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# Introduction

This Cole Crops 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 cole crop production system. The workbook is organized into five chapters— preplant, planting, in-season, harvest, and post-harvest. Each chapter is further divided into pertinent topic sections with self-assessment statements followed by information on standard recommended practices as well as advancements to a biointensive production system.

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

At the beginning of each topic there is a set of statements about the farm's current production practices. This self-evaluation section is formatted on a scale, with Category A being the minimal practices that could be used, 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 cabbageworm. 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 cole crops system.



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

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

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

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The UW Extension publications that are referenced in this workbook can be viewed and purchased at:

<http://learningstore.uwex.edu/>

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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 cole 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 cole 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 to 6 inches.

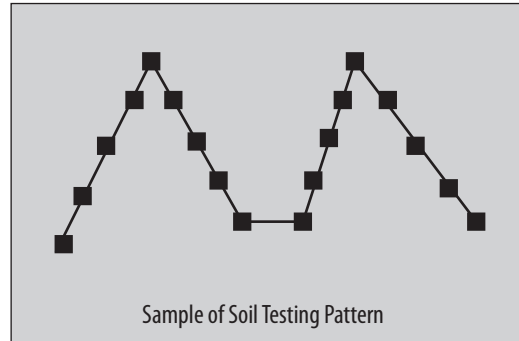


*Stainless steel soil probe*

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 to 20 soil cores that are mixed together in a plastic or stainless steel bucket. The more soil cores you collect, the more representa-



tive the soil sample will be. Walking in a W-shaped sampling pattern is a good technique to use 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 2 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.

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



*Making a composite sample*

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 micronutrient, 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 cole crops are not based on any soil tests for nitrogen.



### Quick Note

The UW Soil and Plant Analysis Lab soil test information sheet can be found online at <http://uwlab.soils.wisc.edu/>



### Soil Names

Some soils and subsoils are naturally higher in nutrients than others. The University of Wisconsin fertilizer recommendations accounts 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).

## 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.

Interpretation of soil test P and K values includes placing each test result into a soil test category based on the demand level category of the crop and the soil type it will be grown in. Cole crops are considered high demand vegetable crops (demand level 5). Soil test categories include: very low, low, optimum, high, very high (soil test K only), and extremely high. The P and K fertilizer recommendations associated with each soil test category are based on optimal production levels. 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 in Wisconsin* (UW-Extension A2809). Soil test categories have also been developed for calcium, magnesium, boron, zinc, and manganese. Sulfur requirements are determined from a Sulfur Availability Index (SAI) which utilizes soil test S and organic matter concentration, as well as other estimated S components.



Spreading manure



### Quick Note

Use the information provided in your soil test to plan your fertility program. Soil test reports from the University of Wisconsin will include recommended amounts of N, P, and K to apply based on the soil analysis, soil type, and crop demand.

Finally, the soil test report will include nutrient or fertilizer recommendations. The recommendations are based on the crop demand for nutrients in single season and are calculated to tell you how much more (if any) of a particular nutrient is need-



ed for optimum crop growth, without waste or run-off. Nutrient recommendations for cole crops are in the section **Soil Fertility and Plant Nutrition**.

## ★ 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 category 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 category, 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 to 6 year period.

## C. Recommended fertilizers

It's usually best to use a combination of both organic and inorganic fertilizers. Inorganic chemical fertilizers are concentrated, and provide nutrients to the plants quickly. Organic fertilizers come directly from plant or animal sources. An advantage of organic fertilizers is that they not only provide nutrients, but also improve the structure, tilth, and biological activity of the soil.

Inorganic fertilizers are sometimes called chemical or commercial fertilizers because they are produced in an industrial manufacturing process. Examples of inorganic fertilizers include 10-10-10, ammonium nitrate, and triple superphosphate. An advantage of inorganic chemical fertilizers is that they contain a higher concentration of nutrients per unit weight than organic fertilizers. Thus, much less fertilizer needs to be applied. Their nutrients are water-soluble and immediately available to plants. A disadvantage of inorganic chemical fertilizers is that they contain a limited number of macronutrients and are so concentrated that you can easily apply too much fertilizer and damage your

plants. If too much chemical fertilizer is applied, there is a risk of fertilizer run-off into streams, rivers, and lakes.

