading, is one of the best ways to prevent disease problems.

Several pathogens of vine crops such as Alternaria leaf spot, viruses, Phytophthora, anthracnose, angular leaf spot, and downy mildew are spread from field to field on seed. Seedlots, therefore, should be entirely free of pathogens before planting. The best way to do this is to purchase certified, pathogen-free seed.



Pathogens also enter a field through infected transplants. If using transplants, it is important to make certain that the plants are disease-free. One way to do this is to grow your own transplants, so that they can be inspected weekly for disease symptoms. If plants are purchased commercially, communicate with the supplier about their growing practices and carefully check transplants for disease symptoms before planting.

Soil-borne pathogens such as *Phytophthora*, *Fusarium*, and scab are 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.

Many pathogens that cause disease in the field can also cause fruit rot in storage. These include angular leaf spot, bacterial leaf spot, anthracnose, black rot, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, scab, septoria, and white mold. Handle fruits carefully to minimize wounding. Harvest before frost. Discard suspect fruit. Pack in disease-free storage boxes.

## **Insect and Weed Control**

Bacterial wilt is spread by cucumber beetles as they feed on plants. Management of this disease is completely linked with preventing feeding of cucumber beetles on susceptible hosts. Control bacterial wilt by keeping cucumber beetles under threshold levels, especially during the seed to five-leaf stage.

Aphids feeding on virus-infected weeds and volunteers obtain the viruses and transmit them when they move into the vine crop. Watermelon mosaic virus occurs in weeds such as goosefoot, lambsquarters, Russian thistle, various legumes, cheeseweed, and other related plants. Viruses are also found in wild and volunteer cucurbits. Removing this source of inoculum is a good preventative strategy for viruses.

Using insecticides to control aphids is not effective, however, because the virus is transmitted before the aphid can be killed. After feeding on an infected plant, aphids retain the ability to transmit these viruses for very short periods of time (minutes to a few hours). In general, spread of potyviruses in the field occurs when aphid activity is high and is often very rapid and localized.

## **Fungicides and bacteriacides**

There are fungicides and bacteriacides labeled for cucurbit crops. If conditions warrant an application of a product and you are considering treating a disease problem, it's important to accurately identify if the problem is caused by bacteria or fungi so that the correct product is used.

Preventative fungicides are generally not used in vine crops except in the cases of especially conducive weather conditions and when the field has a history of the disease. If your field has a history of downy mildew or powdery mildew, a susceptible variety has been planted, and the weather conditions are particularly favorable, a protective fungicide may prevent a severe case. Choose a fungicide specifically targeted for that disease. Consult the publication A3422 *Commercial Vegetable Production in Wisconsin* for fungicides currently labeled for vine crops. There are some fungicides and bacteriacides that are allowable for organic production. Check with the Organic Materials Review Institute (OMRI) at [www.omri.org](http://www.omri.org) and with your certifier.

Proper timing and excellent coverage of these fungicides are essential for efficacy. Remember that relying on products for disease control can be expensive and must be appropriately timed for efficacy. It's important to develop an effective system of cultural practices to prevent diseases from occurring.

## **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 variety planted, soil amendments, 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.

## Common nonpathogenic disorders of vine crops

**Oedema** on winter squash is due to inconsistent moisture. Provide a consistent level of moisture to help reduce this water-stress related problem.



Ontario Ministry of Agriculture, Food & Rural Affairs

**A lack of female flowers** on cucumber and winter squash is usually due to poor weather conditions and variety.

**Misshapen fruit and fruit hollows** on cucumber is due to poor pollination and inconsistent water supply during fruit enlargement. Provide good water management during fruit enlargement.

**Poor fruit set** on cucumber and winter squash is usually due to poor pollination and poor weather conditions at flowering. Provide honeybee hives at one hive per two acres.






**Poor fruit set can be the result of poor pollination; providing habitat for bees can be a good strategy for solving this problem.**


**Notes:**

[illegible]


## Summary of IPM Strategies for Cucurbits (cucumber, zucchini, muskmelon, watermelon, winter squash and pumpkins)


Alternaria leaf blight	Preplant	Planting	In-Season/Harvest
<p><i>Alternaria cucumerina</i></p>  <p>© Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Use a two year crop rotation.</li> <li>▶ Select sites with good air movement that encourages leaf drying.</li> <li>▶ Some resistant watermelon varieties are available.</li> <li>▶ Buy disease-free or fungicide-treated seed.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Do not plant near other cucurbit fields.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Remove or plow under plant debris after harvest.</li> <li>▶ Fungicides are available for susceptible crops when weather conditions are conducive. Consult A3422 for currently labeled products.</li> </ul>
Angular leaf spot	Preplant	Planting	In-Season/Harvest
<p><i>Pseudomonas lachrymans</i></p>  <p>© Howard F. Schwartz, Colorado State University, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Use a 3-4 year rotation away from cucurbit crops so the bacteria die out between crops.</li> <li>▶ Choose a field location with maximum air flow to keep leaves dry.</li> <li>▶ Choose varieties with some resistance. Fruit may exhibit more resistance than leaves.</li> <li>▶ Use certified disease-free seed.</li> <li>▶ Hot water and chemical seed treatment is often not effective in removing the bacteria from seed.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Allow for good air movement by planting with wide spacing, in rows parallel to prevailing winds, and not close to hedge-rows.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Do not work in the fields when plants are wet as this will spread the bacteria.</li> <li>▶ Keep cucumber beetles under control.</li> <li>▶ Scout for angular leaf spot. If found, plan preventative strategies for next season.</li> <li>▶ If angular leaf spot is found, copper sprays may protect uninfected plants. Treat when symptoms first appear if weather will be cool and rainy.</li> <li>▶ Pick fruit when vines are dry.</li> <li>▶ At harvest, inspect fruit for lesions caused by angular leaf spot. Discard suspect fruit.</li> <li>▶ Handle fruits carefully to minimize wounding. Harvest before frost. Pack in disease-free storage boxes</li> <li>▶ Turn under crop debris after harvest so that it decomposes quickly and thoroughly.</li> </ul>


Anthracnose	Preplant	Planting	In-Season/Harvest
<p><i>Colletotrichum lagenarium</i></p>  <p>© Charles Averre, North Carolina State University, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Use a three year crop rotation away from cucurbit crops to avoid build up of the pathogen.</li> <li>▶ Choose a field location with maximum air flow to keep leaves dry.</li> <li>▶ Choose varieties with some resistance.</li> <li>▶ Buy certified disease-free seed.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Allow for good air movement by planting with wide spacing, in rows parallel to prevailing winds, and not close to hedge-rows.</li> <li>▶ Do not plant near other cucurbit fields.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Do not work in the fields when plants are wet.</li> <li>▶ Scout weekly. If anthracnose is found and weather conditions are conducive for disease, fungicides are available to protect still-healthy plants. Consult A3422 for products.</li> <li>▶ At harvest, inspect fruit for lesions caused by anthracnose. Discard suspect fruit. Handle fruits carefully to minimize wounding. Harvest before frost.</li> <li>▶ Prevent anthracnose in storage by keeping fruit dry. Do not wash fruit and keep humidity low. Pack in disease-free storage boxes</li> <li>▶ Turn under crop debris after harvest so that it decomposes quickly and thoroughly.</li> </ul>


Bacterial wilt	Preplant	Planting	In-Season/Harvest
<p><i>Erwinia tracheiphilia</i></p>  <p>© Jack Dykinga, USDA Agricultural Research Service, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Use crop rotation to reduce cucumber beetle population.</li> <li>▶ Cucumbers and some varieties of squash are most susceptible. Watermelons are not susceptible to bacterial wilt.</li> <li>▶ Choose varieties that are less attractive to beetle feeding.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Bacterial wilt is controlled by keeping cucumber beetles under threshold levels, especially during seed to five leaf stage.</li> <li>▶ Plant when peak beetle activity is over. Use transplants rather than direct seed for older, more tolerant seedlings when beetles are active.</li> <li>▶ Treat transplants with Surround®.</li> <li>▶ Spunbonded row covers will exclude cucumber beetles.</li> <li>▶ Plant a sprayed perimeter trap crop of Blue Hubbard squash (attractive to beetles and not susceptible to wilt) to protect more susceptible crops.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Scout weekly early in the season, especially if cucumber beetles are feeding. If bacterial wilt is found, remove plants and destroy.</li> </ul>



Downy mildew	Preplant	Planting	In-Season/Harvest
<p><i>Pseudoperonospora cubensis</i></p>  <p>© Dr. Amanda Gevens, UW-Madison</p>	<ul style="list-style-type: none"> <li>▶ Look for resistant or tolerant varieties, especially cucumber and muskmelons.</li> <li>▶ Choose a site with good air drainage.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Allow for good air movement by planting with wide spacing, in rows parallel to prevailing winds, and not close to hedge-rows</li> <li>▶ If possible, trellis cucumbers.</li> <li>▶ If possible, separate successive plantings into distant fields to help slow disease spread.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Avoid overhead irrigation.</li> <li>▶ Fungicides are available that may protect plants that are not infected. Consult UW Extension publication A3422 for a list of currently labeled fungicides.</li> <li>▶ Rotating fungicides is important as downy mildew fungi have developed resistance to some systemic fungicides.</li> </ul>

Fusarium wilt	Preplant	Planting	In-Season/Harvest
<p><i>Fusarium osysporum</i></p>  <p>© Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Use resistant cultivars.</li> <li>▶ Rotate crops to avoid build-up of the pathogen.</li> <li>▶ If a field is infested with Fusarium, do not plant for 10 years to allow the fungus to die out.</li> </ul>		<ul style="list-style-type: none"> <li>▶ To avoid storage rots, handle fruits carefully to minimize wounding. Harvest before frost. Discard suspect fruit. Pack in disease-free storage boxes.</li> </ul>

Powdery mildew	Preplant	Planting	In-Season/Harvest
<p><i>Erysiphe cichorancearum</i></p> <p><i>Sphaerotheca fuliginea</i></p>  <p>© Howard F. Schwartz, Colorado State University, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Choose resistant varieties.</li> <li>▶ Vigorous indeterminate varieties may maintain sufficient numbers of healthy leaves to tolerate powdery mildew longer in the season.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Growing the crop in smaller parcels may slow disease spread.</li> <li>▶ Do not plant sequential plantings near each other.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Scouting is essential. Once you can easily see signs of powdery mildew when walking through a field, it is too late to apply any treatments for control.</li> <li>▶ Scout weekly when fruits start to enlarge. Examine upper and lower leaf surface of five old crown leaves in at least 10 locations in the field.</li> <li>▶ Fungicides are available that may protect plants that are not infected. Consult UW Extension publication A3422 for currently labeled fungicides.</li> <li>▶ Rotating fungicides is important as powdery mildew fungi have developed resistance to some systemic fungicides.</li> </ul>

Viruses of cucurbits	Preplant	Planting	In-Season/Harvest
<p>Cucumber mosaic virus, Squash mosaic virus, Zucchini yellow mosaic virus, Watermelon mosaic virus, and others.</p>  <p>© Alton N. Sparks, Jr., University of Georgia, Bugwood.org</p>	<ul style="list-style-type: none"> <li>▶ Plant resistant varieties.</li> <li>▶ Choose short-season varieties that set fruit early.</li> <li>▶ Buy seed that is certified virus-free.</li> <li>▶ Keep fields and surrounding areas free of volunteer cucurbits and weeds such as burdock, jimsonweed, and pokeweed that may harbor viruses.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Plant as early as possible so that fruit is set before the effects of virus diseases become apparent.</li> <li>▶ Silver reflective plastic mulches applied at planting can be effective in repelling aphids from plants.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Control aphids by cultural and biological methods. Insecticides are not effective because the virus is transmitted before the aphid is killed.</li> </ul>

# Insect Management

## In-Season



An integrated insect management program is prevention-based. Control strategies are implemented throughout the season—from pre-plant decisions to harvest—and include cultural, mechanical, and carefully-chosen chemical control methods.



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

For many decades, insecticides have been the primary form of insect management by many growers, and many sprays were made according to calendar schedules, not due to the presence and population level of insect pests. Current insect management recommendations 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. Current IPM recommendations take a broader, more preventative approach to insect control and include cultural controls, host plant resistance, and biological control. One of the goals of IPM is to reduce pesticide use to the bare minimum.



*Cucumber flower and immature fruit*

## B. Determining threshold levels

There are several species of insect pests that are sporadic and sometimes frequent pests of all vine crops in the upper Midwest. These include:

- ▶ Melon aphid
- ▶ Seedcorn maggot
- ▶ Spotted cucumber beetle
- ▶ Squash vine borer
- ▶ Squash bug
- ▶ Striped cucumber beetle
- ▶ Two-spotted spider mite

You should be able to recognize these insects and be familiar with their life cycle so that you can scout effectively for them in your fields. See **Key Insect Pests of Vine Crops in Wisconsin** in the General IPM chapter, **Scouting Guidelines for the Key Insect Pests of Vine Crops in Wisconsin** in the Scouting chapter, and the Pest Profiles in the **Appendix** of the workbook to learn about these insects.

Chemical controls should only be considered when insect populations have reached or exceeded an established 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 vine crops to help commercial growers weigh the costs of their pest management strategies against the potential economic impact of each pest and the value of the crop. Threshold levels for key insect pests of vine crops are included in the Scouting section of this workbook.



*Cucumber beetles*

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 strategies for vine crop 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 vine crops is on the following page.

### **Cultural control/mechanical control/exclusion**

There are many cultural practices that are effective in keeping insect pests below damaging levels. Turning under crop residues after harvest and rotating vine crops to different fields each year is a highly recommended way to avoid the build-up



of key pests such as the striped cucumber beetle, squash vine borer, squash bug, and seedcorn maggot. The most damaging first generation of the seedcorn maggot can be avoided by incorporating the cover crop or organic soil amendments three weeks before planting and timing planting when the adult egg-laying flies are not prevalent. Spun-bonded row covers work well in vine plantings to exclude cucumber beetles and squash vine borers until the vines begin to flower.

### Host Resistance

Some vine crops are more attractive or less attractive to specific pests than other crops. For example, squash vine borers prefer thick-stemmed winter squash, pumpkins, and zucchini, while butternut squash is resistant to them. Cucumbers and melons are less preferred by the squash vine borer because of their thinner stems. Similarly, cucumber beetles prefer certain winter squash varieties like 'Turk's Turbin' and 'Blue Hubbard,' zucchini, cucumbers, yellow summer squash, and acorn squash and will feed less often on pumpkins, muskmelons, butternut squash, or watermelons. Switching crops and/or choosing varieties that are less attractive to persistent insect pests is an economical and highly effective control option for vine crops.

### Biological control

Biological control occurs regularly in vegetable plantings and can be highly effective in controlling populations of aphids and spider mites. Be aware of biological control activity, and implement practices that do not disrupt the activity of natural enemies. Read the chapter on **Biological Control** for specific guidelines.

### Chemical control

Carefully chosen and timed application of chemical insecticides may be necessary to augment cultural and biological controls, especially in the seedling stage and at flowering. The selection of treatment depends on the pest species present and the developmental stage.

## 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 the season, can lead to a resurgence of pest populations due to a lack of natural controls or to secondary pest outbreaks. Choose pesticides with little or no residual activity to control soil-inhabiting pests such as the seed corn maggot preserves beetles and other 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.

### Pollinator protection:

Pollinators are essential in the production of many fruit and vegetable crops. Honeybees and pollinator species have been in decline in recent years, and this is a concern for the production and ecological needs in the system. Therefore, it is important to use many approaches to limit pollinator disruptions including:

- ▶ Develop conservation sites that can serve as nesting sites for pollinators.
- ▶ Maintain a diversity of plants to encourage multiple species of pollinators, and to allow them to hide from their own predators.
- ▶ Maintain a source of water nearby.
- ▶ Apply insecticides when pollinators are not in fields (late evening, during bloom).
- ▶ Limit insecticide drift into pollinator mating, nesting, and off-site areas.
- ▶ Properly follow insecticide labels to ensure adequate timing to limit and amount to limit exposure to pollinator species.



### Quick Note:

For a current list of insecticides labeled for vine crops, see *A3422 Commercial Vegetable Production in Wisconsin*.