Many types of organic fertilizers are used in vegetable production, including 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, cover crops (especially legumes), 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>		PLOW DEPTH } <b>8"</b>		Credit Card No.		Exp. Date ____/____/____ VISA ____ MC ____										
						FERTILIZER CREDIT INFORMATION										
		4-YEAR CROP ROTATION		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)	Check if Conservation Tillage	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>	<b>17</b>		<b>160</b>		<30			<b>1</b>	<b>20</b>	Surface	<b>1</b>
						<b>29</b>		<b>3</b>		30-70			Incorporated	2		
						<b>1</b>		<b>6</b>		>70			Injected	3+		
						<b>1</b>		<b>6</b>								
<b>2</b>	<b>4-7</b>		<b>Sisson</b>	<b>20</b>	<b>5</b>	<b>17</b>		<b>160</b>		<30			<b>1</b>	<b>20</b>	Surface	<b>1</b>
						<b>29</b>		<b>3</b>		30-70			Incorporated	2		
						<b>1</b>		<b>6</b>		>70			Injected	3+		
						<b>1</b>		<b>6</b>								
										<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:		3 Swine	13 Beef
growing corn (field or sweet) Zn and SO <sub>4</sub> -S		4 Duck	14 Swine, indoor pit
growing legume forage B and SO <sub>4</sub> -S		5 Chicken	15 Swine, outdoor pit
growing small grain or soybean (with pH>7.0) Mn		6 Turkey	16 Swine, farrow-nursery indoor pit
growing potato or apple (with pH<5.5) Ca/Mg		7 Sheep	17 Duck
growing specialty or vegetable crop B, Zn, and Mn		8 Horse	18 Poultry
acid of sandy soil with high amounts of applied K Ca/Mg			

**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	Don't be misled by this section. The micronutrients that are listed are not analyzed unless you specify that they should be.						1.1	48	2	1.08	N.R.
Adjusted Averages	7.5	2.9	101	203												

**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

# Field Selection

## Preplant



A healthy cole crop begins with selecting a favorable planting site. The best cole crops are grown in moist, fertile, well-drained soil. Choosing a site where cole 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. Cole crops have not been grown in the field for at least 3 years.**
- ☐ **B. Crop rotations are planned to prevent build-up of diseases, insects, and weeds.**
- ☐ **C. Soil qualities and field characteristics are considered in the selection process.**
- ☐ **D. The cole crop follows a legume crop.**



# A. Crop rotation

Crop rotation is one of the most important pest control strategies for cole crops. Several key pests and diseases, such as cabbage maggot and black rot, survive in the residues of previous crops. Crop rotation allows enough time for the residue to decompose completely, and the pest population to die out, before the next susceptible crop is grown.

If you have the land available, do not plant a crucifer crop more often than every three years in a field. Crucifer crops include cabbage, broccoli, cauliflower, collards, kale, kohlrabi, radish, turnip, rutabaga, arugula, mustards, bok choy, Chinese cabbage, and several other specialty Oriental greens in the *Brassica* genus.

The distance between this year’s cole crop and last season’s cole crop can affect pest pressure, too. For example, flea beetles often move from old fields to new plantings. By increasing the distance between the overwintering sites and newly planted fields, colonization by flea beetles may be delayed long enough for the crop to grow out of the most susceptible stage. Plant late cole crops (those planted after mid-June) in a different field from the spring crop so that summer adults emerging from spring crops do not attack the new late-summer plantings.

Onion thrips will migrate into cabbage from surrounding fields of wheat, oats, and alfalfa. Separate cabbage fields from these crops to reduce colonization by thrips later in the season. Avoid planting onions close to brassicas, because the same species of thrips attacks both crops.

# B. Choosing rotational crops

A good rotation plan will prevent the build-up of pests, weeds, and diseases. There are many rotation crops that do not include members of the brassica family. Good choices are beans and other legume vegetables, tomatoes, potatoes, corn, squash, lettuce, onion family (onions, garlic, leeks, scallions), carrots, beets, and spinach. Keep a record of the cropping history in each field, and use this information to help you in decision-making each year.

Consider cover crops in the rotation scheme. In addition to breaking pest cycles, rotating with a cover crop has the benefits of adding organic matter and nutrients and suppressing weeds. Living cover crops as well as their residues can increase water infiltration into soil — an important soil quality for future cole crops. 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.



## Quick Note

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

**Spatial rotation** – refers to the distance from the current cole crop field to last year’s cole crop’s fields.

## Cole Crops

Cole crops are also called crucifers. All are members of the plant family *Brassicaceae* or mustard family. The following plants are all crucifers:

- |                    |                |                   |
|--------------------|----------------|-------------------|
| • cabbage          | • arugula      | • mustards        |
| • broccoli         | • bok choy     | • turnip          |
| • Brussels sprouts | • collards     | • radish          |
| • canola           | • garden cress | • rutabaga        |
| • cauliflower      | • kale         | • watercress      |
| • kohlrabi         | • kohlrabi     | • chinese cabbage |
- plus several other specialty oriental greens in the mustard family*

## C. Characteristics of a good planting site

Cole crops need fertile, moist soil relatively high in organic matter and nitrogen. Because diseases of cole crops can progress quickly in wet conditions, plant in well-drained fields which dry out quickly. Choose a sunny location with good air circulation where the morning dew dries early.

Mineral soils with good water-hold capacity and organic matter content are ideal. If only light-textured, sandy soils are available, the field may have to be irrigated to keep soil moisture continuously available. Avoid fields with heavy infestations of perennial weeds or fields with a history of persistent soil-borne diseases such as *Fusarium* wilt or clubroot.

Cauliflower is considered to be the most exacting in its growing requirements. Good soil drainage and a cool, humid climate are important. Brussels sprouts, broccoli, kohlrabi, and cabbage can be produced over a wider range of conditions, but all do best with ample moisture and good fertility, especially nitrogen.



**Cauliflower needs certain growing conditions**

© Howard F. Schwarz

## D. Benefits of legumes

A cole crop following a legume crop is a particularly good rotation scheme. Brassicas thrive on the extra nitrogen that a leguminous crops provides. 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. As with all cover crops, adding a legume to the rotation can also increase organic matter, break pest cycles, suppress weeds, and encourage beneficial insects, especially if allowed to flower.



**Red clover**

Green manuring is the practice of sowing a cover crop, often a legume, in early spring, and tilling it in the next spring. The amount of nitrogen and organic matter added to the soil from a legume depends on how long the crop has grown. A summer or fall-seed legume will have had comparatively little time to grow than one that is seeded in the spring or early summer. Growth of over six inches provides the most nitrogen. The more residues you return to the soil, the better the effect on soil organic matter.

### Notes:

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### Rotation Choices

Good rotation choices for cole crops are beans and other legume vegetables, tomatoes, potatoes, corn, squash, lettuce, members of the onion family (onions, garlic, leeks, scallions), carrots, beets, and spinach.

**Notes:**



# Seed Selection

Preplant



Seed selection is an important decision affecting the health, vigor, and yield of your crop. Choosing well-adapted, disease-resistant varieties is an economical and effective 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. Seeds are treated with hot water shortly before planting to prevent seed-borne diseases.**
- ☐ **C. Varieties are selected with resistance to one or more diseases.**
- ☐ **D. If the crop will start with transplants, care is taken that they are purchased or grown insect- and disease-free.**

## A. Variety Selection

Get to know varieties that perform well in your growing area and that have good marketing characteristics. Ask other growers which varieties have worked well for them, and why. When trying a new variety, do not use it exclusively. Grow new trials next to old standbys so you can compare the characteristics objectively.

### Broccoli

Most broccoli varieties are hybrids which produce one large, early head with two or three subsequent, smaller harvests. Varieties with smaller central heads and good side shoot production are also available and can be a good fresh market choice. Choose vigorous varieties with good horticultural characteristics, including well-rounded heads that will shed water – this helps to prevent bacterial soft rot. Some varieties have resistance to downy mildew.



*Young broccoli plants*

© M.E. Bartolo

### Brussels sprouts

Brussels sprouts is a hardy, slow-growing, long-season crucifer. The “sprouts” are small heads that resemble miniature cabbages. They are produced in the leaf axils, starting at the base of the stem and working upward.



*Brussels sprouts*

Sprouts improve in quality and grow best during cool or even lightly frosty weather. Choose varieties with good uniformity, vigor, leaf cover, and disease resistance. Top in early fall to encourage an even sprout maturity.

### Cabbage

Green, red, and savoy types are grown in Wisconsin. Most varieties have smooth leaves, but the Savoy types have crinkled textured leaves. All cab-

bage can be grown for fresh eating, and green cabbage is also grown for sauerkraut. Cabbage varieties that mature later usually grow larger heads and are more suitable for processing than the early varieties. Early season varieties generally have small 1-2 pound heads and mature 50-60 days after transplant. Full season varieties produce much larger 10-12 pound heads that require 130 days to harvest. The longer cabbage crop gives you some flexibility in scheduling harvest. Be sure to include disease resistance in your variety choice, especially resistance to thrips, cabbage yellows (*Fusarium wilt*), and black rot.



*Savoy cabbage*

### Cauliflower

White “Snowball” types are the most common varieties grown today. Early season cultivars mature in 50-55 days from transplanting. Late season cultivars mature in 75-80 days. To keep heads from yellowing during hot weather, some growers gather the outer leaves over young heads with string or a rubber band to preserve the white curd color. Self-blanching varieties are available that do not require tying to preserve white curd color.



*Cauliflower*

© Doug Wilson, USDA ARS

### Kohlrabi

Kohlrabi is an easy-to-grow cole crop with an unusual form. Kohlrabi leaves stand out like spokes from the edible rounded stem portion which is called a bulb, (even though it is not botanically a bulb). Its flavor is similar to turnip, but milder and sweeter. There are white (actually light



*Kohlrabi bulb*

apple-green) and purple kohlrabi varieties. The purple types only have purple skin; the interior flesh is white. Choose among varieties that differ in color, size, tenderness (woodiness), flavor, and disease resistance. Some varieties mature in as few as 38 days, others grow a larger bulb over a longer growing season.