## Summary of IPM Strategies for Insect Pests of Vine Crops (continued on next page)

Pest	Cultural control	Mechanical control / Exclusion
<b>Aphids</b>	<ul style="list-style-type: none"> <li>▶ Separate early and late plantings.</li> <li>▶ Plow debris under after harvest.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Reflective mulches may help to repel aphids while also providing horticultural benefits.</li> <li>▶ Eliminate virus host plants, including broadleaf weeds.</li> </ul>
<b>Cucumber beetles</b>	<ul style="list-style-type: none"> <li>▶ Delay planting.</li> <li>▶ Crop rotation and sanitation are important.</li> <li>▶ Rotate cucurbits to distant fields (less than on-half of a mile) to help delay infestations.</li> <li>▶ Avoid leaving cucurbit crop debris available for overwintering sites.</li> <li>▶ Plow debris under after harvest.</li> <li>▶ Plant a cover crop.</li> <li>▶ Keep headlands mowed.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Floating row covers are very effective.</li> <li>▶ Plant a perimeter trap crop to protect more susceptible crops.</li> <li>▶ Yellow sticky cups or tape can trap adults. Replace regularly.</li> <li>▶ Use black plastic mulch—it can reduce larvae on roots considerably.</li> </ul>
<b>Seedcorn maggot</b>	<ul style="list-style-type: none"> <li>▶ Use crop rotations.</li> <li>▶ Time planting to avoid peak adult emergence. Late planting will avoid the most damaging first generation.</li> <li>▶ Plant in well-drained, warm soil to promote seedling vigor.</li> <li>▶ Plant seed shallow to speed emergence.</li> <li>▶ Turn under cover crops or soil amendments 10-14 days before planting.</li> <li>▶ Destroy crop residues at harvest.</li> </ul>	<ul style="list-style-type: none"> <li>▶ In smaller plantings, use barriers around transplants to prevent egg-laying.</li> <li>▶ Use row covers to exclude adults.</li> </ul>

Host plant resistance	Biological control	Chemical control/ Reduced-risk products
<ul style="list-style-type: none"> <li>▶ The use of resistant varieties is the only reliable control for diseases caused by viruses.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Natural enemies will help keep aphid populations in check.</li> <li>▶ Less effective in very hot weather when aphids reproduce rapidly.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Soil and foliar applied insecticides; soap.</li> <li>▶ Both the green peach and the melon aphid have shown problems with insecticide resistance.</li> <li>▶ Use selective insecticides for other pests to conserve natural enemies. Refrain from using broad-spectrum insecticides.</li> </ul>
<ul style="list-style-type: none"> <li>▶ Plant varieties that are less attractive to the beetles or less susceptible to bacterial wilt</li> <li>▶ Plant trap crops using preferred cucurbit crops: acorn squash, zucchini, cucumbers, yellow summer squash and winter squash, such as “Turk’s Turbin” and “Blue Hubbard.”</li> <li>▶ Pumpkins, muskmelons, butternut squash and watermelons are less preferred.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Cucumber beetles are attacked by a variety of natural enemies, the most important being a parasitic tachinid fly, <i>Celatoria diabroticae</i>.</li> <li>▶ Natural enemies are rarely effective enough, however, to reduce populations below economically damaging levels.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Scout to determine when threshold is reached. Treat only when beetles are active.</li> <li>▶ Insecticide sprays must be directed at adult beetles. The larvae are located on roots where they cannot be controlled.</li> <li>▶ Watch for distinct “hot spots”, and consider spot treatments.</li> <li>▶ Some insecticide formulations are phytotoxic and may cause flowers to drop. Some biorational pesticides are available. Consult A3422 for registered products</li> <li>▶ Apply treatments before beehives are introduced into the field.</li> <li>▶ Apply insecticides in late afternoon and evening when bees are inactive.</li> <li>▶ Treatments may kill beneficial insects keeping mites and aphids in check.</li> </ul>
<ul style="list-style-type: none"> <li>▶ Varieties with tolerance are available.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Ground beetles feed on eggs and larvae but not enough for complete control.</li> <li>▶ The commercially-available nematode <i>N. carpocapsae</i> has potential against seed-corn maggot.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Seed treatment or banded row treatment at planting can be an effective preventative treatment.</li> <li>▶ Consult A3422 for registered products.</li> </ul>

## Summary of IPM Strategies for Insect Pests of Vine Crops (continued from previous page)

Pest	Cultural control	Mechanical control / Exclusion
<b>Squash bug</b>	<ul style="list-style-type: none"> <li>▶ Crop rotation and sanitation are particularly important.</li> <li>▶ Destroying or removing debris should be done throughout the season and is especially important during the fall to limit overwintering.</li> <li>▶ Maintain vigorous plant growth to limit squash bug damage.</li> <li>▶ Keep headlands mowed.</li> <li>▶ Plant a cover crop.</li> </ul>	<ul style="list-style-type: none"> <li>▶ In small plantings, manually remove adults from under boards placed between the plants. Turn the boards over early in the morning, and destroy aggregated bugs.</li> <li>▶ Destroy egg masses on the underside of leaves.</li> <li>▶ If squash bugs are a persistent problem, avoid heavy mulch.</li> </ul>
<b>Squash vine Borer</b>	<ul style="list-style-type: none"> <li>▶ Rotation is important to avoid build-up of this pest.</li> <li>▶ Soon after crop harvest, flail chop and plow the vine debris deeply to bury over larvae.</li> <li>▶ Disking the soil in early fall should expose cocoons that are buried 1-6 inches deep.</li> </ul>	<ul style="list-style-type: none"> <li>▶ In small plantings, manually remove the larvae. Find the frass on the plant stem, and locate the larva by slicing lengthwise along the stem. Destroy the larva, and then cover the slit stem area with soil.</li> <li>▶ Floating row covers prevent moths from laying eggs.</li> </ul>
<b>Two-spotted spider mite</b>	<ul style="list-style-type: none"> <li>▶ Keep soil moist – dry conditions and drought stress favors infestation.</li> <li>▶ Plant in fields away from dusty areas such as gravel roads or grassy areas.</li> </ul>	



Host plant resistance	Biological control	Chemical control/ Reduced-risk products
<ul style="list-style-type: none"> <li>▶ Butternut, “Royal Acorn”, or “Sweet Cheese” are resistant varieties.</li> <li>▶ Maintaining a healthy plant through proper fertilization and watering is also important to limiting squash bug damage.</li> </ul>	<ul style="list-style-type: none"> <li>▶ A beneficial insect, <i>Trichopoda pennipes</i>, parasitizes adult squash bugs, and several wasps parasitize the eggs. Provide habitat for these in or near the field.</li> </ul>	<ul style="list-style-type: none"> <li>▶ If insecticides are used, treat when bugs are young; older nymphs and adults are harder to kill.</li> <li>▶ On young nymphs, Neem products may work well. Consult A3422 for registered products and application rates.</li> <li>▶ It is most effective to spray just as the eggs are hatching as the small nymphs are more easily controlled.</li> <li>▶ Populations are often aggregated, spot-treat localized infestations.</li> </ul>
<ul style="list-style-type: none"> <li>▶ Butternut squash are resistant.</li> <li>▶ Pumpkins can sustain high infestations without yield reductions.</li> <li>▶ Blue Hubbard and acorn squashes are highly susceptible to borer damage.</li> </ul>		<ul style="list-style-type: none"> <li>▶ Timing is very important.</li> <li>▶ Treat when adults are observed (900 DD) or when chicory is in bloom, especially when runners are less than 2 feet long.</li> <li>▶ Moth presence can be monitored with pheromone traps near squash or pumpkins. However, the traps will attract a variety of clearwing borer moths, so ability to identify borer moths will be necessary.</li> <li>▶ Treat stem base thoroughly to target hatching larvae. Some selective materials provide excellent control of hatching larvae. Consult A3422 for registered products and application rates.</li> </ul>
<ul style="list-style-type: none"> <li>▶ Watermelons tend to be most susceptible.</li> <li>▶ Cucumbers may be damaged late in the season.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Important. Predatory thrips, minute pirate bugs, and predatory mites keep spider mites in check.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Treat only if mite populations are high and weather conditions are conducive (very hot and dry).</li> <li>▶ Consider spot treatments with miticide (see A3422).</li> <li>▶ Many insecticides used for cucumber beetle also kill beneficials that keep spider mites in check.</li> <li>▶ Pyrethroids can flare mite populations by killing mite predators.</li> </ul>

# Weed Management

## In-Season



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Weeds can be one of the most challenging problems that a vegetable grower will face. Weeds compete with the crop for limited resources such as light, water, and nutrients. In addition, weeds can harbor insects and disease and interfere with harvest by making fruit difficult to find.

The weed history in a field is a good guide to predict future weed problems. The most successful weed control programs combine multiple management strategies that minimize risk of control failure and provide season-long control.

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

- ☐ **A. Weeds are controlled solely by chemical means.**
- ☐ **B. Weeds are managed preventatively, using a combination of methods to avoid in-season weed problems.**
- ☐ **C. Weeds are cultivated to prevent maturation and seed formation.**
- ☐ **D. Mulching is considered for weed control and water retention.**

## A. Chemical weed control

Some growers choose weed control programs that rely exclusively on herbicides to control weeds. However, complete reliance on herbicides can lead to control failure and concerns about weed resistance, as well as non-target environmental effects.



*Redroot pigweed in pumpkins*

The current bioIPM recommendation is to combine multiple strategies for weed control. The vigorous growth of most cucurbit crops makes this approach feasible, and it reduces the need for herbicides. In any case, an integrated approach is necessary because of the limited availability of registered, effective, selective herbicides for vine crops.

Be aware that herbicide options for vine crops are limited mainly to pre-emergence products (applied before or during weed seed germination). Options for post-emergent herbicides, applied to older weeds, are limited primarily to grass control. If a pre-emergence herbicide is part of your weed management program, use the information you have on the weed history in that field to help you select an appropriate pre-emergence herbicide. Consult A3422 *Commercial Vegetable Production in Wisconsin* for herbicides currently labeled for vine crops.

Using herbicides with the same mode of action in the same field every year can result in the development of weed biotypes that are resistant to the herbicide. Read more about weed resistance in the Resistance chapter of this workbook.

## Integrated Weed Management

The most successful weed control programs combine multiple management strategies. There are several benefits to an integrated program:

- ▶ The risk of complete weed control failure drops when using multiple strategies, since the chance that all strategies would simultaneously fail is minimal.
- ▶ Multiple strategies minimize the chance of selecting for weeds that tolerate or resist a single control strategy. For example, perennial grass weeds such as quackgrass are often not controlled by flex-tine cultivation, but may be suppressed by a competitive cover crop and timely mowing.
- ▶ Multiple strategies minimize the likelihood of herbicide resistance.
- ▶ Integrated weed management programs provide season-long weed control, minimizing competition between the crop and weeds and limiting production of weed seeds. For example, beginning the season using the stale seedbed system, followed by timely in-season control, strategies such as cultivation can delay weed emergence and development to the point where no mature weed seed is present by crop harvest. Timely mowing after harvest will then prevent weed seed production, and winter cover crops will suppress future weeds.

Finally, consider the crop rotation when planning integrated weed management programs. By controlling weeds well during the part of the crop rotation that allows the most weed management strategies and greatest weed suppression by the crop, you will reduce weed pressure during more difficult crops in the rotation. A little bit of planning can make a world of difference when growing less-competitive crops in the rotation.



### Quick Note

Consult A3422 for herbicides currently labeled for vine crops.



## Quick Note

Both annual and perennial weeds affect vine crops. Annual weeds complete their life cycle in a single growing season. These weeds germinate from seed, grow quickly, flower, set seed and die all within one growing season. Perennial weeds live for several years and regenerate shoots each year from underground roots or rhizomes. With much of their reproductive potential found below the soil surface, perennials can be extremely difficult to manage. Quackgrass, Canada thistle, and common milkweed are examples of perennial weeds.

## B. Pre-emergence weed control

Weeds in cucurbits are difficult to control once the crop vines out into the row. Pre-plant weed management therefore becomes an important window for weed management. Plant in fields where weed seed numbers have been reduced through crop rotation and that are free of very difficult to control perennial weeds such as quackgrass, johnsongrass, or Canada thistle. Choose vigorous, well-adapted cultivars that can compete with weeds through rapid early-season growth.

By far the best management strategy for any weed is to prevent its introduction and dispersal. There are several ways that weeds are introduced into a field, and most of them are preventable. The most common sources of new weed seed on the farm are compost, manure, straw mulch, equipment, open irrigation water, contaminated crop seed, and transplant containers.

Consider how you might reduce these potential entry routes into your fields. For example, question providers about weed contamination before purchasing straw, compost, or manure. Clean any equipment used in one field that could be contaminated with weed seed or otherwise introduce weed species to other fields. Use a power washer or compressed air to help remove seed and weed plant parts. Buy crop seed that is certified free of weed seed.

## Stale seedbed technique

A stale seedbed is created when a field is prepared for planting and then left fallow while non-dormant weed seeds germinate and emerge. Vine crops are particularly suited for the stale seedbed technique because they do best with later planting when the soil is warm.

Encourage weed seeds to sprout by tilling and preparing the soil for planting. Tillage stimulates the germination of many weed species. Shortly before planting, eliminate the emerged weed seedlings with very shallow cultivation. The key is not to disturb the soil to the extent that would stimulate further weed germination. The vine crop is then direct-seeded or transplanted without additional tillage into a seedbed that has been depleted of a good proportion of germinable weed seeds.



*Stale seedbed method on left, conventional seedbed on right*

## 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.
- ▶ Rotate herbicides by choosing products with a different mode of action than the one(s) you used last year. The active ingredient and mode of action will be listed on the label. Some products are a combination of more than one active ingredient.
- ▶ Follow herbicide label instructions.
- ▶ Prevent weed seed production by cultivating and mowing weed escapes before they set seed.
- ▶ Rotate crops or use different strategies to manage weeds in rotational years.



## C. In-season cultivation

Cultivation is most effective with small, shallow-rooted annual weeds early in the season and less effective later in the season when weeds are larger. In small plantings, hand cultivation can keep minor weed problems under control. For larger plantings, many different and innovative types of cultivation implements have been developed to control weeds in and between crop rows. However, even the best cultivators will not eliminate all weeds, so hand weeding may also be needed. When planning your cultivation, pay special attention to soil stewardship practices, and never till when the soil is wet and susceptible to compaction.

There are many kinds of between-row cultivators ranging from the traditional S-tine cultivators to the newer designs such as brush hoes. Rolling cultivators use toothed wheels that are angled to uproot weeds between the rows while throwing a small amount of soil over the weeds with the row.

In-row cultivators are specifically designed to weed slowly and precisely within the crop row.

Weed control is greatest when the weeds are very small, ideally with two leaves or less. Some examples of in-row cultivators are the finger weeder and the torsion, or rod weeder. The finger weeder is a light-weight precise tool that can be belly-mounted on a small tractor. It pulls the soil and weeds away from the crop row and then pushes a shallow layer of soil back over the crop row to cover small weeds (see photo). The rod weeder is a simple, affordable design of two steel rods, one on either side of the crop row, that uproots small weeds while pushing the soil into the row.



**Brush hoe**



**Finger weeder**

## Preventing weed seed production

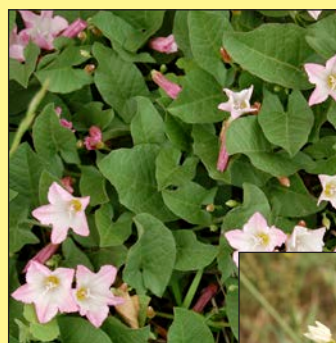
Another key aspect of weed control is preventing the spread of seed from weeds already present on the farm. Weeds are very prolific seed producers. For example, common lambsquarter can produce 38,000 seeds in a single season, and the seeds can remain viable for a long time. The highly prolific and enduring nature of weeds requires diligence in preventing the addition of new seeds to what is called the soil seed bank. Cultivate or mow any remaining weeds after crop harvest but before weeds go to seed.

### Weed Control for Virus Management

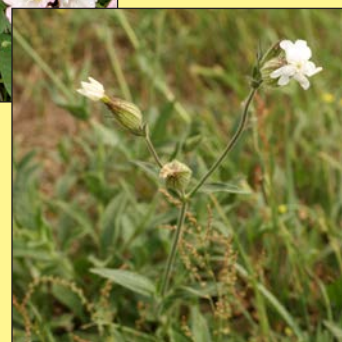
Many weeds host cucumber mosaic virus, squash mosaic virus, and other viruses that infect vine crops. If viruses have been a problem, keep areas surrounding vine fields free from the following plants: burdock, wild cucumber, wild ground cherry, horse nettle, jimsonweed, milkweed, morning glory, pokeweed, flowering spurge, and white cockle.



**Burdock**



**Morning Glory**



**White Cockle**

## D. Mulching for weed control

Mulching is covering the ground between crop plants with natural or synthetic materials to suppress weeds. When the ground is covered by a mulch, weeds are deprived of light and die out. Many growers find that muskmelons, watermelons, cucumbers, squash, and pumpkins will all ripen earlier and produce better yields and fruit quality when grown on plastic polyethylene mulch. Black plastic mulch is most commonly used, which can provide excellent control of weeds except in the hole in which the crop plant is transplanted. The most serious disadvantage of using plastic mulch is the removal from the field and disposal.



***Black plastic mulch provides excellent weed control***



***Black plastic mulch provides excellent weed control***

Examples of organic materials used to mulch vegetables are dead cover crops grown in place prior to cucurbit planting, wood chips, yard waste and leaf debris, and straw. Benefits of using a natural material for mulch are that they add organic material to the soil and help to hold and regulate soil moisture. This can be very beneficial for vine crops, as they require a good water supply. Pumpkin growers often notice less mud attached to the fruit when grown using a ground-covering mulch, such as straw. However, if squash bugs are a persistent problem, heavy mulch should not be used. Squash bugs like shelter and can be favored in reduced tillage or mulched crop systems. Additionally, organic mulches can harbor rodents and plant pathogens.