## B. Eliminate pathogens from seed

It is significant that the main disease problems of crucifers are seed-borne. For example, the bacteria that cause black rot, one of the most destructive diseases of cole crops, is spread on seed. As few as three infected seeds in 10,000 (0.03%) can cause a black rot epidemic in a field. Seeds can also contain the pathogens that cause black-leg, *Alternaria* leaf spot, anthracnose, *Fusarium* yellows, and downy mildew. These pathogens are capable of decimating seedlings and older plants if introduced into fields with conducive conditions for disease development.



**Black rot**

Eliminating pathogens from seed before planting in the field is a key disease management strategy for cole crops. Seedlots should be entirely free of black rot bacteria before planting. A reputable seed supplier will test seed lots for black rot and other seed-borne diseases and certify the lot as disease-free. Always choose certified, disease-free seed. For extra precaution, you can treat the seed with

### Hot Water Treatment

For cabbage and Brussels sprouts; soak seed for 25 minutes in 122 degrees F water; soak for 20 minutes for Chinese cabbage, broccoli, and cauliflower. Precise time and temperature control is essential to minimize damage to the seed.

hot water by using the technique described below. Some seed suppliers offer seed pre-treated with hot water.

## C. Disease resistance

Selecting a plant variety that has resistance to one or more key diseases is one of the most economical and effective ways to prevent diseases, and some pest problems, later in the season.

Varietal selection is also an important way to avoid physiological disorders, such as hollow stem of broccoli. Fortunately, varieties that have good horticultural characteristics as well as disease resistance are available for all the cole crops.



**Chinese cabbage**

Disease resistance can be defined as the ability of a plant to keep pathogen growth in check, compared to a more susceptible plant. Some varieties aren't resistant, but they are more tolerant than others, which means they are able to withstand or recover from insect or disease damage.

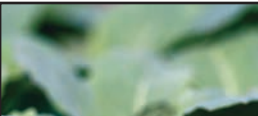
No variety is resistant or tolerant to all insects and diseases, so it's important to consider field history and your field conditions when selecting varieties. Over time, identify those pests or diseases that have the greatest potential to cause damage in your fields, or are the most challenging to control. In particular, consider varieties that have resistance to cabbage yellows, black rot, and thrips. Varieties which are less prone to physiological disorders such as tipburn, riceyness of cauliflower, hollow stem in broccoli, buttoning of broccoli and cauliflower, and bolting can also be selected.

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



## D. Grow or obtain clean transplants

Cabbage and broccoli can either be direct-seeded or transplanted. Direct-seeding broccoli during mid-summer for a fall crop is less expensive than using transplants, while using transplanted broccoli for early spring production could be a good market window. Cauliflower, with its more exacting growing requirements, and Brussels sprouts, with its longer growing season, are often transplanted to the field.



***Cabbage transplants***



### ***Cabbage transplants***

The advantages of using transplants are the ability to choose your own variety, efficient use of seed, season extension, uniform stand and quality, reduced weeding costs, shortened cropping period in the field, and less exposure to pests.

Many Wisconsin growers grow their own transplants, others purchase transplants from suppliers. If you grow your own early crop of broccoli, cauliflower, cabbage, and Brussels sprouts, start transplants 6 to 8 weeks before the frost-free date. In southern Wisconsin, this would be mid-March. Shortly before planting, treat the seeds with hot water to kill the seed-borne bacteria and fungi that will kill young seedlings. Sterilize empty transplant trays in a 10% bleach solution. You can buy or mix your own sterile potting mix for starting transplants.

When buying transplants, purchase carefully. Transplants should be weather-hardened, free of pests, and not be long or leggy. When contracting to buy your transplants, insist on the following terms from your supplier:

- Certification that the seed is free of black rot and/or heat-treated.
- Certification that the transplants are pest-free. This is especially important when the transplants are obtained from those southern areas where insect resistance has been documented. These seedlings should be inspected by regula-

tory authorities prior to and at pulling time and should have certification.

- ▶ Documentation that the transplants are not trimmed (“topped”) with mowing machinery which could spread disease.
- ▶ The supplier uses only new packaging material to ship.



### Quick Note

Be cautious if you buy transplants from the south. Diamondback moths have developed resistance to insecticides and Bt in areas of the southern United States. Transplants sold in the north may harbor this insect.

### Notes:

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

# Field Preparation

## Planting



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. Preplant tillage is adequate for planting and weed control, but not excessive.
- ☐ B. Soil moisture levels are monitored, and soil moisture is considered when planning tillage and planting operations.
- ☐ C. A pre-emergence weed management plan is in place, and weeds are controlled before planting.
- ☐ D. Cover crops, green manure, and other organic amendments are incorporated on a timely basis to add nitrogen and increase soil organic matter.

## A. Tillage

Tillage loosens the soil and prepares the seed-bed 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, macro-pore formation, 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.

Follow these general guidelines for pre-plant tillage:

- ▶ Do not till if soil moisture is greater than 80 percent.
- ▶ Clean tillage equipment of soil and plant residues when moving from field to field to prevent the spread of weeds and soil-borne pathogens.
- ▶ 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.

## 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** in this section.



*Estimating soil moisture*

## C. Pre-plant weed management

Proper bed preparation is important for successful weed cultivation after the crop is planted. Prepare a straight, well-made bed and as straight seeding and transplant lines, so that cultivating implements can later 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.

If the cole crop will be planted later in the spring, and soil conditions are right, there may be time to eliminate some annual weeds with the stale seed-bed method. To encourage weed seeds to sprout before planting, till and prepare the soil for planting, before letting it rest while non-dormant weed seeds germinate and emerge. Tillage stimulates the germination of several weed species. Shortly before planting, eliminate the emerged weed seedlings by using a flame torch, by very shallow cultivation, or by mowing very near the ground. It is essential to keep tillage to a minimum to avoid stimulating further weed seed germination. You can then direct-seed or transplant the crop into a seedbed that has been depleted of a good proportion of germinable weed seeds.

Avoid fields that are heavily infested with hard-to-control perennial weeds. If problem weeds are present in significant numbers, the best strategy is to rotate to a crop in which they can be successfully controlled. Some perennial weed problems can be addressed by pre-plant plowing, followed by discings before bed formation.



*Canada thistle*

Monitoring your fields and keeping records of the weed species that occur in each field will help you track the occurrence of hard-to-control weeds and plan effective weed management strategies before planting and during all stages of crop production. There are a few pre-emergent herbicides registered for cole crops in Wisconsin, as well as foliar-active herbicides that can be used on fallow beds to control troublesome weeds before planting.



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

### Sand or loamy sand soil texture

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

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

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

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

**70-80%:** Forms weak ball. Distinct fingerprint outline on ball. Soil particles will stick to palm. **This is optimum for cole crop planting.**

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

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

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

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

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

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

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

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



### Quick Note


Refer to the UW Extension publication A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products for weed management.

## D. Incorporating cover crops and soil amendments

Cole crops grow best in soils with good organic matter content that provide a steady nutrient and water supply. 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.

Have a goal in mind when choosing a cover crop, for example, 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 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 crop. Grass or grain crops planted in the fall and tilled into the soil as green manures before planting are good soil improvers. They can also capture any excess nitrogen that might otherwise leach from the soil over the winter.

Incorporate cover crops and organic amendments at least two weeks before planting to permit the decomposition of the cover crop. This will improve the seedbed and avoid attracting the adult flies of the cabbage maggot, which prefer to lay eggs in decomposing residues.



### *Incorporating rye*

### 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



Attention to environmental conditions and strict sanitation at this stage will contribute to the quality and health of the final stand. Rapid, steady, early-season growth of the cole crop will improve resistance to pest 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 planting spacing.**
- ☐ **C. Vigorous, disease-free transplants are used.**
- ☐ **D. Planting is timed to avoid the peak emergence of the cabbage maggot.**

# A. Planting date

Cole crops can be planted from mid-April through mid-June in Wisconsin. Plant when the soil temperature at 2 inches is at least 50 degrees F; soil temperatures between 65 and 75 degrees F are optimal. Soil moisture should be adequate but not excessive. Planting in soils that are too cold or too wet can result in a poor stand, seed and seedling decay (damping off), or physiological disorders. Sandy loam soils will warm up the fastest and are best for the earliest crops.



Cabbage transplant

© Howard F. Schwarz

Cole crops grow well in cool temperatures of 60 to 65 degrees F. However, prolonged periods below 50 degrees F may induce bolting in broccoli and cauliflower, especially after the five-leaf stage.

Spring crops can generally be transplanted around May 1 in southern Wisconsin and two weeks later in northern counties. Ten days before planting to the field, move plants outdoors to a cold frame to harden them off. Once cole crop seedlings have been hardened off, they can withstand temperatures as low as 28 degrees F.



## Quick Note

Diamondback moths have developed resistance to several insecticides and to Bt in areas of the southern United States. Check purchased transplants carefully. You do not want to import these pests!



© Russ Ottens, University of Georgia

Diamondback Moth Larvae

# B. Optimal row & plant spacing

Optimal 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. Plant a straight, well-made bed that will be easy to cultivate.