### **Watermelon mulched with straw**

### Notes:

[illegible]

# Soil Fertility and Plant Nutrition

## In-Season



Vine crops are heavy feeders and do best in fertile soils. A good fertilizer program at planting is crucial for vigorous growth during the early season. Good plant nutrition improves plant resistance to pests and diseases and increases the crop's competitiveness with weeds. Vine crops do best in fertile soils relatively high in organic matter. Follow the University of Wisconsin research-based nutrient recommendations for vine crops.



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 is applied in accordance with University of Wisconsin-Extension guidelines, which are based on soil test results.
- ☐ B. The fertilizer source will be considered when calculating fertilizer rates.
- ☐ C. Split applications of nitrogen are applied.
- ☐ D. Practices that maintain or build soil organic matter levels are implemented.



# A. Plant nutrition & fertilization

A good fertility program is an important part of IPM. Good plant nutrition improves plant resistance to pests and diseases and increases the crop's competitiveness with weeds. Good nitrogen nutrition and organic matter content of the soil are especially critical for overall growth and best yields of vine crops.

Using the fertilizer recommendations based on your soil test results provides the basis for good nutrient management. In addition to applying proper rates, you should also consider your soil type and texture, cropping history, and current soil conditions when determining when and how to fertilize. Just as under-fertilizing can lead to a reduction in profitability, so can over-fertilization. Unused fertilizer not only represents an economic loss to your cropping system, but it can also cause unneeded nutrients to enter surface and groundwater. Over-application of fertilizer can also damage the crop. For example, over-application of nitrogen can cause a bitter flavor in cucumber.



Good plant nutrition improves resistance to pests

The University of Wisconsin has produced research-based fertilizer recommendations for vine crops. University of Wisconsin guidelines for P and K applications on vine crops are based entirely on soil test P and K levels. Soil testing every 2-4 years will ensure that you are making the most efficient use of P and K fertilizer. The University of Wisconsin guidelines for nitrogen applications are based entirely on soil organic matter concentrations. There has yet to be a reliable soil test for N that provides insight into how much N fertilizer is required. The soil organic matter concentration provides a general indication of how much N the soil will supply. Nitrogen recommendations are provided for four categories of organic matter concentrations (<2%, 2-10%, 10-20%, and >20%) with less N recommended with greater organic matter concentrations. Routine soil analysis will also provide a measure of pH and a recommendation for lime application if necessary.



## Quick Note

UW fertilizer guidelines for P and K are based on removal rate of the crop and adjusted based on soil type and soil test levels. The long-term goal of P and K management is to maintain soil tests in the optimum soil test category and balance P and K inputs with removal. This is referred to as a "maintenance" approach.

**Annual Phosphorus fertilizer application rate guidelines for vine crops—total amount of P<sub>2</sub>O<sub>5</sub> to apply per acre including starter fertilizer** Source: UW Extension publication A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin

Crop	Yield goal tons/acre	Soil Test Category				
		Very low	Low	Optimum	High	Excessively High
		-----lb P <sub>2</sub> O <sub>5</sub> per acre-----				
Cucumber	5-10	85	60	10	5	0
Melon	8-10	115	90	40	20	0
Pumpkin	15-20	125	100	50	25	0
Squash	12-16	115	90	40	20	0



## B. Using soil tests and nutrient recommendations

Inorganic (or commercial) and organic fertilizers (or manures) can be used for vine crop production. Inorganic fertilizers are sometimes called chemical fertilizers because they are produced in an industrial manufacturing process. They often contain higher concentrations of nutrients compared to organic fertilizers, meaning that much less fertilizer material needs to be applied compared to organic fertilizers. Nutrients in inorganic fertilizers are water-soluble and immediately available for plants, while organic fertilizers require soil microorganisms to convert nutrients into plant-available forms. Animal manure is the most commonly used organic fertilizer, but the amount of nutrients that are available will vary based on form (solid or liquid), method applied (surface or injected), and animal species (see A2809). Furthermore, application of animal manure can provide nutrients for the crop grown in the second year after application. For certified organic farming, other approved fertilizers include blood meal, bone meal, fish meal and powder, and feather meal. To learn more about fertilizer and plant nutrients, go to <http://www.soils.wisc.edu/extension/> to view additional learning materials.

**Annual Nitrogen (N) recommendations for vine crops—total amount of N to apply per acre including starter fertilizer** Source: UW Extension publication A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin

Crop (yield range per acre)	Organic matter (%)	Amount to apply
<b>Cucumber</b>	Less than 2	100
(5-10 ton)	2.0-9.9	80
	10-20	60
	> 20	30
<b>Melon</b>	<2	100
(8-10 ton)	2.0-9.9	80
	10-20	60
	> 20	30
<b>Pumpkin</b>	<2	100
(15-20 ton)	2.0-9.9	80
	10-20	60
	> 20	30
<b>Squash</b>	<2	80
(12-16 ton)	2.0-9.9	60
	10-20	40
	>20	20

**Annual Potassium fertilizer application rate guidelines for vine crops—total amount of K<sub>2</sub>O to apply per acre including starter fertilizer** Source: UW Extension publication A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin

	Yield goal	Soil Test Category					
		Very low <sup>1</sup>	Low <sup>1</sup>	Optimum	High	Very High	Excessively High
Crop	tons/acre	-----lb K <sub>2</sub> O per acre-----					
<b>Cucumber</b>	5-10	125,150	85,110	25	15	5	0
<b>Melon</b>	8-10	245,270	205,230	145	75	35	0
<b>Pumpkin</b>	15-20	210,235	170,195	110	55	30	0
<b>Squash</b>	12-16	190,215	150,175	90	45	25	0

<sup>1</sup> Where there are two application rates in a category, the lower rate is for organic (mucks and peat) and sandy coarse-textured (sands and loamy sands) soils. Use the higher rate for all other soils. See A2809 (referenced above) for more information.



### Quick Note

Raising or lowering your soil test P or K level in the soil will take time. Increasing your soil test from low to optimum will take 4-6 years if you follow UW guidelines. However, lowering your soil test levels if they are above optimum can take between a few years to decades depending on how high your soil test values are. In this way, just the right amount of fertilizer is added each year.

## C. Split applications of nitrogen

Vine crops such as melons, squash, and pumpkins can have a very long growing season. It may be advantageous to divide nitrogen fertilization into one or more applications throughout the season, perhaps once at planting, another when plants have 2 or 3 true leaves, and maybe a third application at flowering.

## D. Organic soil amendments and cover crops

### Manure and composts

Cow, sheep, horse, goat, swine, and poultry manure and compost of various kinds can be added to soil for their nutritional and soil-building qualities. Most organic soil amendments are a good source of the N, P, K, as well as micronutrients.

### Maintaining Crop Health for Pest Control

Creating the best growing conditions as possible improves crop tolerance to pests. Practices such as optimizing soil fertility, building soil organic matter content, and minimizing soil compaction will support a vigorous crop that will be less attractive to pests such as aphids, and crop yield will be less affected by pest feeding and plant diseases.

Even more significantly, these materials feed and support the soil biota, which in turn increases the nitrogen mineralization (release) rate of the soil. The soil therefore becomes more fertile.

The nutrient contribution of organic amendments can and should be calculated towards the total nutrient budget for the vine crop. Keep in mind, however, that if manures and composts are supplied in the amounts needed to supply enough N to the crop each year, the phosphorus levels may become excessive. These materials should therefore be considered as soil amendments to improve the soil and supplement the nutrient needs of the crop. Also be aware that manures and composts can contain weed seeds. If obtaining composts or amendments from off the farm, ask the supplier about the potential for weed seeds or pathogens.



Spreading manure

The nutrient content and availability of manures depends on the animal species, bedding, manure storage, and whether or not the manure was applied to the surface or incorporated into the soil within three days of application. It's best to incorporate the manure as soon as possible so that nutrients aren't lost by volatilization or run-off. Estimates for first-year available nutrient content of various manures can be found in the UW Extension publication *A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops*. You can also send a sample of the manure, compost, or other soil amendment to the soil testing lab for nutrient analysis or have the UW Soil Testing lab make these calculations for you. For detailed information on applying manure to cropland, see the University of Wisconsin Extension publication *A3392 Guidelines to applying manure to cropland and pasture in Wisconsin*.

### Cover crops and green manure

Green manuring is the practice of planting a cover crop, often a legume, in the spring, summer, or fall and plowing it under the next spring. It was once the conventional method of supplying nitrogen to

## Soil organic matter

The sustainability of your cropping systems relies on maintaining the quality of your soil system. Building, or at least maintaining, soil organic matter in your soil will improve the water and nutrient holding capacity of your soil, increase nutrient availability, and improve soil tilth. Maintaining or building soil organic matter levels is a long-term achievement for a cropping system. It relies on a cut-back in unnecessary tillage operations and an increase of organic carbon to your soil. This organic carbon can come from animal manures or plant material (i.e. incorporated plant residues or green manure). Implement these practices in your IPM program that work best for you. Even small increases in organic matter have a beneficial effect.

crops and was widely practiced before inexpensive commercial nitrogen fertilizer became available. Consider the cover crop to be as valuable as the vegetable crop, with attention to when and how to plant, plant establishment and weed control, and how the crop will be harvested or incorporated into the soil.

Sweet clover was the traditional green manure crop in Wisconsin. Red clover (*Trifolium pratense*), hairy vetch (*Vicia villosa*), annual medic (*Medicago spp.*) and berseem clover (*Trifolium alexandrinum*) are other legume cover crops well-adapted to Wisconsin conditions. Grass and grain crops such as winter rye, ryegrass, or oats are productive soil builders as they grow quickly to provide ground cover and have an extensive root system. They can also be used as a “catch” crop for residual soil nitrates following corn or wheat harvest. However, these crops will not lead to an N credit to the subsequent crop because of the relatively high C:N ratio of their plant biomass.



Sweet clover flowerhead

The amount of nitrogen and organic matter added to the soil from a legume or other cover crop depends on how long the crop has grown. A summer- or fall-seed legume will have had little time to grow in comparison to one that is seeded in the spring or early summer. Growth of more than six inches provides the most nitrogen, ranging from 40 to over 100 lb/a depending on the plant species.

Incorporate cover crops and organic amendments at least two weeks before planting to permit the decomposition of the cover crop.



### Quick Note

**Calculating nitrogen credits:** Nutrient credits from animal manures, compost, green manures, leguminous crops, and other organic amendments can and should be calculated and your fertilizer rates reduced accordingly. Estimates of green manure nitrogen credits can be found in the UW Extension publication *A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops*. Soil testing labs can also make these calculations for you if you supply them with information on the cropping history and soil amendment applications you have made to your field.

## Growing Legume Cover Crops

Red clover (*Trifolium pratense*), hairy vetch (*Vicia villosa*), sweetclover (*Melilotus officinalis*), annual medic (*Medicago spp.*), and berseem clover (*Trifolium alexandrinum*) are examples of legume cover crops well-adapted to Wisconsin conditions. When evaluating a new legume for use on your farm, start small. A given legume may or may not perform satisfactorily under your soil conditions and management. It may take a couple of years to find which legume will work for you.

Some guidelines for growing legumes for green manure are:

- Inoculate the seed with the proper strain of *Rhizobium* bacteria. Different legumes require different strains, and many commercial products contain strains for several species. Inoculation

is an inexpensive way to ensure adequate nitrogen fixation will occur.

- Use common seed, but with a high germination rate. Low germination will reduce yield and may lead to a weed problem the following year. You do not need to plant an improved variety, however. The improved varieties have been bred for persistence—a trait unnecessary for legumes used as green manures.
- Provide good seed-to-soil contact. Legume seed needs good seed-to-soil contact to germinate rapidly. Cover seed when possible. This is especially true for large-seeded species such as hairy vetch.
- Minimize competition from weeds. Small-seeded legumes germinate and grow very slowly initially, making them poor competitors with weeds. Anything you can do to reduce or suppress weed competition will improve the chances for legume success.



### **Quick Note**

Be careful with timing of manure application and cover crop plow under. Seed corn maggots will be attracted to manures and plant debris in the spring as viable egg laying sites. If root rot disease and damping off are a problem in the field, legumes should be avoided in those areas.

## **Irrigation scheduling**

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. An irrigation scheduling spreadsheet which uses the checkbook method can be accessed at: <http://www.soils.wisc.edu/wimnext/water.html>.

The amount of available soil water can be derived from the WISDOM computer irrigation scheduling tools, which are based on the Wisconsin Irrigation Scheduling Program (WISP). The irrigation-scheduling module requires the input of the following parameters for successful and effective operations:

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



# 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. Pesticide resistance is prevented by minimizing pesticide use and avoiding consecutive use of products with a similar mode of action against the same target pest.



### **Admire® 2 Flowable Insecticide**

For uses in pest management and suppression of insect vectored diseases and maintenance of plant health.

ACTIVE INGREDIENT:	
Imidacloprid, 1-[(6-Chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine	21.4%
OTHER INGREDIENTS:	
	78.6%
	100.0%

EPA Reg. No. 264-758	EPA Est. No. 3125-MO-001
Contains 2 pounds of imidacloprid per gallon.	SHAKE WELL BEFORE USING

GROUP 4A INSECTICIDE

*Example of pesticide label with EPA Resistance Management Crop Group Information.*

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

- ☐ A. Pesticide resistance is 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 or alternate pesticide use are used to slow the development of resistance.
- ☐ D. Disease, insect, and weed populations are monitored for resistance development.

## 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 individual(s) then has the genetic potential to pass along the resistant traits to future generations.

Pesticides all have a specific way in which they affect pests. 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, over successive generations, 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 pest, weed, or disease control can greatly increase the likelihood of developing pesticide-resistance.

**Herbicide Resistance:** The development of herbicide-resistant weed species is an increasing problem in Wisconsin. Most weed species contain a tremendous amount of genetic variation that allows them to survive under a range of environmental conditions. Resistance develops through selection pressure imposed by repeated, often nearly continuous use of a herbicide, or several herbicides that have the same mode of action. Long residual preemergence herbicides, repeated application of postemergence herbicides, or application rates that are too high or too low relative to the amount needed for weed control will further increase selection pressure.

Complete reliance on herbicides for weed control can greatly increase the likelihood of herbicide-resistant weeds. This can be especially true for no-till or reduced till systems. Weeds that are most likely to develop resistance are annual weeds with high seed production and high germination rate, especially those that produce more than one generation in a year, or that are extremely sensitive to a

particular herbicide.

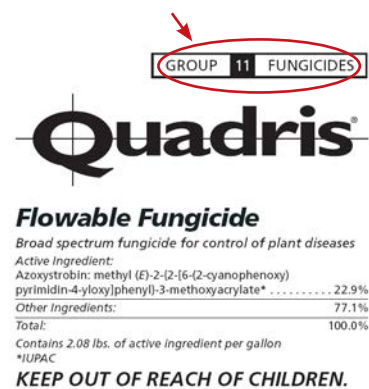
**Insecticide Resistance:** Concerns with insecticide resistance is relevant with certain insect pests to pyrethroid insecticides and neonicotinoids.

**Fungicide resistance:** There is a concern with any single site fungicide material when used in back to back applications.

## B. Pesticide mode of action

The Environmental Protection Agency (EPA) and the Fungicide, Insecticide, and Herbicide Resistance Action Committees (FRAC, IRAC, HRAC) have developed a voluntary pesticide labeling proposal that groups pesticides with similar modes of action and designates them with a number. The purpose of the labeling 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.



### Pests to Watch for Resistance Development

► **Insects:** Seedcorn maggot, cucumber beetle

► **Diseases:** Downy mildew, powdery mildew

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

## 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 things you can do to prevent resistance from developing in your fields over time.

### Strategies to prevent resistance

#### Herbicides

- ▶ Rotate crops
- ▶ Rotate herbicide families and use herbicides with different modes of action
- ▶ Spot treat when feasible and appropriate
- ▶ 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

#### Fungicides

- ▶ Rotate crops
- ▶ Use good sanitation methods to prevent pathogens from entering and spreading in the field
- ▶ Use fungicides only when necessary

#### Insecticides

- ▶ Rotate crops
- ▶ Use sanitation methods and other cultural controls to avoid introduction of pests into the field and keep populations low
- ▶ Treat only at economic thresholds
- ▶ Time application(s) 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 and appropriate

## D. Monitoring for pesticide resistance

Early detection is important if resistance is developing in a population of insects, pathogens, or weeds. Scout fields and 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 or weed 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.



**Monitor weeds for resistance to herbicides**

### Notes:

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# Biological Control

## In-Season



Biological control is the use of living beneficial organisms, sometimes called natural enemies, for the control of pests. Several key insect pests of vine crops are frequently kept in check for much of the growing season by the activity of their natural enemies. Biological control can be easily and effectively supplemented with cultural and carefully-chosen chemical controls when necessary for a truly integrated pest management approach.



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

- ☐ **A. Biological control is considered as a pest management strategy for vine crops.**
- ☐ **B. Common beneficial insects are recognized.**
- ☐ **C. The presence of common natural enemies and signs of biological control are noted during scouting.**
- ☐ **D. Populations of beneficial insects are encouraged by preserving or planting habitats. Release of specific natural enemies is considered when available.**



## A. Role of biological control in vine crop IPM

Biological control is the use of living beneficial organisms, also called natural enemies, for the control of pests. Birds, mammals, and reptiles feed on insect pests, but the most important group of natural enemies are insects that feed on other insects. These beneficial insects are abundant in cropland and provide significant control of some crop pests.