Plant single seed about one-half inch deep and 3 to 4 inches apart. Thin to final row spacing when seedlings are about 2 inches high. If cluster-seeding, plant 3 seeds per cluster, spacing seed 2 inches apart. Thin to remove all but one plant per cluster.

## Planting guidelines for cole crops

	Plant spacing between rows	Plant spacing between plants
Broccoli and Cauliflower	18-36 inches	12-24 inches
Brussels sprouts	24-30 inches	12-18 inches
Cabbage	24-36 inches	12-24 inches
Kohlrabi	12 inches	6 inches

# C. Plant healthy transplants

Planting infested transplants is one of the most common ways that diseases and pests of cole crops enter a field. Good IPM practices at this step can prevent problems later in the season. It's very important to buy or grow high-quality transplants that are absolutely free of black rot and caterpillars. Do not plant any transplants with signs of these pests. Practice strict sanitation in the greenhouse and cold frames and inspect seedlings frequently.

Once planted, scout seedlings twice a week, and rogue out and destroy any seedlings with black rot symptoms or insect larvae.

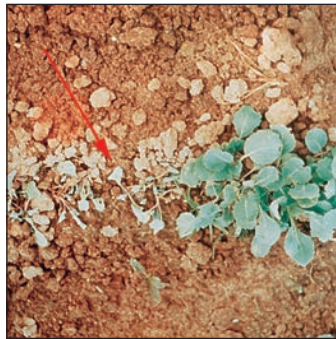


Black rot



## D. Time planting to avoid the cabbage maggot

Cole crops are most susceptible to damage by cabbage maggot larvae if they are in the seedling stage when the first generation of adults (small flies) are laying eggs. Transplanted crops are most susceptible during the first 2 to 3 weeks after planting. Schedule planting to avoid the peak fly emergence and egg-laying periods. This way the crop will be protected from the largest population of the pest.



*Stunted plants caused by cabbage maggots*

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 lilacs and yellow rocket are flowering, around early May. 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>. See the following page for a description of how to calculate degree days. The first generation of flea beetles and imported cabbageworms can also be monitored with this system.

The first generation maggots develop from eggs laid when 300 DD have accumulated, which also corresponds to the blooming of yellow rocket and lilac (usually early May). Do not transplant during this time or seed approximately 2 weeks before this time. The ideal time to seed is after the peak emergence (300 DD) which is towards the end of the yellow rocket bloom period. Plant transplants at least one week before or after the peak. For direct-seeded crops, begin planting at least 3 weeks before the peak or 1 week after the peak.



*Blooming yellow rocket*

### Season-extending techniques

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

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

### Physical barriers to exclude insect pests

Consider row covers to keep out adult cabbage maggot flies, flea beetles, and caterpillar larvae. Floating row covers are made of spun-bonded polyester and polypropylene that is 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 of a greenhouse. Plants are protected from drying winds and temperature extremes, as well as from insect pests. Note, however, that the row covers would not keep out cabbage maggot flies that are emerging from pupae that overwintered in the soil.

In small plantings, physical barriers such as tar-paper or plastic discs cut to fit snugly around the plant stem can be used to prevent the cabbage maggot flies from laying eggs at the base of the plant.

## 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. Cool-season cole crops have a base temperature of 40 degrees F. Begin recording degree day accumulations for Wisconsin on March 1<sup>st</sup>.

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 cabbage maggots and other 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 1 degree above the developmental base temp) 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/>

### Degree Day Thresholds for Cole Crop Pests

	Developmental base temperature	1 <sup>st</sup> generation	2 <sup>nd</sup> generation	3 <sup>rd</sup> generation
Cabbage maggot	43 degrees F	300 DD	1476 DD	2652 DD
Other indicators		Yellow rocket Lilac	Daylily	New England aster
Fleabeetles	50 degrees F	150-200 DD		
Other indicators		Norway maple late bloom, redbud early bloom		
Imported cab- bageworm	50 degrees F	150-240 DD (adult butterflies)		
Other indicators		redbud early to full bloom, Black Hills spruce bud caps splitting		

# General IPM

## In-Season



Integrated pest management (IPM) is a long-term, decision-based approach to managing pests that makes use of all available pest management tools in a way that minimizes the economic impact of pests on the crop, and the risks to health and the environment.



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 pests and economic thresholds of cole 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, genetic control (host resistance), biological control, and chemical control.



*Young broccoli*

© Howard F. Schwarz

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 cole crops 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 cabbage yellows is noted this season, a yellows-resistant variety can be chosen for next year 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 of cole crops

The more you know about the common pests 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 many different control strategies throughout the season.

Accurate pest identification is a crucial first step for effective pest management. Following this section are two tables which provide brief descriptions of the major insect and disease pests of cole 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 2 cotyledons, or seed leaves. Seed leaves or cotyledons are the first pair of leaves to appear as the plant emerges through the soil and generally have a different shape and appearance than true leaves.