It's important to recognize that the intent of biological control is not to eradicate the pest population but to keep it at a level where the pest causes no appreciable harm. In fact, because natural enemies require prey or hosts for survival, biological control works best when there is always a small population of pests to sustain their natural enemies. This is a major difference between biological control and the use of pesticides. Biological control can be easily and effectively supplemented with cultural and carefully-chosen chemical controls when necessary.

The use of broad-spectrum insecticides is one of the main obstacles to effective biological control because natural enemies are just as susceptible to the insecticide as the pest. Sometimes one pest will be under good biological control, but another one is reaching an economic threshold. This is a difficult situation because if one pest is treated, an outbreak of the secondary pest can occur because the treatment eliminated its natural enemies. A similar situation called pest resurgence occurs when the population of the treated pest, often aphids, rebounds rapidly because of the elimination of its natural enemies.



*Convergent lady beetle larvae*



*Aphid mummies*

## B. Common beneficial insects

Natural enemies of insect pests fall into three categories: general predatory insects, parasitic insects, and insect pathogens.

### General Predators

Predatory insects are usually much larger than their prey. They are generally voracious feeders that eat a wide variety of insects. Ground beetles, minute pirate bugs, lacewings, and ladybeetles are examples of predatory insects. Most predators are fairly mobile and can search for their prey. Many predators are active in both their immature larval or nymph stage as well as in the adult stage. You and your scout will learn to recognize common predatory insects in both their immature and adult stages.



*Commercially packaged green lacewing larvae*

© Joseph LaForest, University of Georgia

### Conserving the natural enemies in your fields

- Avoid the use of broad-spectrum insecticides.
- Reduce the impact of insecticide sprays by spot-treating, banding, timing treatments carefully, and choosing compounds with low toxicity and short persistence.
- Maintain plantings that provide nectar, pollen, alternate hosts, and humid resting places in or near the field. Sweet alyssum, cilantro, and goldenrod are particularly attractive to adult syrphid flies and parasitic wasps, but any noninvasive mix of plants that include flowering plants will be competitive with weeds will be beneficial.
- Maintain overwintering sites for beneficials on the border of fields.

Predators are especially active and effective in small, diverse plantings and are often present even before pests arrive. They are also active in larger monocultures, but they may need augmentation or extra conservation methods to reach the same level of activity.



*A predatory assassin bug*

## Insect Parasites

Some of the most effective natural enemies are tiny and easily overlooked. These are the insect parasites, also called parasitoids, which are tiny flies or non-stinging wasps. The eggs of the parasite are laid in the host, and larvae hatching from the eggs eat their host from within, ultimately resulting in the death of the host insect. When scouting for this type of biological control activity, you will look for signs of the parasitized pest rather than the parasite itself.



*A parasitized diamondback moth pupae*



*A fungal-parasitized aphid*

© Ken Gray, Oregon State University

© Bill Stoneman

## Insect pathogens

Insect pathogens are microorganisms that cause lethal disease in insect pests. The most well-known insect pathogen is *Bacillus thuringiensis*, or Bt, which has been made into a commercially-available microbial insecticide. Fungi that attack insect pests are called entomogenous fungi and are fairly common. Under rainy, humid conditions, entire populations of aphids can be wiped out. However, most of the time infection does not occur early enough or often enough to be an important control agent. Fungicide sprays may kill entomogenous fungi. Nematodes, which are tiny soil-worm worms, is another type of insect pathogen.

## Biological control of specific vine crop pests

**Aphids:** The green peach aphid, melon aphid, and other aphids that feed on cucurbits have many natural enemies that are often numerous enough to keep aphid infestations below economic levels. The most effective control agent varies according to environmental conditions. In some cases, wasp parasites such as *Aphidius*, *Diaeretiella*, and *Aphelinus* species are the most effective; at other times, predators, especially syrphid fly larvae, ladybird beetles, or lacewing larvae are the most effective. Under specific weather conditions, fungi might cause the most mortality. In general, predators and fungal pathogens are favored by wet weather, which is unfavorable to the aphid.

**Cucumber beetles:** Several predators and parasitic natural enemies feed on cucumber beetles, the most important being a parasitic tachinid fly, *Celatoria diabroticae*. Generalist predators will feed on larvae and pupae in the soil. Some work with insect-feeding nematodes has been done. In one study, the nematode *Steinernema riobravis* reduced cucumber beetle emergence to nearly 50% when applied through a trickle irrigation system. However, natural enemies are rarely effective to reduce populations below economically damaging levels.

**Seedcorn maggot:** Predacious ground beetles eat seedcorn maggot eggs, larvae, and pupae and can be important in reducing maggot numbers. Naturally-occurring fungal diseases will occasionally reduce seedcorn maggot numbers.

**Two-spotted spidermite:** Naturally-occurring predatory mites, predatory thrips, minute pirate bugs, and pathogenic fungi keep spider mites in check, especially after vines have developed runners.

## Common Predators and Parasites of Insect Pests in Vine Crops

Most predatory insects are called generalist predators because they feed on a wide variety of insects. Aphids, two-spotted spider mites, and larvae of the seedcorn maggot and cucumber beetle are prey for generalist predators. You and your scout should learn to recognize the presence of predatory insects. Note that some of them are active in both the larval and the adult stages.

In contrast, insect parasites are usually very specific in the host they infest. Parasites are so tiny (some are the size of a pinhead), you will probably never notice them in the field. However, you can learn to recognize the signs of their activity. In particular, learn to tell the difference between a healthy aphid and an aphid mummy (a parasitized aphid).

### Lady beetles

#### *Hippodamia convergens* and other species



**Convergent lady beetle adult**  
© Frank Pearis



**Convergent lady beetle larvae**

Lady beetles are a large group of well-known beneficial insects. The convergent lady beetle, *Hippodamia convergens*, is one of the most common species on vine crops in the upper Midwest. Other common species include the twelve-spotted lady beetle, *Coleomegilla maculata*, and the seven-spotted ladybeetle, *Coccinella septempunctata*. All are important aphid predators in both the larval and adult stages. Lady beetles will also feed on cabbage looper larvae, especially when aphids are not present.

Learn to recognize the lesser-known larval stage of the ladybeetle as well as the adult. Larvae are active, black, elongated insects with bright red or orange spots and long legs and resemble tiny alligators.

**Availability for release:** Lady beetles are available commercially, but their use has been limited by their tendency to disperse. The best time to release is when prey is abundant.

### Ground beetles

#### *Many species, including Lebia grandis*



© Gyorgy Csoka, Hungary Forest Research Institute

Ground beetles are probably the most numerous predatory insects in crop fields. There are hundreds of species of ground beetles, most of which are dark, shiny, and somewhat flattened. They live in cracks and burrows in the soil and debris and are fierce predators of caterpillars, larvae of other beetles, and cabbage maggots. They can consume their body weight in food daily.

Conserve ground beetles by reducing tillage to a minimum and not using broad-spectrum soil insecticides. Their survival will be enhanced by providing refuges and overwintering sites such as hedgerows or mulch.

**Availability for release:** Not available commercially.



## Syrphid or hover fly

### *Many species in the family Syrphidae*



**Hover fly adult**



**Hover fly larvae**

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Syrphid or hover flies, also called flower flies, are common and important natural enemies of vegetable pests. The larvae of many common species of the syrphid fly feed on aphids and caterpillar larvae in vine crops. The pale green to yellow maggots have a slug-like appearance and can consume 400 aphids each during their development.

The adult flies resemble bees or wasps and are often seen visiting flowers. There are many different species that range in size from less than one-fourth of an inch long to more than three-fourths of an inch long. Many have the typical black and yellow stripes on the abdomen that give them a bee-like appearance.

The adults need flowers as nectar and pollen sources. They are attracted to weedy borders or mixed plantings that are also infested with aphids. Some flowers that are especially attractive include wild carrot or Queen Anne's lace, wild mustard, sweet alyssum, coriander, dill, and other small-flowered herbs.

**Availability for release:** Not available commercially.

## Green lacewings

### *Chrysoperla spp.*



**Green lacewing adult**

© Joseph Berger

The adult lacewing is easily recognized as a slender flying insect with veined gauze-like wings, but it is the larvae, called aphid lions, that are the important predators. Aphid lions resemble little green alligators with mouthparts like ice tongs. They are voracious feeders that will consume more than 200 aphids a week, as well as insect eggs, thrips, and small caterpillars, especially cabbage loopers. They can detect the larvae of leafminers within the mines and will pierce the leaves in order to feed on the miners within.

**Availability for release:** Green lacewings are available from many commercial suppliers and can be extremely effective under certain conditions. Two or three successive releases at two-week intervals are usually better than a single release. Ask the supplier to recommend the most appropriate species and stage for your pest management needs.



**Green lacewing larvae**

© Whitney Cranshaw, Colorado State Univ.

Lacewings are usually supplied as eggs, but larvae and adults are also available. Eggs are shipped in a carrier material, which makes it easier to distribute them onto infested plants. Lacewings released as pre-fed adults ready to lay eggs can fly away immediately, so take care to provide adequate food and habitat to encourage their remaining and reproducing in the crop. They must have a source of nectar or pollen. A sprayable food supplement can be applied to the crop to encourage lacewings and other predators to remain in the crop.



## Insect-feeding nematodes

Insect-feeding nematodes are naturally-occurring tiny worms that live in the soil. The nematodes feed on a variety of insects, including the western corn rootworm and cucumber beetle larvae. The nematode life cycle consists of an egg, four juvenile stages and the adult. The third stage larva is the infective stage.

**Availability for release:** Infective third-stage juveniles of several species are available commercially. Effective use of nematodes depends on providing proper conditions for their survival after application and proper selection of nematode species for the desired target pest. Nematodes are dependent on the availability of a water film for their movement and survival, so adequate soil moisture must be maintained.

## Damsel bugs, Big-eyed Bugs & Minute pirate bugs

### *Nabis* spp., *Geocoris* spp., and *Orius* spp.



**Damsel bug**



**Big-eyed bug**

© Bradley Higbee



**Minute pirate bug**

© John Ruberson, University of Georgia

Damsel bugs, big-eyed bugs, and minute pirate bugs are common and active predators in crop fields.

Damsel bugs, *Nabis* spp., are one-half inch long tan or black bugs with wings. The nymphs are similar but do not have wings. The piercing mouthparts curve down from the head. Both the young nymphs and the adults are active predators that feed on important crops pests such as aphids and caterpillars.

Big-eyed bugs, *Geocoris* spp., are very small, only one-sixteenth inch and usually brown or black. Both adults and nymphs consume numerous aphids, flea beetles, small caterpillars, and spider mites. Big-eyed bugs are common in agricultural fields, especially when broad-spectrum insecticides have not been used.

Minute pirate bug adults, *Orius* spp., are black, about one-fourth of an inch long with distinctively patterned black and white wings. The nymphs are yellow to light brown. Both nymphs and adults have prominent beaks and are active predators of thrips, mites, aphids, and caterpillar eggs. Minute pirate bugs are common in pastures, crop fields, and field margins, especially where broad spectrum insecticides are not routinely used.

**Availability for release:** *Orius* spp. and *Orius tristicolor* are available commercially. They are supplied as adults in a carrier material along with a food source. Shake the carrier onto the plants, and the bugs will readily disperse and locate prey. Ask your supplier for suggested release rates for your crop and pest situation.



**Aphid mummy**  
© Dan Mahr, UW-Madison

This tiny wasp and other relatives in the braconoid wasp family are important parasites of the green peach and melon aphids. The adult fly lays an egg in the young aphids, which provide the food source for the wasp larvae, turning the empty body of the aphid into a hardened, light brown shell called a mummy. Look for mummies when scouting.

**Available for release:** *Diaeretiella rapae* is available commercially, and releases can be effective in achieving good aphid control.

## C. Scouting for beneficial species

Check for and count mummies (parasitized aphids) on the undersides of the leaves. Parasitized aphids slowly decline, turning tan, brown, or black and are several times larger than normal aphids. Numerous mummies means active biological control. There are quite a few fungal pathogens that can cause high levels of mortality in aphids, especially during warm, humid periods. Aphids infected by fungi will have varying degrees of “fuzzy” fungal mycelial growth emerging from their dead bodies.

Watch for natural predation at work. Note the presence of predators such as the syrphid fly, ladybeetles (adult and larvae), and lacewing larvae. Look for ground beetles moving in cracks and burrows in the soil surrounding infested plants.

The biological control occurring in your field can be a solid base of insect pest management that you can build on with cultural controls and carefully-chosen and timed chemical controls.

### Biological control information

An excellent reference is *Biological Control of Insects and Mites: An introduction to beneficial natural enemies and their use in pest management* (A3842).

## D. Conserving and releasing beneficial species

Although not extensively researched in field-grown cucurbits, you may want to consider augmenting the natural population of beneficial insects by purchasing and releasing additional beneficial insects into the field. In the greenhouse setting, augmentation is commonly used to control two-spotted spider mites as well as aphids.

For example, green lacewings are available from many commercial suppliers and can be extremely effective predators of aphids under certain conditions. Lacewings are usually supplied as eggs, but larvae and adults are also available. Eggs are shipped in a carrier material, which is distributed onto infested plants. Lacewings released as pre-fed adults ready to lay eggs can fly away immediately, so take care to provide a source of nectar or pollen to encourage their remaining and reproducing in the crop. A sprayable food supplement can be applied to the crop to encourage lacewings and other predators to remain in the crop. Two or three successive releases at two-week intervals are usually better than a single release.

Ask the supplier to recommend the most appropriate species and stage for your pest management needs. They will also be able to guide you on application rates and timing. Because conditions at each farm are unique, some experimentation on your part will be necessary to optimize the activity and survival of released beneficial insects under your conditions.



**Notes:**



# Harvest and Storage



Careful harvesting at the optimal time and attention to storage conditions will preserve crop freshness and quality for the market.



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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. Crops are harvested at the optimal time for the variety and market.**
- ☐ **B. Good harvest practices are followed to keep the crop cool and minimize mechanical injury.**
- ☐ **C. The crop is stored in optimal environmental conditions (temperature, humidity, and sanitation) to maintain quality.**
- ☐ **D. Storage conditions are managed to prevent injury from ethylene.**

## A. Signs of crop maturity & quality

### Cucumber

Harvest bright, firm, dark green fruits near full size but before the seeds fully enlarge and harden.

Slicing cucumbers are typically 6-8 inches long, pickling cucumbers are 1-1/2 to 4 inches long.

Cucumber quality is based mainly on shape and size, firmness, and a dark green color.

Fruits that are very firm and very glossy are probably not quite ripe. At proper harvest maturity, a jellylike material begins to form in the seed cavity. Cucumbers that are past their prime are large, dull, puffy, and yellow. Large cucumbers left on the vine will inhibit the development of younger fruit. Therefore, once harvest begins, pick regularly, at least several times per week.



**Cucumbers**

### Summer squash/zucchini

Summer squash develops very rapidly after pollination and is usually ready to pick 4-8 days after flowering. Harvest summer squash at an immature stage, while still young and tender and before seeds begin to enlarge and harden. Good quality summer squash is uniform in shape, tender in rind and internal tissue and firm with a glossy skin.

Harvest at the desired fruit size: usually 2 inches or less in diameter and 6-8 inches long for the elongated types. Patty pan or scallop squash are best when small, about 3-4 inches in diameter. Do not allow summer squash to become large, hard, and seedy because they sap resources from the plant that could better be used to produce more young fruit. Pick oversized squash with developed seeds and hard skin and discard.



**Patty pan squash**

### Muskmelon/cantaloupe

Muskmelons develop their best flavor when they ripen in warm, dry weather. Check the maturity by lifting the fruit and tugging very gently — the stem of ripe melons should separate easily from the fruit. This is called the “full slip” stage. Commercial maturity is ideally at the firm-ripe stage or “3/4 to full-slip” when a clear separation from the vine occurs with light pressure. Melons picked at a less mature stage can be left at room temperature for several days to soften and improve in aroma and flavor. However, they will not produce any additional sugars off the vine since there are no starch reserves to break down.



**Cantaloupes**

Muskmelon skin color typically changes from gray to dull green when immature, deep uniform green

### Keys to Postharvest Quality

- ▶ Harvest produce at the appropriate maturity.
- ▶ Harvest during the coolest part of the day (usually morning).
- ▶ Only harvest produce that is free of disease and damage.
- ▶ Handle the produce carefully during harvest and storage to keep bruising to a minimum.
- ▶ Keep the produce out of the sun.
- ▶ Cool the harvested produce within one hour of harvest.
- ▶ Clean the storage facility and boxes before the harvest season.
- ▶ Maintain optimum storage temperature, ventilation, and humidity.

at maturity, and light yellow at full ripeness. A raised and well-rounded netting on the fruit surface of cantaloupe varieties is another indicator of maturity.

Good quality melons are well-shaped and nearly spherical. The stem end is smooth with no adhering stem attachment. The fruit should be firm with no bruising or excessive scuffing. A good quality melon appears heavy for its size and has a firm internal cavity without loose seeds or liquid accumulation.

## Watermelon

Watermelon is harvested by hand at full maturity as they do not develop in internal color or increase in sugars after being removed from the vine. Ripeness in watermelon is difficult to determine because the fruit remains attached to the vine, rather than 'slipping' off. If your crop is large enough, you can periodically sample the fruit for flavor. The flesh of a typical red-fleshed watermelon changes from immature pink to red-ripe, and then to overripe within a 10-14 day harvest window. Overripe fruits have a watery, mushy texture and lower sugar content.



*Harvested watermelons*

Another method to determine watermelon ripeness is to observe the part of the fruit that touches the soil, called the ground spot. When the ground spot changes from white to a creamy yellow color, the melon is usually ripe and ready for harvest. A deep yellow ground spot usually indicates an overripe fruit.

A third method is to observe the tendril nearest to the watermelon. If the tendril is firm and green, the melon is not yet ripe. If the tendril is wilting, the watermelon is ripe. If the tendril is completely wilted, the watermelon is likely overripe.

## Winter squash and pumpkins

Pumpkins can be harvested whenever they are a deep, solid color and the rind is hard. If vines remain healthy, harvest in early October, before heavy frosts. If vines die prematurely from disease or other causes, harvest when fruits are mature and store them in a moderately warm, dry place until market. Cut pumpkins from the vine, leaving 3-4 inches of the stem attached.



*Pumpkins at harvest*

Harvest winter squash when the fruit has a deep solid color and the rind is hard (no moisture collects in the mark made by pressing a fingernail into the rind). Corking of the stem is another external indication of winter squash maturity: immature fruit have a fleshy stem, maturing fruit will have some stem corking, and well mature fruit will have a well-corked stem. The internal color should be intense and typical of the cultivar -- internal color will not increase during storage. Winter squash is typically harvested after vines die down but before the first hard freeze. Light frost will not damage mature fruit. Cut squash from the vines carefully, leaving 1-2 inches of stem attached.

### Signs of watermelon ripeness

- ▶ The curled tendril nearest the fruit begins to shrivel and dry up.
- ▶ The underside of the melon where it touches the soil turns from a white or light green to a creamy yellow color.
- ▶ You sample the fruit and find the flesh is a deep color and the flavor is good.



## B. Harvesting procedures

Harvest vine crops by cutting the fruit from the vine with a knife or pruning shears. Keep harvesting knives sharpened to reduce effort and lessen fatigue. The fruit should not be removed by snapping or twisting it because this practice can damage the head and create an uneven end. Be aware that vine crops damage easily from careless handling.

Cucumbers, melons, and summer squash are particularly susceptible to dehydration after harvest and retain their quality and fresh taste if they are hydro-cooled and kept under high humidity (especially muskmelons). Hydro-cool the crop by submerging the fruit in a cool water bath for a few minutes immediately after harvest. Dry on screen tables and pack into waxed cardboard boxes. Maintain high humidity by lining the box with a clean, damp cloth.

### Cucumber

Cucumber is harvested by hand, beginning a few days after pollination. By 12 days from the first open female flower, some fruit will be too large to be marketable (more than two inch diameter for picklers, or 2-1/2 inch diameter for slicers). Once the vines are bearing fruit, pick mature fruit daily if possible or several times per week. Oversized fruit left on the vine will prevent subsequent fruit from developing. Pick oversized fruit and discard.

Harvesting should be done by cutting the fruit from the vine rather than tearing it. Bruising, compression injury, and “pulled end” are very common when careful attention to harvest and handling is not practiced. Cucumbers can be field-packed or transported to a packing shed to be cooled, washed, and packed into waxed cardboard boxes.



*Harvest vine crops by cutting the vine, never twist or snap the fruit off*



*Ripe pickling cucumber*

### Summer squash

Squash grows rapidly, especially in hot weather and is usually ready to pick within 4-8 days after flowering. Frequent, sometimes daily, harvests are required because of the fast growth rate of squash fruit during this period. Fruit should be no longer than 7-8 inches at the time of harvest to be considered top quality. Fruit set and development will continue throughout the season if older fruit are removed.

Like most immature fruit, summer squash is highly perishable and easily blemished. Pickers should wear gloves and use great care in extracting the fruit through the leaves to prevent bruising and scratching of the fruit, which will quickly turn brown. Harvesting should be done by cutting the fruit off the vine rather than by snapping. A poorly trimmed stem-end reduces quality and promotes decay. Be careful when picking summer squash, as the leafstalks and stems are prickly and can scratch and irritate unprotected hands and arms.



*A good size zucchini ready to harvest*

Water loss is a serious and common postharvest problem for summer squash. Once harvested from the vine, loss of firmness and shriveling develop very rapidly unless cooled to the proper short-term storage temperatures.

### Notes:

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## Muskmelon/cantaloupe

Muskmelons are harvested by hand, usually every three days once the crop comes into maturity. Melons damage easily with careless handling.

Muskmelon quality declines rapidly when field heat is not removed promptly after harvest. Harvested melons must be shaded, and hydro-cooling to 50 degrees F is recommended. If this is not done, sugars will be burned up, decreasing quality and reducing shelf life. In hot areas of the country, night harvesting is sometimes used to reduce the field heat of harvested melons.



**Muskmelons**

## Watermelon

Watermelons must be handled carefully during harvest. If the field has received abundant water, the watermelons may crack open during harvest, especially if harvested in the morning when full of water (turgid). The risk of cracking can be reduced by cutting the stem rather than pulling the fruit off. Stacking watermelons on the side, rather than on end, also reduces the risk of cracking.



**Handle watermelons with care when harvesting**

Direct sunlight on watermelons after harvest (especially on the groundspot) quickly reduces watermelon quality. Place harvested melons in the shade. If plants are not too turgid, field heat can also be minimized by harvesting in the morning. Watermelons should be dry when loaded, however, rather than dew-covered. Handle watermelons carefully. Rough handling and loading of watermelons often result in serious transit losses due to bruising and cracking. Internal bruising leads to premature flesh breakdown and mealiness.

## Winter squash

Pumpkin and winter squash fields are normally harvested just once. Cut fruit from the vines carefully, using pruning shears or a sharp knife. Leave 3-4 inches of stem attached to pumpkins, slightly less for other winter squash. Snapping the stems from the vines will result in broken or missing “handles.” Pumpkins and squash without stems usually do not keep well. Care should be taken, especially if pumpkins are slightly immature, to avoid lifting the pumpkin by its stem at harvest.



**Leave 2-3 inches of stem attached to fruit when harvesting winter squash**

Wear gloves when harvesting fruit because many varieties have sharp prickles on their stems. Avoid cutting and bruising the squash and pumpkins when handling them. Fruits that are not fully mature or that have been injured do not store well.

The fruits may have tender rinds when freshly harvested. You can allow the rind to “cure” or harden in the field (with protection from the sun by placing under the leaves) before stacking into bins or wagons. You can also harvest and cure the squash in a warm (75-85 degrees F), dry place for 10 days. The recommended storage conditions for squash also favor curing of the rind.

### To prevent storage decay:

- ▶ Harvest at the proper maturity.
- ▶ Handle the crop carefully to avoid injury during harvest.
- ▶ Cut stems rather than pulling the fruit off the vines.
- ▶ Keep the crop cool during and after harvest.
- ▶ Clean the storage facilities and boxes before harvest season.
- ▶ Store the crop at appropriate temperatures with good ventilation.

## Optimum storage conditions for harvested vine crops

Crop	Temperature degrees F	Relative Humidity	Storage Time	Notes
Cucumber	50-55	95%	2-3 weeks	Shriveling, yellowing, and decay are likely to increase beyond two weeks. Chilling injury (water-soaked areas, pitting and accelerated decay) will occur at cooler temperatures (such as 45 degrees F) after 2-3 days.
Summer Squash/ Zucchini	41-50	95%	10 days	Ideally, do not store summer squash for longer than 10 days, as shriveling, yellowing, and decay are likely to increase. Summer squash is sensitive to chilling injury at temperatures below 40 degrees F.
Muskmelon	36-41	90-95%	12 -15 days	High relative humidity is essential to maintain postharvest quality and prevent desiccation. Water loss through scuffed and damaged surface netting can be significant.
Watermelon	50-60	85-90%	14 days	
Pumpkin	50-55	50-70%	2-3 months	Pumpkins and winter squash are sensitive to chilling when stored below 50 degrees F. Symptoms of chilling injury are sunken pits on the surface and high levels of decay once fruit are removed from storage. Depending on the cultivar, storage for several months at 50 degrees F may cause some chilling injury.
Hubbard squash	50-59	50-70% with 60% usually considered optimum	5-6 months	It's important to keep the surface of stored squash dry. Provide excellent ventilation or use forced air ventilation if necessary. High humidity will promote decay.
Butternut squash	50		2-3 months	Do not store squash with apples
Acorn squash	50		1-2 months	Temperatures over 55 degrees F causes yellowing and stringiness.

## C. Storage conditions

Fresh produce continues to respire after harvest. This process of “breathing” releases heat and moisture from the vegetables, which tends to decrease the appearance, weight, and nutritional quality of the produce. The respiration rate is what determines how long the product can be stored. Storing produce under refrigeration helps to slow respiration rates. That’s why hydro-cooling and cooled storage facilities are important.

Storage facilities should also be clean to prevent post-harvest diseases and decay. Clean the storage facilities thoroughly before harvest time. Remove all crop debris and disinfect floors and shelves. After cleaning, ventilate the facility so that it dries thoroughly and has no odors from cleaning products. Remove crop debris from storage boxes and allow them to air out in the sun.

### Post-harvest decay

Diseases are an important source of post-harvest loss of vine crops, particularly in combination with physical injury or chilling stress. Post-harvest diseases are caused by a number of fungal and bacterial pathogens. The fungi and bacteria that cause post-harvest disorders are common in the environment, but many of them need an entryway through a wound or injury to infect the fruit. Therefore, avoiding injury is a good way to prevent post-

#### Preventing Anthracnose

- At harvest, inspect fruit for lesions caused by anthracnose and discard suspect fruit.
- Handle fruits carefully to minimize wounding.
- Harvest before frost.
- Prevent anthracnose in storage by keeping fruit dry. Do not wash fruit. Keep humidity low, and pack fruit in disease-free storage boxes.
- Turn under crop debris after harvest so that it decomposes quickly.

harvest decay. Harvesting the crop at the proper maturity, cutting the stem rather than pulling the fruit to harvest, keeping the crop cool during and after harvest, and low storage temperatures are other good decay-prevention methods.

The most common decay-causing pathogens of vine crops are bacterial soft rots caused by various bacterial species including *Erwinia*, *Pseudomonas*, and *Xanthomonas*. Bacterial soft-rots cause a slimy breakdown of the infected tissue. Fungal diseases such as *Alternaria* leaf spot, *Anthrachnose* (*Colletotrichum*), *Didymella* black rot, *Pythium* cottony leak, and *Rhizopus* soft rot are common decay problems in storage. Use good sanitation practices to reduce the amount of these fungi in storage facilities.

## D. The problem with ethylene

Ethylene is a common, naturally-occurring plant hormone that is produced as a gas from ripening fruit. Some fruit require ethylene to ripen; others are not regulated by ethylene. Tomatoes, apples, melons, and bananas are examples of fruit that produce high amounts of ethylene. Ethylene is also an exhaust product of combustion engines.

Most fresh vegetables are sensitive to the presence of ethylene and will decline in quality if ethylene is present in the air. For example, cucumbers are highly sensitive to ethylene in the environment. Accelerated yellowing and decay will result from low levels (1-5 ppm) of ethylene during storage. Watermelon is also sensitive to ethylene and even low concentrations will cause unacceptable loss of firmness and eating quality. Summer and winter squash are moderately sensitive.

Muskmelons produce high amounts of ethylene, and they are also moderately sensitive to ethylene in the environment. Over-ripening may be a problem during storage if ethylene concentrations are allowed to build up.

To protect stored crops from ethylene damage, be sure to provide adequate ventilation during storage. Do not store high ethylene-producing crops such as apples, melons, or tomatoes with sensitive crops such as cucumber, summer squash or watermelon.

**Notes:**



Aphids are common, soft-bodied insects that feed in colonies on the undersides of leaves and on growing points of plants. Watermelon is most affected by aphids in the upper Midwest, and occasionally cucumber and muskmelon. There are many species of aphids; the melon aphid (*Aphis gossypii*) and the green peach aphid (*Myzus persicae*) are the most common species on vine crops. Both the melon aphid and the green peach aphid have a wide host range that includes many vegetable crops as well as common weeds.

Aphids generally do not cause direct feeding damage to cucurbits, although heavy infestations can cause distorted leaf growth and reduced yield. Aphids excrete honeydew, which gives leaves a glossy appearance and can serve as a growing medium for sooty mold, a black fungus that can disfigure fruit. Many aphid species are able to transmit cucumber mosaic virus and other important virus diseases of cucurbits, which in some years can be more destructive to crops than direct aphid feeding.

One of the unique characteristics of aphids is their ability to bear live young, which gives them a tremendous reproductive capacity. In spring, overwintering eggs hatch, and the first aphid generation migrates to weeds or crop plants. Some aphids migrate into Wisconsin from overwintering sites in southern states. In the summer, the aphid population consists of females that give birth to live young females. These female nymphs mature in a few days and begin producing their own young. The female nymphs do not have wings but can produce winged aphids when conditions become crowded. Winged aphids may stay in the same field, fly to nearby fields, or migrate longer distances. In late summer, in response to shortened day length, winged females and males mate to produce the fertilized eggs for overwintering.



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**Aphids vary in color and have both winged (shown left) and wingless types.**

**Examine the underside of leaves for presence of aphid "mummies," which indicate that natural enemies are at work.**

**Scouting:** Aphid populations usually start to build around the time when the vines form runners. Aphid populations can increase rapidly in hot weather, so check plants more frequently under these conditions. This is especially true if broad-spectrum insecticides have been used for squash bug control. Cover the field thoroughly, including the edges of fields and along dirt roads. Because of the spotty nature of infestations, a number of plants in several areas should be examined for aphids. Examine leaves from 10 consecutive plants, count the number of aphids on the underside of leaves, and rate the plants as infested or uninfested. Repeat checks at weekly intervals to determine the need to treat.

Aphids feed mainly on the underside of the leaves and on growing points, where they suck the sap from the plants. Infested leaves curl downward and may turn brown and die. Other signs that indicate an aphid infestation are cast skins, honeydew, sooty mold, and ants attracted to the honeydew. Careful examination of infestations should show the presence of a variety of natural enemies, including lady beetles, syrphid flies, lacewings, and swollen hard-shelled aphid "mummies" (those parasitized by wasps).

**Threshold:** No threshold has been established for aphid feeding on cucurbits. If scouting indicates localized and increasing infestations and predators are not reducing their numbers, spot spraying can be considered to prevent direct damage from aphid feeding. Insecticides do not control viruses transmitted by aphids.

## Management Strategies

### Cultural control

- ▶ Planting resistant varieties is the most effective way to control aphid-transmitted viruses.
- ▶ Eliminate alternate hosts of both aphids and virus diseases. Control weeds along ditches, roads, farmyards, and other non-cultivated areas. These include virus hosts such as pokeweed, burdock, and other perennial broad-leaf weeds, as well as milkweed, jimsonweed, pigweed, plantain, and field bindweed that harbor aphids.

Continued on next page...

- ▶ Plant later season fields as far away from existing cucurbits as possible.
- ▶ Row covers can be used to exclude early aphid infestation.
- ▶ Do not overfertilize with quick-release nitrogen.
- ▶ Aphids are less attracted to mulched plantings than bare ground between plants. Reflective mulches tend to repel aphids.
- ▶ Infested crops should be destroyed immediately after harvest to prevent dispersal.

### Biological control

- ▶ Both the melon aphid and green peach aphid have many natural enemies, including ladybeetles, syrphid flies, and parasitic braconid wasps. Natural enemies are often numerous enough to keep aphid populations in check, depending on environmental conditions. Under periods of humid, wet weather, insect-infecting fungi can wipe out entire colonies. Sometimes wasp parasites are the most effective, sometimes generalist predators.
- ▶ Be sure to evaluate predator and parasite populations when making treatment decisions. An increase in aphid populations can sometimes be caused by applications of insecticides that have killed natural enemies.
- ▶ Encourage the activity of beneficial insects by maintaining habitat for them around the field.
- ▶ Heavy rain can rapidly decrease aphid populations as well as produce ideal conditions for the rapid spread of several fungal diseases, which can rapidly reduce populations.
- ▶ Natural enemies will not kill aphids in time to prevent the spread of viruses.