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**. Below it is the **ligule**, a small, pointed structure. The **sheath** is the lower part of the leaf, which is divided into **collar and auricles** (lobes) on either side of the ligule.

[illegible]

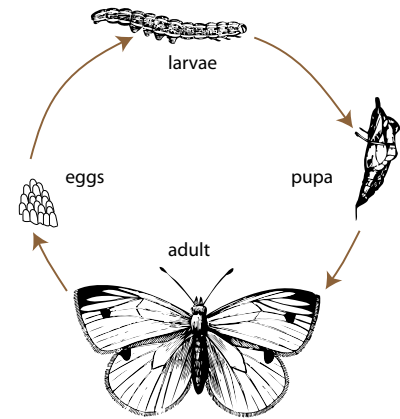
## Key Insect Pests of Cole Crops

These are the main insect pests of cole crops that you and your scout should be able to recognize. Detailed information on the life cycle, scouting, and integrated management of each pest are in the following chapters and in the Pest Profiles section of the Appendix.



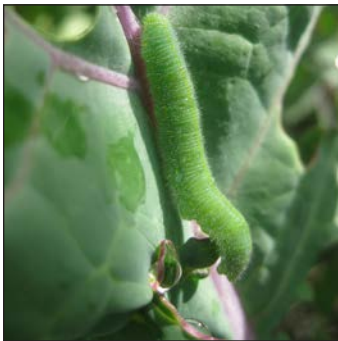
### Quick Note

Three of the most common pests of cole crops are caterpillars. These are the young (larva) stage of moths and butterflies. They are the Diamondback Moth, the Imported Cabbageworm and the Cabbage Looper.



### Imported cabbage-worm

*Pieris rapae*



The imported cabbageworm is the most common of the three caterpillar pests of cole crops. It is an insect that overwinters in the upper Midwest and can be a pest throughout the entire growing season, feeding on the upper side of plant leaves. Extensive feeding can kill small plants, but older plants can tolerate quite a bit of feeding until flowering stages. The adults are white butterflies that appear in early May. The adult butterflies do not feed on plants, but they are a clue to the presence of the cabbageworm larvae.

### Cabbage looper

*Trichoplusia ni*



© Whitney Cranshaw, Colorado State Univ.

The looper is a late-season pest in the upper Midwest. Most damage from this pest is likely to occur in August and September as it often migrates into the region as adult moths on weather fronts throughout the growing season. The larvae are pale green caterpillars that move with the characteristic “looping” movement that gives them their name. Loopers eat holes in leaves and heads. Broccoli and cauliflower are generally less tolerant than cabbage, and cannot tolerate direct damage once heads begin to form.

### Diamondback moth

*Plutella xylostella*



The larvae of the diamondback moth is one of three major caterpillar pests of cole crops. The caterpillar is easily overlooked because it is small and blends in very well with cabbage leaves. Look for one-half inch long light-green caterpillars that wriggle furiously or drop off the leaf when disturbed. It generally does not overwinter in the colder areas the upper Midwest, but arrives in the north on imported transplants and on weather fronts from south to north.

### Cabbage maggot

*Delia (=Hylemya) radicum*



Cabbage maggot is an important early-season pest of cole crops. Maggots feed and tunnel through the roots, causing injury that can stunt plants and lead to invasion by secondary pathogens such as soft rot bacteria and the fungus that causes black leg. Maggots can cause serious damage to young transplants and seedlings between seedling emergence until about a month after thinning or transplanting. A well-established planting can usually tolerate moderate infestations.

### Flea beetles

*Phyllotreta spp.*



© Whitney Cranshaw, Colorado State Univ.

Flea beetles are occasional pests of cole crops. Adults are very small, which have a hardened outer shell (elytra), beetles that chew holes in the leaves, causing bleached, pitted areas and a shot-hole appearance. Seedlings are the most susceptible to flea beetle damage. A well-established planting can usually tolerate moderate infestations.

### Cabbage aphid

*Brevicoryne brassicae*



© Dr. Amanda Gevens, UW-Madison

The cabbage aphid occurs every year in the Midwest but is usually only a pest late in the season as the numbers of parasites and predators decrease. Aphids are tiny, soft-bodied insects that use their piercing mouthparts to suck juices from plant tissues. Large populations can kill seedlings, but most cole crops can tolerate a moderate aphid population until heading begins. After that, even a low level of infestation can reduce the quality of broccoli and cauliflower heads.

### Onion thrips

*Thrips tabaci*



© Whitney Cranshaw, Colorado State Univ.