### Chemical control

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



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***Aphids generally do not cause serious direct injury to cucurbits, but many species of aphids can transmit virus diseases (shown here on watermelon). In the Midwest, this is generally late in the season.***



***Aphids (green peach aphid shown here) use their piercing/sucking mouthparts to remove sap from the leaves, which weakens the plant and may affect yield.***



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***Natural enemies (parasitoids, predators, and fungal diseases) are frequently associated with aphid colonies (melon aphids shown here).***

# Cucumber Beetles *Acalymma vittatum*, *Diabrotica undecimpunctata howardi*

	peak activity			peak activity		
April	May	June	July	August	September	October

The striped, *Acalymma vittatum*, and spotted, *Diabrotica undecimpunctata howardi*, cucumber beetles are common and potentially damaging insect pests of vine crops, with the striped cucumber beetle being the most important. Cucumber beetles injure plants directly by feeding on stems and cotyledons and indirectly in some years by transmitting bacterial wilt caused by *Erwinia tracheiphila* as it feeds. The bacterium causes plants to wilt, and once the infection is established, there is no control. Cucumbers and muskmelons are the most wilt-susceptible cucurbits. The best way to stop the occurrence and spread of bacterial wilt in these crops is to control adult striped cucumber beetles.

Plants are most susceptible to cucumber beetles in the cotyledon to 3rd leaf stage. At this stage, the plants are small enough that high beetle populations can defoliate the plants completely or girdle the stem. As plants grow beyond the 3<sup>rd</sup>-leaf stage, most vine crops can tolerate high levels of defoliation. When flowering begins, adults often move to the blossoms and fruit, which may cause cosmetic damage but usually does not affect yield.

The **adult striped cucumber beetle** is yellow-green, about one quarter of an inch long with three dark longitudinal stripes along the length of the body. It is easily confused with the adult of the common western corn rootworm (*Diabrotica virgifera virgifera*), which is not a pest in cucurbits. An easy way to distinguish between the two is to turn them over and check their undersides. The striped cucumber beetle has a black abdomen and the western corn rootworm adult has a yellow abdomen. The spotted cucumber beetle *Diabrotica undecimpunctata howardi* is an occasional pest of cucurbits and is recognized by the twelve prominent black spots on its body.

Striped cucumber beetles overwinter as unmated adults in bordering vegetation, plant debris, woodlots, and fence rows. Overwintered beetles are active in the



*Striped cucumber beetle and spotted cucumber beetle.*

**Scouting:** Scout fields two or three times per week early in the season for early migrants and the early emergence of overwintering beetles. Cucumber beetles can colonize emerging seedlings and transplants quickly. There is not yet reliable degree day information to predict peak activity. Walk the field in a “W” shape, and inspect 50 randomly chosen plants per field. Note the number of beetles per plant, and calculate the average for the field. Note that beetles are often localized in the field. Pay particular attention to field edges where beetles are entering from overwintering sites. Be sure to distinguish the striped cucumber beetle from the adult western corn rootworm, which is not a pest in cucurbits.

Adult striped cucumber beetles feed on cotyledons, emerging leaves, and stems at the soil line. Wilted plants or their runners may indicate the presence of bacterial wilt. If bacterial wilt has already occurred, remove diseased plants immediately to prevent the spread of the disease while the beetles are present. When flowering begins, the beetles often begin feeding on blossoms and pollen. This will be more noticeable on the large-flowering cucurbits like squash and pumpkin.

**Threshold:** Treat when there are more than 4 or 5 adults per 50 plants. Second generation beetles can cause serious injury to squash if plants are not yet touching within the row. Threshold at this stage is an average of more than five beetles per plant.

## Management Strategies

### Cultural control

- ▶ Crop rotation and field sanitation are effective in keeping beetle populations from building. Plow or remove debris after harvest, and plant a cover crop. Keep adjacent areas mowed. Rotate cucurbits to distant fields (more than one-half mile) to help delay infestations.
- ▶ Varieties differ in their attractiveness to beetles. Plant varieties that are less attractive to the beetles or less susceptible to bacterial wilt.
- ▶ Use transplants instead of direct seeding. They will be older when beetles arrive and therefore more tolerant.
- ▶ If feasible, delay planting until peak beetle activity is over.



- ▶ Floating row covers used early in the season can be very effective to prevent infestation by overwintering beetles. Remove when flowering begins to allow pollination by bees. Be aware that row covers may stimulate the germination of weed seeds.
- ▶ Plant a perimeter trap crop about two weeks earlier than the main cucurbit crop. Beetles will be attracted to the earliest emerging, or most mature, cucurbits on a given farm. Plant preferred varieties or varieties that are not susceptible to wilt, such as “Blue Hubbard” squash. Be sure the trap crop completely encircles the main crop to gain the most benefit and discourage entry to the main crop. Once the beetles build up on the trap crop, spray with an insecticide or flame on a cool morning. At low populations, sprays may not be needed. Yellow sticky cards placed in the trap or yellow mulch will enhance the attractiveness of the trap crop.
- ▶ Alternatively, some growers plant a row of a preferred variety of cucurbit crop near the upwind edge of the field on yellow or gold plastic mulch. This colored mulch attracts cucumber beetles to the crops in that row where they can be killed or removed.
- ▶ Yellow sticky cups or tape can trap adults. Replace regularly. Attractant-baited traps are being developed that could be used for early detection of infestations and possibly for control if several traps are used per field.

### Biological control

- ▶ Many common natural enemies feed on or parasitize cucumber beetles, including the soldier beetle, carabid ground beetles, spiders, the parasitic tachinid fly, *Celatoria diabroticae*, and braconid wasps. Enhance cumulative biocontrol results by providing habitat for beneficial insects.
- ▶ Predacious nematodes feed on cucumber beetle larvae and are available commercially.

### Chemical control

- ▶ Insecticide sprays must be directed at adult beetles. The larvae are located on roots where they cannot be controlled.
- ▶ Consider the susceptibility of the variety to bacterial wilt. Cucumbers and melons are highly susceptible, other cucurbits are less susceptible, and watermelon is not affected by the disease. Do not treat tolerant crops except to prevent heavy feeding damage.
- ▶ Consider the timing of applications. Striped cucumber beetles appear to be most active between dusk and dawn, suggesting that contact insecticides applied in the evening may be more effective than during the day.
- ▶ Apply treatments before beehives are introduced into the field.
- ▶ Striped cucumber beetles colonize cucurbits and continue to increase in numbers for about two weeks early in the season. To avoid having to treat more than once, wait until the field is fully colonized rather than treating at the first sign of a beetle if the crop is not susceptible to bacterial wilt.
- ▶ Watch for distinct “hot spots,” and consider spot treatments.
- ▶ Some insecticide formulations are phytotoxic and may cause flowers to drop.
- ▶ Several systemic soil-applied insecticides options are now available.
- ▶ Treatments may kill beneficial insects that are keeping mites and aphids in check. Consult A3422 *Commercial Vegetable Production in Wisconsin* for registered products.

spring by the time the earliest cucurbits are planted or are emerging, and temperatures reach about 65 degrees F. Once feeding begins, cucumber beetles use an aggregation pheromone to call others to the food source. The adults lay eggs at the base of plants. As soon as they hatch, larvae begin to feed on plant roots and complete their development in the soil. Root feeding by larvae can predispose plants to soil-borne diseases such as fusarium wilt. Summer adults emerge and feed in flowers, on foliage, or on the surface of fruit. There is usually only one generation per year in the upper Midwest.

While the striped cucumber beetle generally feeds only on cucurbits, **the spotted cucumber beetle** will also feed on beans, peas, potato, beet, tomato, eggplant, and cabbage. The larva of the spotted cucumber beetle is the well-known southern corn rootworm, which feeds on the roots of corn, peanuts, small grains, and other plants, but it does not feed on cucurbit roots.

Spotted cucumber beetles do not overwinter in northern areas and must migrate from southern states each year. They usually do not arrive until later in the season and therefore are not nearly as serious as striped cucumber beetles.



**The adult striped cucumber beetles look very similar to the western corn rootworm adult. It's important to distinguish between the two because the western corn rootworm does not transmit bacterial wilt and does no real damage to cucurbit plants. Turn the beetle over and examine the underside of the abdomen. The cucumber beetle has a black abdomen, and the western corn rootworm has a yellow abdomen.**



# Seedcorn Maggot *Delia platura*

peak activity

April

May

June

July

August

September

October

Seedcorn maggots are small fly larvae that bore into seeds—especially larger seeds like corn, beans, and peas—as well as seedlings of a wide variety of plants. It is generally only a pest early in the season before the soil is thoroughly warm.

Seedcorn maggots are particularly damaging when residues of the previous crop or other soil amendments have not thoroughly decayed before planting cucurbits. Direct-planted cucumber and melons are generally most affected by seedcorn maggots. Infested seeds may fail to germinate or may produce stunted plants. Damage may be to the seed itself or to roots, stems, or cotyledons. Conditions that cause slow seed emergence such as cold, wet soils favor seedcorn maggot damage.

Seedcorn maggots look like typical fly maggots: cream-colored, legless, and wedge-shaped with the head end sharply pointed, resembling a grain of rice. The adult flies resemble miniature house flies. Adults emerge from overwintering pupae (the cocoon-like resting stage in the soil) from early to mid-May in Wisconsin and mate within 2-3 days after emergence. Females prefer to lay eggs in soils containing high organic matter and are attracted to recently-tilled fields. The resulting larvae burrow through the soil to feed on seed or organic residue. Generally, seed corn maggots complete their life cycle within three weeks and have three generations in the upper Midwest. The first generation causes the most crop damage.



*Seedcorn maggots look like typical fly maggots: cream-colored, legless, and wedge-shaped with the head end sharply pointed, resembling a grain of rice.*

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**Scouting:** Scout for seedcorn maggot starting in early May. Areas in the field where seedling emergence is poor or seedlings are wilting may indicate seed maggot injury. Examine 5-10 seedlings in these areas, and note if heavy root feeding is apparent. Although the seedcorn maggot can't be controlled once the plants are infested, noting the presence of seedcorn maggot and extent of infestation is important for planning future management strategies.

Damage caused by the seed corn maggot is sometimes difficult to distinguish from other problems. For example, poor seedling emergence during a wet, cold spring could indicate infection by fungal pathogens such as pythium. In addition, wireworms (the larvae of the adult click beetle) also invade seeds of many vegetable crops. Wireworms are hard, dark brown, wire-like worms 1/2 to 1-1/2 inches in length. Do your best to diagnose accurately.

**Threshold:** There are no thresholds established for seedcorn maggot because damage cannot be detected until it is too late to take control action. However, it is possible to minimize damage by planting the crop during "fly free" periods that occur between generations of flies.

Forecast the appearance of generations by accumulating degree days (DD) after the ground has thawed. For seedcorn maggot, degree days are accumulated each day using the formula  $((\text{minimum temperature} + \text{maximum temperature})/2) - 39$ . Peak emergence of the first generation of adult flies will occur after a total of 200<sub>DD</sub> have accumulated. The next generations occur when 600<sub>DD</sub> and 1000<sub>DD</sub> have been reached. Planting at the tail end of first generation or in between first and second generation flights will help reduce damage.

## Management Strategies

### Cultural control

- ▶ Since adult seed corn maggot flies are attracted to rotting organic matter and freshly plowed fields, disk down cover crops and incorporate organic soil amendments at least 3-4 weeks before planting to allow sufficient time for decomposition.

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- ▶ Plant seed during fly-free periods as noted above to decrease the likelihood of an infestation.
- ▶ Assure rapid seed germination by planting in moist soil and not too deep when weather conditions are ideal. Warmer soils will promote vigorous seedling growth that can tolerate moderate maggot feeding.
- ▶ If infestations are severe and replanting is considered, wait 10 days to re-plant if the maggots are immature (less than one-quarter of an inch). If they are full grown, replant after five days.

### **Biological control**

- ▶ Predaceous ground beetles, which eat seedcorn maggot eggs, larvae, and pupae, can also be important in reducing maggot numbers. Because these soil-inhabiting beetles are susceptible to insecticides, broadcast soil insecticide treatments should be avoided whenever possible.
- ▶ Naturally occurring fungal diseases occasionally will reduce seedcorn maggot numbers significantly, particularly when flies are abundant and relative humidity is high. During a fungal epidemic, dead or diseased flies can be seen clinging to the highest parts of plants along field edges.

### **Chemical control**

- ▶ The available chemical options are preventative; no insecticides are labeled for use once outbreak has occurred.
- ▶ Seeds can be pretreated with an insecticide, or insecticides can be banded into the rows at planting. See A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products. Consider that applying soil insecticides will also kill natural enemies of maggots such as beetles and other ground insects that eat maggot eggs.

# Squash Bug

*Anasa tristis*

peak activity

April

May

June

July

August

September

October

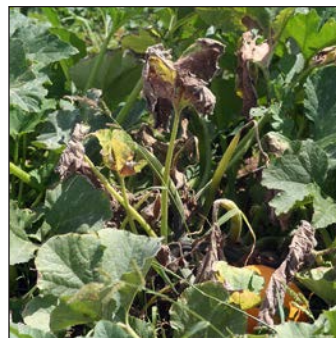
Squash bugs have become more prevalent in Wisconsin in recent years. Adults and nymphs feed on leaves and stems, as well as developing fruit. They can be difficult to control because they feed on the undersides of leaves in a very dense crop canopy. Young nymphs tend to aggregate at the base of the plant and disperse quickly when disturbed. The key to managing squash bugs is early detection and control of nymphs.

Squash bugs feed by sucking nutrients from leaves and disrupting the flow of water and nutrients, which can cause wilting. In the early season, young vine crops are easily killed; older plants may have runners damaged or killed. The wilting can resemble bacterial wilt, which is a disease spread by the cucumber beetle. Before wilting, yellow specks will develop on the foliage that eventually turn brown and dry. If the infestation is severe, leaves on mature plants will appear blackened as if burned. Cosmetic damage to developing fruit may occur from adult or nymph feeding.

Squash bug adults are flattened insects about 5/8 of an inch long, brownish-gray with orange and brown stripes along the edge of the abdomen. Squash bugs overwinter as adults under dead leaves, rocks, wood, and crop debris. Adult females lay eggs on the lower surface of cucurbit leaves in late spring. Eggs hatch in late June to early July into light green or gray nymphs that congregate on leaves or fruit. The nymphs undergo five molts before reaching maturity in late July to early August. Adults enter a resting state called diapause in the fall.



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**The squash bug sucks sap from the leaves and stems of squash and pumpkins, causing the leaves to wilt.**

**Scouting:** Egg placement and hatch occur on the undersides of leaves, and the nymphs tend to cluster there. Check the lower leaf surfaces of young susceptible plants several times a week from spring to mid-summer for egg masses. The orange-yellow to bronze-colored eggs laid in neat clusters can be readily found and identified. Small nymphs are much easier to control with insecticides than large nymphs or adults, so time insecticides to kill small nymphs.

Even though large populations of squash bugs are not likely to occur early in the season, growers should check their transplants or newly emerged seedlings for the presence of adults. Warm winter weather favors the survival of overwintering adults, increasing the likelihood of outbreaks. If wilting is observed, check the undersides of the leaves for the presence of squash bug adults or signs of their feeding.

Squash bugs are easy to identify, although they can sometimes be misidentified as a stinkbug. Both insects look similar and emit a disagreeable odor when crushed; however, the stinkbug is not a pest of cucurbits. Squash bug nymphs are pale green to white and somewhat resemble aphids in shape. Older nymphs become dark, greenish gray or brown as they mature.

**Threshold:** Early season: Wilting observed and squash bugs present on a susceptible crop. Early flowering: Threshold is reached when the average number of egg masses (groups of eggs) is greater than one or 1-1/2 egg masses per plant before or at early flowering. Squash bug populations should not be allowed to increase at this stage because they will damage plants, reduce yield, and become too numerous to control. Do not scout for scout bug nymphs or adults as the primary way to make spray decisions.

## Management Strategies

### Cultural control

- Choose varieties that are less preferred by the squash bug, especially in fields with a history of the pest. Acorn squash and *C. moschata* types (Butternut, Green-striped Cushaw and Dickenson pumpkin) are quite tolerant of squash bug damage. *C. maxima* (Hubbard type) is most susceptible.

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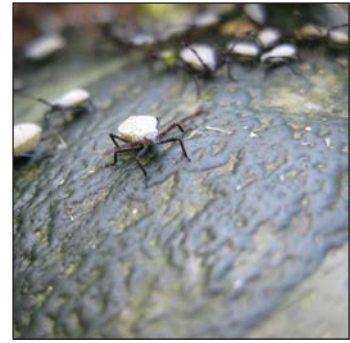
- ▶ Rotate annually to a non-cucurbit crop to delay population build-up early in the season.
- ▶ Row covers applied at planting and removed at first bloom exclude squash bugs.
- ▶ Because squash bugs have a preference for squash, a squash planting can be used as a trap crop near other cucurbits plantings such as watermelon to concentrate an infestation.
- ▶ If squash bugs are a problem on your farm, avoid heavy mulch or no-till in susceptible crops such as zucchini. Squash bugs like shelter and appear more numerous in reduced tillage or mulched crop systems.
- ▶ Clear adjacent areas of litter, leaf piles, and cucurbit weeds.
- ▶ In small plantings, deliberately supply shelter in the evening with boards on the soil surface near the squash. Collect and destroy the pest in the morning.
- ▶ Destroy egg masses on the underside of leaves.
- ▶ Prompt post-harvest tillage is very effective in destroying overwintering sites and preventing nymphs from developing into overwintering adults.

### Biological control

- ▶ A parasitic fly, *Trichopoda pennipes*, is a common parasite of adult squash bugs, and several wasp species parasitize the eggs. Provide habitat for these in or near the field.
- ▶ Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Generalist predators such as ground beetles, spiders, predatory mites, and robber flies prey on squash bugs and nymphs.

### Chemical control

- ▶ Insecticide treatments should be directed against young nymphs and timed with egg hatch. Refer to UWEX publication A3422 *Commercial Vegetable Production in Wisconsin* for a list of registered insecticides.
- ▶ Squash bugs are secretive and difficult to reach with insecticides. Thorough and directed coverage is important.
- ▶ Consider effects of pesticide use on mites and aphids as well as beneficials. Consider less toxic alternatives.
- ▶ Squash bugs have developed resistance to some insecticides. Do not use products with the same mode of action more than twice per season to help prevent the development of resistance. Rotate with pesticides with different Resistance Group numbers.



**Squash bugs will feed on all vine crops but prefer pumpkins and squash.**



**Seedlings, new transplants, and flowering plants are the most critical growth stages to monitor, as these are the stages when the most damage can occur.**



**When scouting, look for egg masses on the underside of leaves.**

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# Squash Vine Borer *Melittia cucurbitae*

peak activity

April

May

June

July

August

September

October

The squash vine borer is a moth larva that bores into thick-stemmed winter squash, summer squash, and pumpkins. Thin-stemmed squash, melons, and cucumbers are less preferred. The adult moth is a fast, noisy daytime flyer that looks so similar to a wasp that it is often not recognized as a pest.

Damage caused by squash vine borer larvae often goes undetected until infested plants wilt and die in late July and August. Wilting is caused by larvae as they tunnel through vines and destroy the tissue that transports water. Several larvae boring into the main stem can kill the plant, while the loss of a runner or two when the plant is larger will not cause economic damage. Wilt symptoms may be confused with those caused by bacterial wilt or fusarium wilt. To distinguish between squash vine borer injury and these diseases, look for entrance holes near the base of wilting vines.

Fully grown larvae are 1-1/2 to 2 inches long, white, and wrinkled with brown heads. The adult moth resembles a wasp, with greenish-brown forewings and transparent hind-wings with a fringe of reddish-brown hairs. The wingspan is about 1-1/2 inches. Squash vine borers emerge as adult moths from overwintering pupae in late June and July. Female moths lay eggs at the base of plants when cucurbits begin to bloom. Hatching larvae immediately begin burrowing into the stem of the plant, leaving behind a characteristic light brown frass that resembles sawdust. There is one generation per year in the upper Midwest.



*The squash vine borer is an occasional pest of cucurbits, particularly in smaller plantings.*

*When scouting, look for frass at entrance holes.*

**Scouting:** Scout for squash vine borer when the vines begin to run. Look for tell-tale signs of frass at entrance holes in the stem. If frass is found, split stems to check for young borers.

Adult activity can be used to time insecticide applications where squash vine borer is a perennial problem. Adult activity may be monitored using pheromone traps or predicted using base 50 degrees F degree-day accumulations. Pumpkin and squash crops should be monitored once 900<sub>DD50</sub> have accumulated. This coincides with full bloom of the common roadside chicory.

**Threshold:** Currently there are no treatment thresholds for the squash vine borer. Consider treatment if borers are found in a susceptible crop grown in a field with a history of significant borer damage and the vines are less than two feet long.

## Management Strategies

### Cultural control

- ▶ Choose a resistant or less susceptible crop if the field has a history of squash vine borer. Most winter squash, especially Hubbard squash, pumpkins, and zucchini are very susceptible. Butternut and green-striped cushaw squash are resistant.
- ▶ Floating row covers can be used during the flight period of adult squash vine borers to prevent egg-laying on susceptible plants. Keep covers in place after transplanting or direct seeding until flowering.
- ▶ Rotate fields with non-cucurbit crops to delay early season build-up of the pest.
- ▶ Maintain conditions for vigorous crop growth that can tolerate one or two borers and still produce a good crop through additional rooting along the stem.

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- ▶ In small plantings, it may be possible to manually remove the larvae. Find the sawdust-like frass on the affected plant stem, then locate the larva by slicing lengthwise along the stem until you reach it. Destroy the larva, and cover the slit stem area with soil.
- ▶ Plow the vine debris deeply after crop harvest to destroy remaining larvae.

### Biological control

- ▶ Predators, parasitoids, and other pathogens, including nematodes, help suppress infestations. However, because a single borer can be so destructive, biological control has not been considered a key strategy in borer control.
- ▶ *Bacillus thuringiensis* (subspecies BTK and Bta) can kill larvae if present on stems when newly hatch larvae enter stems.
- ▶ Insect pathogenic nematodes or Bt can be injected into infected stems.

### Chemical control

- ▶ Once the larvae bore into the stems, insecticides are generally not effective. Treatments can be effective if applied to the base of the stem prior to the insect entering the plant. Refer to UWEX publication A3422 *Commercial Vegetable Production in Wisconsin* for a list of insecticides registered for squash vine borers.
- ▶ Two to three insecticide treatments directed at the base of the plant five to seven days apart during the three week egg-laying period around 1000<sup>DD50</sup> should control newly-hatched larvae before they burrow into vines and become protected by vine tissue.
- ▶ Treat plants before the runners are more than two feet long so that coverage can be maintained.
- ▶ Direct the spray to the stems of the plant near the base for good control, and treat late in the day (when blossoms are closed) to minimize harm to bees.



**Look for sawdust-like frass on plant stems, then locate larvae by slicing the stem lengthwise along the stem.**



**The adult moth is a fast, noisy daytime flyer that looks so similar to a wasp that it is often not recognized as a pest.**

# Two-spotted Spider Mite *Tetranychus urticae*

peak activity

April

May

June

July

August

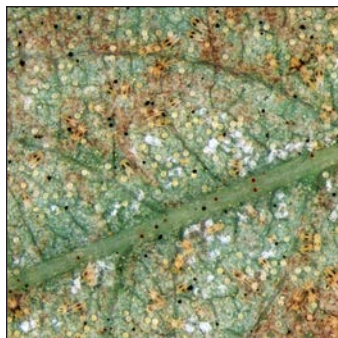
September

October

Two-spotted spider mites can be a serious problem on cucurbits during hot, dry weather. Watermelons and cantaloupes are especially susceptible, especially as the fruit is developing. Because of their small size, spider mites are hard to detect until vines are damaged. Broad-spectrum insecticides applied early in the season for other insect control can contribute to severe outbreaks of mites on melons by killing their natural enemies.

Light infestations of mites can be tolerated, but when heavy, mite feeding can result in planting stunting, lowered yield, and reduced quality of fruit. Webbing indicates the presence of mites, and hundreds of tiny mites may be present on a single leaf. Heavily-infested leaves turn yellow and stippled, and the undersides of the leaves appear crusty.

Spider mites overwinter as female adults in crop residue or sheltered areas. In early spring, they lay eggs on grassy weeds, in fence rows, and in wheat fields. Each adult female can lay up to 100 eggs. Spider mites often move into vegetable crops as wheat fields and other grasses begin to dry down. Under hot, dry conditions, spider mites may complete a generation in as little as six days, in cooler conditions up to a month.



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**Two-spotted spider mites and their eggs can be found on the underside of leaves.**

**Spider mites are very small, so use a hand lens when scouting.**

**Scouting:** Spider mite infestations often start at the edge of a field, especially those near dusty roads. Look for “bronzed” leaves and for signs of webbing, eggs, or mites on the lower leaf surface. Examine leaves with a hand lens for spider mites. Adult mites are about the size of a dot on a printed page and have four pairs of legs. Spider mites produce webbing that is often filled with cast skins, dust, and other debris. If spider mites are present, record the percentage of plants infested and the severity of the infestation. Re-visit the field over a 3-5 day period to determine if the mite population is increasing.

**Threshold:** No specific threshold recommendations have been developed for spider mites.

## Management Strategies

### Cultural control

- ▶ Choose fields with good water-holding capacity. A good water supply increases plant tolerance to this pest.
- ▶ Avoid planting in areas where dust occurs, such as near dirt roads. Avoid planting susceptible cucurbits in fields adjacent to wheat or bean fields or grassy areas.
- ▶ Field bindweed can be a source of mites. Control this weed growing in or at the edges of the field.

### Biological control

- ▶ After runners are 14 inches long, natural enemies such as six-spotted thrips or predaceous mites usually control pest mite populations. Monitor predatory mites and thrips to determine if they are present in the field and their relative population density in comparison with pest mites. Other mite predators include lady beetles, minute pirate bugs and lacewing larvae .



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**Biological control (minute pirate bug shown here) is an important component of mite management.**

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- ▶ Because biological control is an important component of mite management, take measures to ensure the survival of predators and parasites. The best way to establish a predator mite population is to conserve and promote those that exist naturally.
- ▶ To maintain a population of beneficial predators, a long-term pesticide program using the least toxic materials must be adopted. One application of a chemical considered highly toxic to a predator species, at any time during the season, will significantly decrease populations.

### **Chemical control**

- ▶ If mite buildup is observed, chemical treatment can be effective if done before webbing occurs or before runners are 14 inches in length, providing no predatory thrips or predaceous mites are present. Spot treatment may be all that is necessary. After the rows close over, the canopy is too thick to penetrate, and treatments are less effective.
- ▶ Pesticides only moderately toxic to predators may have little or no long-term effect on overall populations when applied sparingly. If applied too often, however, these same materials may have a very negative impact on beneficial insects.
- ▶ Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- ▶ Do not use products with the same mode of action more than twice per season to help prevent the development of resistance. Rotate with pesticides with different Resistance Group numbers.



# Alternaria Leaf Blight *Alternaria cucumerina*

peak activity							
April	May	June	July	August	September	October	

Alternaria leaf blight is a fungal disease similar to anthracnose that develops during mid-season as the canopy closes. Leaves and fruit of all cucurbits can be affected, especially muskmelon, cucumber, summer squash, and watermelon. Infection is most likely to occur on vine crops weakened by poor growing conditions or aging.

Alternaria infection begins with small lesions on the upper surface of crown leaves. As the lesions enlarge, infected plants eventually lose their leaves and photosynthetic capacity, resulting in reduced fruit size and quality.

The fungus overwinters in infected plant debris, weeds, and seed. Spores produced on infected plants provide inoculum for repeating secondary cycles during the season. The spores are spread by wind, splashing water, and human activity. Infection and disease development are favored by periods of high relative humidity over a broad range of temperatures (68-90 degrees F).



**Lesions caused by Alternaria have a characteristic target-like pattern.**

**A two-year rotation out of cucurbits is the easiest way to break the alternaria disease cycle.**

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**Scouting:** Begin scouting when plants begin to run (vine types) or flower (bush types). Check five plants in 10 different locations in a field. Look for small, circular, water-soaked lesions on the upper surface of crown leaves and the characteristic target-like pattern of dark concentric rings within older, larger lesions. Spots coalesce to affect large areas of leaves and can cause defoliation that begins on crown leaves. Infected fruit have circular sunken brown spots that develop into a dark green or black powdery mat.

**Threshold:** Fungicide treatments may be effective to protect healthy plants. Begin treatment if symptoms are found on one leaf per 50 leaves inspected.

## Management Strategies

### Cultural control

- ▶ Rotate out of vine crops for at least two years.
- ▶ Select sunny sites with good air movement that encourages leaf drying.
- ▶ Choose fields with fertile, well-drained soil, and maintain conditions that support vigorous plant growth.
- ▶ Do not plant near other cucurbit fields.
- ▶ Buy disease-free or fungicide-treated seed.
- ▶ Some resistant watermelon varieties are available.
- ▶ Plow under plant debris after harvest.

### Chemical control

- ▶ Fungicides are available for susceptible crops when weather conditions are conducive. Consult A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- ▶ Alternaria fungi have developed resistance to some systemic fungicides. Do not use products with the same mode of action more than twice per season to help prevent the development of resistance. Rotate with pesticides with different Resistance Group numbers.

# Angular Leaf Spot *Pseudomonas lachrymans*

peak activity

April

May

June

July

August

September

October

Angular leaf spot is a bacterial disease that can infect the leaves, stems and fruit of cucurbits during all stages of growth. The angular shape of the leaf lesions gives the disease its name. Cucumbers, honeydew melon, and zucchini squash are most commonly affected. Many varieties of cucurbits now have good resistance to angular leaf spot.

Angular leaf spot can be a destructive disease when environmental conditions are favorable. In addition to leaf damage, the lesions on fruit often crack open and predispose the fruit to secondary bacterial soft rot, resulting in a loss of yield and quality.

The angular leaf spot pathogen overwinters in seeds and on diseased plant debris in the field. Seed-borne bacteria spread to the cotyledons when the seed germinates. Splashing rain spreads bacteria from the soil to plant parts and from plant to plant, where the bacterium enters the leaf through pores or wounds. The organism is easily spread from field to field on equipment and by wind-blown rain. Prolonged leaf wetness and warm temperature 75-80 degrees F favor infection.



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**The angular shape of the leaf lesions gives the disease its name.**

**Scouting:** Scout closely for the disease in the early to mid-season as immature fruit appear. Infection begins with small water-soaked spots that later turn brown, often with a yellow halo. As the lesion dries, the affected tissue may fall out, causing a shot-hole appearance. The lesions are delimited by the leaf veins, giving them an angular shape. The sunken lesions on fruit are generally superficial and may have a white crust.

Bacterial leaf spot, caused by a different bacteria, looks similar in size and color to angular leaf spot, but the spots are circular.

**Threshold:** Treat when symptoms are found on one leaf per 25-50 leaves sampled if weather is predicted to be cool and rainy.

## Management Strategies

### Cultural control

- ▶ Rotate out of vine crops for at least two years.
- ▶ Resistant varieties of most vine crops are available and should be planted. In some of these varieties, tolerance to the disease is most strongly expressed in the fruit.
- ▶ Buy certified, disease-free seed. Hot water and chemical seed treatments do not completely remove the pathogen.

### Chemical control

- ▶ Copper fungicides may be helpful during periods of conducive weather. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.

Anthracnose is a common fungal disease of leaves, stems, and fruit. Cucumber, muskmelon, and watermelon are most affected by anthracnose. It can also be a post-harvest problem for all cucurbits, especially winter squash and pumpkins. Anthracnose usually becomes established in mid-season after the plant canopy has developed. Significant breeding efforts have increased the number of varieties available with anthracnose resistance.

When conditions are favorable, anthracnose lesions can enlarge and coalesce quickly, killing large areas of leaves. If anthracnose lesions girdle the fruit stem while the fruit is still developing, the plant will produce small, distorted fruit that often abort. Lesions on fruit are large, depressed areas that rarely penetrate through the rind but are prone to infection by soft rot organisms and do not ship or store well.

The fungus that causes anthracnose overwinters in plant debris, in soil, or on seed. It may survive in the soil for two years. Moisture is required for the spread of the disease; temperatures between 70-80 degrees F and periods of rain increase the risk of infection to epidemic proportions. The disease is spread in the field by running water, splashing rain, beetles, and tools.



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**Large, irregular tan to black lesions are signs of anthracnose on leaves and stems. On fruit the lesions are circular, sunken, and water-soaked, with a black center. They serve as entry points for secondary rots.**



**Anthracnose is a destructive fungal disease of the foliage, stems, and fruit of cucumbers, muskmelons, and watermelons.**

**Planting resistant varieties is the best way to control anthracnose.**

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**Scouting:** Scout for signs of anthracnose during warm, moist weather from mid-season through harvest. Symptoms of anthracnose vary. On cucumber and muskmelon, symptoms usually begin as small, yellowish, water-soaked lesions, which can enlarge considerably. Stem lesions on muskmelon tend to be more severe and can girdle the stem and cause vines to wilt. Stem cankers are less obvious on cucumbers. On watermelon, anthracnose lesions are irregular and turn dark brown or black, rather than tan.

Fruit lesions are circular, sunken, and water-soaked, with a black center. When moisture is present, the black center of the lesion is covered with salmon-colored spores. Use a 10X lens to inspect the lesions.

**Threshold:** If fungicide treatment is considered, begin when symptoms appear.

## Management Strategies

### Cultural control

- ▶ The best way to control anthracnose is to plant resistant varieties. Buy certified, disease-free seed.
- ▶ Rotate fields out of vine crops for at least three years to prevent pathogen build-up.
- ▶ Destroy crop debris as soon after crops are harvested.
- ▶ After harvest, take care to keep the fruit dry. Don't wash fruit before storage. Keep the relative humidity low in fruit storage areas. Provide for adequate air circulation when fruit is shipped, stored, or on display.

### Chemical control

- ▶ On susceptible crops, fungicides may be applied to protect healthy plants. These treatments will have no effect on plants that are already diseased. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- ▶ Anthracnose fungi have developed resistance to some systemic fungicides. Do not use products with the same mode of action more than twice per season to help prevent the development of resistance. Rotate with pesticides with different Resistance Group numbers.



Bacterial wilt is an infectious disease of cucumber and muskmelon that does not occur every year but can be very destructive when it does occur. The bacterial wilt pathogen is transmitted by cucumber beetles as the insects feed. Even a few adult beetles carrying the bacteria can quickly spread the disease throughout an entire planting of susceptible plants. Bacterial wilt can occur in at any growth stage, but plants are most susceptible to in the cotyledon and 1<sup>st</sup> to 3<sup>rd</sup> leaf stages. The main control of bacterial wilt is to prevent beetles from feeding on the plant. A few cucumber cultivars with some level of resistance are available, and more may become available in the future. Pumpkins and squash are generally tolerant or resistant to bacterial wilt, and watermelon is not affected.

Wilt symptoms begin in leaves and petioles and spread quickly to lateral shoots. Wilted parts may appear to recover at night but continue to wilt on sunny days and finally die. The entire vine may wilt within two weeks after infection. Fruits of an infected plant may be small and wilted with poor flavor.

Bacteria overwinter in infected beetles, or the beetles may pick up bacteria from infected weeds. Not all beetles carry the pathogen, and not all wounds cause infections, even if the beetle is a carrier. The pathogen can also enter plants through mechanical injury. Adult cucumber beetles become active as soon as cucurbit seedlings emerge. The disease can spread rapidly under normal moisture conditions but will be slowed during periods of rain when beetles are less active. Wilt symptoms will also slow during very dry weather because the bacteria require a film of water to enter the plant. Bacterial wilt is not spread by contaminated seed.



**Cucumbers and muskmelons are most susceptible to bacterial wilt.**

**Early season control of cucumber beetles is an important management strategy for bacterial wilt.**

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**Scouting:** Scout young plants closely for signs of bacterial wilt. Symptoms on young plants are wilting of the entire plant and rapid death. On infected older plants, leaf tissue between the veins will wilt and dry out, and one or more runners may wilt. Wilting is most severe when plants are growing rapidly. Signs of insect feeding may or may not be present.

Feeding by the squash vine borer and the squash bug can also cause wilt, as well as infection by the fusarium wilt fungus or phytophthora. Sometimes, if a stem infected by the bacterial wilt pathogen is cut off near the ground, the sap may be milky or sticky. This is an indication of bacterial wilt, but the diagnosis should be confirmed.

**Threshold:** To prevent bacterial wilt in susceptible crops, beetles should not be allowed to exceed 4-5 beetles for every 50 plants. There is no treatment for bacterial wilt once the disease is present.

## Management Strategies

### Cultural control

- ▶ Plant varieties that are less attractive to the beetles or less susceptible to bacterial wilt.
- ▶ Prevent cucumber beetles from feeding on the plant. See Striped Cucumber Beetle for management strategies.
- ▶ Covering plants with floating row covers can protect developing seedlings; be careful to leave no openings as the beetles readily crawl through open spaces.
- ▶ If bacterial wilt has already occurred, remove diseased plants immediately to prevent the spread of the disease while the beetles are present.
- ▶ Consider growing extra transplants to replace those plants lost early in the season to bacterial wilt.
- ▶ Plow under plant debris after harvest.



				peak activity			
April	May	June	July	August	September	October	

Downy mildew is a fungus-like disease of cucurbit foliage that can be potentially serious mid to late season where temperatures are moderate to high and humidity is great. Downy mildew will not affect fruit. All cucurbit crops, especially cucumbers, can be affected by downy mildew.

Downy mildew can be a very destructive foliar disease, resulting in defoliation before the fruit matures. The disease is highly dependent on conducive weather conditions, but when conditions are favorable, it can spread quickly.

Because the pathogen does not overwinter in Wisconsin fields, the disease is reintroduced each season by airborne spores from southern states or from greenhouses. If weather conditions are favorable, large areas of cucurbit plantings can be infected rapidly. Once infected, plants produce abundant spores that are spread from plant to plant by wind and splashing rain. Cucurbit mildew can infect plants over a wide temperature range (50-80 degrees F) when the leaves are wet. Periods of heavy dew lasting into midmorning are sufficient for infection to occur.



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**The downy mildew pathogen overwinter in southern areas or in greenhouses that produce cucurbits in winter months, and can be spread long distances by wind.**

**Downy mildew can develop at any time during crop development, including the cotyledon stage, when weather conditions are favorable.**



© Dr. Amanda Gevens, UW-Madison



**Typical symptoms of downy mildew are pale green angular areas on the upper leaf surface. Under wet and humid conditions, sporulation occurs on the lower leaf surface.**

**Scouting:** Scout crops weekly from early July to the end of the season when conditions are favorable for downy mildew development. Knowing how to identify the first symptoms of downy mildew is a critical component of an effective management program if fungicides are being considered. Foliar symptoms vary depending on how quickly infection occurs. Check leaves for angular pale-green areas bounded by leaf veins that give the impression of mosaic. These areas change to yellow angular spots and the tissue begins to die as the disease progresses.

If leaves remain wet, you may see the downy, gray-purple fuzz of the pathogen on the underside of leaves. With a 10X hand lens, you may see dark gray spores in the lesions on leaf undersides.

**Threshold:** Begin fungicide treatments at the first sign of symptoms before they become severe, especially if weather conditions are favorable.

## Management Strategies

### Cultural control

- ▶ Plant resistant varieties, especially cucumber and muskmelons.
- ▶ Choose a sunny site with good air circulation to encourage leaf drying. Allow for good air movement by planting with wide spacing, in rows parallel to prevailing winds, and not close to hedgerows.
- ▶ If possible, separate successive plantings into distant fields to help slow disease spread.
- ▶ Manage cucurbit weeds.
- ▶ Plow in crop debris after harvest.

### Chemical control

- ▶ If weather conditions are favorable and a susceptible crop is grown, fungicides may be applied at the first sign of symptoms. Fungicide efficacy declines if applications are delayed until symptoms are severe. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- ▶ Rotating fungicides is critical as the downy mildew pathogen may have developed resistance to some fungicide classes. Do not use products with the same mode of action more than twice per season. Rotate with pesticides with different Resistance Group numbers.

Fusarium wilt is a potentially serious soil-borne disease of cucurbits. Once the fungus is established in a field, it can survive in soil for over 20 years. The pathogen infects plants of any age through the roots. Once in the plant, the fungus is transported in the water-conducting tissue of the plant. In older plants, a "one-sided wilt" is a common symptom, with one or more shoots wilting and others remaining healthy. Fusarium wilt develops rapidly when soil temperatures are warm. Varieties resistant to Fusarium wilt are available and should be planted if the fungus is present.

Damping-off of seedlings may occur if inoculum levels in the soil are high. More commonly, however, symptoms of Fusarium wilt tend to appear in older plants after fruit set. The fungus causes wilting, collapse of runners, and plant death.

Fusarium overwinters in infected plant debris, seed and soil. The fungus produces thick-walled spores called chlamydospores that survive for a long time without a host. Spores germinate when roots of susceptible host plants are available. The pathogen enters through the root tips or any openings in the root tissue. Each type of cucurbit crop is susceptible to its own particular strain of the fungus. For example, watermelon is only infected by the strain *Fusarium oxysporum* f. sp. *niveum*. Within each strain, different races infect specific host varieties. Weeds are not known to be hosts. The pathogen is spread from field to field through infected seed, compost and plant debris, and movement of infested soil on boots and equipment.



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**Symptoms of Fusarium wilt are yellowing of older leaves and wilting of runners.**

**The stem, near the crown, has a characteristic vascular discoloration caused by the fungus.**

**Scouting:** Look for signs of fusarium wilt from mid-season to harvest when scouting fields for other pests and diseases. Symptoms are most likely to appear after fruit set and occur in patches in a field. A few infected plants can occur in a field even if a resistant variety is grown.

Look for yellowing of a runner on one side of the plant followed by rapid wilting of the runner. Other runners soon begin to collapse in a similar manner. Vines may crack and ooze sap. In muskmelon and watermelon, early symptoms are stunting or yellowing with a water-soaked tan streak along the vine.

To distinguish this wilt from bacterial wilt or squash vine borer, cut the stem along its length near the crown and check for a characteristic vascular discoloration caused by the fungus.

**Threshold:** There is no treatment for fusarium once it is established. Record the occurrence of Fusarium in a field so that preventative measures can be taken in the following seasons.

## Management Strategies

### Cultural control

- ▶ Plant resistant varieties.
- ▶ Use disease-free seed and transplants.
- ▶ Rotate crops to prevent build-up of the fungus in the soil.
- ▶ If a field is infested with Fusarium, do not plant with a susceptible crop for 5-10 years to allow the fungus to die out.
- ▶ Do not move soil from infested fields into uninfested fields on machinery or boots. Steam clean equipment after working in an infested field.

### Chemical control

- ▶ Fungicides do not provide effective control of this disease.



# Phytophthora crown & fruit rot *Phytophthora capsici*

peak activity						
April	May	June	July	August	September	October

Phytophthora crown and fruit rot can be a highly destructive disease. The causal agent, *Phytophthora capsici*, is a soil-borne fungus-like pathogen that can persist in the soil for 10 or more years. The pathogen is also capable of causing serious damage in squash, pumpkin, watermelon, cucumber, muskmelon, tomato, pepper, eggplant, and snap and lima bean. The first major outbreak in Wisconsin occurred on cucumbers in 1995.

The disease starts as small, brown lesions on the lateral roots and taproots. Infected plants soon begin to show signs of stress, and the crown becomes yellow. As the disease spreads outward from the crown along the runners, the crown begins to die. Plants may wilt during midday and recover in the evening, similar to symptoms caused by bacterial wilt or squash vine borer larvae. Fruit rots are another common expression of the disease, which may appear late season or post-harvest.

Phytophthora blight overwinters on infected debris in the field. Spores may be able to survive in the soil without a host for up to 10 years. New fields become infested when boots or equipment move contaminated soil from a pathogen-infested field. *Phytophthora capsici* may also be seed-borne. Phytophthora is spread within a field by splashing rain, flies, and human activity when the foliage is wet. The pathogen is highly dependent on saturated soil for infection, and the disease is most likely to be found in wet or poorly-drained areas of fields. Therefore, water management is critical in preventing phytophthora.



**Pickling cucumber infected with *Phytophthora***



**Infected plants quickly wilt and die; fruit turns white with powdery masses of spores. Immediately remove and destroy infected plants.**

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**Scouting:** Watch for signs of phytophthora when scouting the field for other pests and diseases. The pathogen can infect plants from the seedling stage through harvest, but symptoms typically appear in July and August after a heavy rainfall. Include any areas where water does not drain well when scouting. Plants growing in low-lying areas or flooded fields will show symptoms first.

When infection occurs on the leaves, the pathogen causes yellow spots that may initially be mistaken for other diseases. However, the disease quickly progresses to affect runners, crowns, and roots, causing the characteristic wilt and death of the entire plant. Infected fruit rot quickly. The roots and stems are soft, water-soaked, and brown.

Record the occurrence and severity of this disease in fields. This is important for future rotations and other management strategies.

**Threshold:** Treat healthy plants with protective fungicides when symptoms first appear in the field. There is no treatment for the *Phytophthora* crown rot phase once infection has occurred.

## Management Strategies

### Cultural control

- ▶ Water management is critical in preventing phytophthora. Plant vine crops in well-drained soils. Do not plant in low-lying areas prone to flooding. Grow bush types on raised, dome-shaped beds. Consider plastic mulch and drip irrigation.
- ▶ Rotate fields out of cucurbits and other susceptible crops such as pepper, eggplant, tomato, snap bean and lima bean for a minimum of three years.
- ▶ Plant certified disease-free seed from a reputable commercial seed dealer. No resistant varieties are currently available across susceptible vegetable crops.
- ▶ Avoid over-irrigating the crop as standing water is a critical factor in disease development.

Continued on next page...

- ▶ Avoid working in the crop when the vines are wet.
- ▶ Thoroughly clean equipment and boots after working in infested fields.
- ▶ If symptoms of phytophthora blight are observed in small plantings, it's important to immediately remove and destroy (burn or bury) all infected plants and fruit from the planting area.

### Chemical control

- ▶ If infection should occur, fungicides may be used to protect healthy plants from becoming infected. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- ▶ Some Phytophthora isolates have developed resistance to systemic fungicides. Do not use products with the same mode of action in consecutive applications. Rotate with pesticides with different Resistance Group numbers. Mefenoxam and metalaxyl resistance has been detected in Phytophthora from Wisconsin fields.



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***Flooded fields create ideal conditions for infection and growth of the phytophthora pathogen.***



***Phytophthora root rot is not a common disease but can be very destructive when it occurs.***



# Powdery Mildew *Golovinomyces cichoracearum*, *Podosphaera xanthii*

peak activity						
April	May	June	July	August	September	October

Powdery mildew is a common and potentially serious foliar disease of cucurbits. It generally develops in the mid- to late-season, depending on weather conditions. Powdery mildew is easily recognized as a white powdery growth, as if leaves were sprinkled with talcum powder. All cucurbit crops are susceptible, but increasing numbers of resistant varieties are available.

On susceptible crops, powdery mildew is often severe enough to significantly reduce photosynthesis, plant vigor, and the number and size of fruit. Although the fruit is rarely infected, the quality of the fruit is indirectly affected by powdery mildew due to sunscald, incomplete ripening, low sugar content, and reduced storage life. Powdery mildew does not cause fruit rot.

There are many different powdery mildew fungi that are fairly host specific. The two fungi that are responsible for powdery mildew on cucurbits are *Golovinomyces cichoracearum*, and *Podosphaera xanthii*. These fungi overwinter on perennial hosts and greenhouse cucumbers in southern states. Each year fungal spores are carried long distances to the north by air currents. Favorable conditions for the disease are dense plant growth and low light intensity. Warm, dry weather of 68-80 degrees F is ideal.



**All cucurbit species are susceptible, although resistant varieties are available and should be planted where powdery mildew tends to be a problem.**

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**Powdery mildew first appears as pale yellow spots on the oldest, shaded leaves. Later, a characteristic powdery growth covers affected leaves.**

**Scouting:** Start by scouting the oldest cucurbit plantings for powdery mildew once a week as soon as the first fruit start to enlarge. Check the top and underside of five old crown leaves in 10 different locations in a field. Lesions usually appear first on lower, older leaves or shaded leaves. Lesions are light yellow at first, then become a white or tan powdery growth that is easy to recognize.

**Threshold:** If fungicide treatment is considered, begin when infection is seen on one crown leaf in 50 inspected.

## Management Strategies

### Cultural control

- ▶ Plant resistant or tolerant varieties. Significant breeding efforts are ongoing to increase the number of varietal options available with powdery mildew resistance.
- ▶ After harvest, plow or remove any infected plant debris.

### Chemical control

- ▶ On susceptible crops, fungicides may be applied to protect healthy plants. These treatments will have no effect on plants that are already diseased. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- ▶ Powdery mildew fungi have developed resistance to some systemic fungicides. Do not use products with the same mode of action more than twice per season to help prevent the development of resistance. Rotate with pesticides with different Resistance Group numbers.

# Viruses of Cucurbits

peak activity

April

May

June

July

August

September

October

Viruses are submicroscopic particles of DNA or RNA that can cause disease in plants. Viruses can grow and reproduce only inside a living plant cell. Unlike other cucurbit pathogens, viruses are not spread by wind, water, soil, or plant debris. Most plant viruses are spread from plant to plant by specific insect vectors. All cucurbits are susceptible to some types of viruses, and multiple infections are common. The most important viruses are cucumber mosaic, squash mosaic, watermelon mosaic, and zucchini yellow mosaic virus.

Virus infection reduces yield by affecting the vigor of the plant and the number and the quality of the fruit. Symptoms occur mostly in the actively growing parts of mature plants and may be mild to severe. Vines of virus-infected plants may be stunted and new leaves may be dwarfed, mottled, or distorted. Some viruses can cause malformations of the fruit. Plants may decline slowly.

Viruses are introduced into new plantings mainly on infected seed. Weeds are also a source of some viruses. With the exception of squash mosaic virus, which is transmitted by beetles, cucurbit viruses are transmitted by several aphid species. Viruses can spread quickly in a field when aphid activity is high. Like aphid infestations, initial virus infection is often localized in hot spots within the field.



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***Resistant varieties are the best control of viruses.***

***Most cucurbit viruses are transmitted by several species of aphids.***

**Scouting:** Look for signs of virus infection when scouting for insects mid-June to harvest. Symptoms vary. Check new leaves and fruit for signs of stunting or mottling. Mosaic patterns of irregularly shaped, dark green areas alternating with light green or yellow areas is a recognizable virus symptom.

**Threshold:** There is no control for viruses once plants are infected.

## Management Strategies

### Cultural control

- ▶ Planting resistant varieties is the most effective way to control aphid-transmitted viruses.
- ▶ Eliminate alternate hosts of both aphids and virus diseases. Common virus hosts are pokeweed, burdock, goosefoot, lambsquarters, Russian thistle, various legumes, and wild and volunteer cucurbits. Common aphid hosts are milkweed, jimsonweed, pigweed, plantain, and field bindweed.
- ▶ Plant later season fields as far away from existing cucurbits as possible.
- ▶ Row covers can be used to exclude early aphid infestation.
- ▶ Rogue virus-infected plants to reduce spread.

### Chemical control

- ▶ Spraying with insecticides is not an effective control because the insect transmits the virus before being killed by the insecticide.