Thrips are very small insects that use rasping-sucking mouthparts to feed on leaf surfaces, causing whitish scratches, often referred to as 'silvering'. They are most damaging to cabbage and cauliflower, sometimes burrowing deep between cabbage leaves. They are most damaging in hot, dry weather. Feeding scars later in the season can appear as small blisters arranged in groups or lines.

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## Key Diseases of Cole Crops

These are the main diseases of cole 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**.

### Bacterial soft rot

*Pseudomonas and Erwinia spp.*



© Paul Bachi, University of Kentucky, REC

Soft rot is a bacterial disease that affects many vegetables, especially in storage and transit, but also in the field. Soft rot is a rotting of plant tissue, often following insect feeding during warm, wet weather, or when plants are injured.

### Black leg

*Phoma lingam*



Black leg is a fungal disease that can affect cole crops at any stage. Check transplants for black leg before they are transplanted into the field. Usually the first symptom is a circular, sunken canker at the base of the stem, that eventually girdles the entire stem. Later, leaf spots and root rot can develop.

### Black rot

*Xanthomonas campestris pv. campestris*



Black rot is caused by a bacterial pathogen and is one of the most destructive diseases of cabbage and other crucifers. The diagnostic symptom of black rot is a yellow to tan V-shaped lesions at the leaf margin. Any yellowing plants or plants with V-shaped lesions should not be planted as they will serve as a source of bacteria that will spread throughout the field.



## Cabbage yellows

### *Fusarium*



© Queen's Printer for Ontario, 2009

Cabbage yellows is a fungal disease that affects all cole crops but tends to be the most serious on cabbage. Infected plants are stunted, lopsided, and yellow, and will lose most of their lower leaves. Resistant varieties have been developed for cabbage yellows and are the only effective control of this disease.

## Clubroot

### *Plasmodiophora brassicae*



© Robert Wick, Univ. of Massachusetts

Roots infected with this fungus enlarge, become distorted, and resemble clubs, hence the name. Roots can be severely affected before above-ground parts of the plant show any symptoms. Once established in a field, the fungus is long-lived in the soil.

## Downy mildew

### *Peronospora parasitica*



© Dr. Amanda Gevens, UW-Madison

Downy mildew is a fungus-like organism that creates a leaf blight. This can be a problem on early-seeded plant beds or on late-maturing crops when the weather is foggy, cool, and wet. Downy mildew symptoms are typically seen on lower leaves first; the first symptoms are discolored spots on the cotyledons. Later, discrete yellow areas and irregular black spots develop on broccoli and cabbage leaves.

## 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, genetic, 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 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, plowing and cultivation to smother weeds and bury overwintering 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



*Green lacewing adult*

© Joseph Berger

- bugs, beetles, and spiders. Natural enemies of pests are common in the field and should be preserved.
- ▶ 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 5 broad categories: chemical controls, such as pesticides; cultural controls, such as controlling plant vigor or rotations; biological controls, such as natural enemy releases or conserving natural enemies; behavioral control, such as the use of insect pheromones; and genetic control, such as the use of resistant varieties.

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

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

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

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

**Notes:**



# Scouting

## In-Season



Scouting provides information on changes in pest populations over space and time, and helps with decision-making. 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.



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

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

## A. Crop scouting 101

Scouting is the regular examination of the crop condition and is the backbone of a successful IPM program. Scout at least weekly from crop emergence until harvest. Scouting involves walking through a field and stopping at a number of locations to observe crop growth and 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 prevent problems 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.



### Quick Note

The two most critical times to scout cole crops are the seedling stage to about a month after transplanting and when the crop is developing heads, flowers, or curds.

## B. Scouting calendar

Seedlings are especially vulnerable to cabbage maggots, caterpillar larvae, flea beetles, black rot, and black leg. After seedling emergence or transplanting, check the crop twice a week for signs of these pests and dis-



*Cabbage transplant*

© Howard F. Schwarz

eases. This is also the time of peak adult cabbage maggot fly emergence. Flea beetles may also be emerging.

Once the crop is established in the early and middle part of the season, it can tolerate more injury from insect pests and diseases because most of the leaves and stems grown until flowering (broccoli) or cupping (cabbage) do not go to market.

Moderate leaf feeding by caterpillar larvae is not of economic concern as long as maturity is not delayed or growth severely stunted.

Natural populations of parasites and predators are active during this time and may keep caterpillar populations at tolerable levels.



*Cabbage at cupping stage*

Caterpillar feeding at the early cupping or flowering stage can affect the quality of future heads of cabbage and the marketable portions of broccoli and cauliflower. Continue to monitor closely and be prepared to treat if more than 20% of the plants are infested with one or more species of caterpillar larvae.

Heading to maturity is the most vulnerable stage in cole crop development, when caterpillars or aphids could feed on the developing heads, flowers, or curds. Scouting should continue weekly and treatment thresholds drop to 10% for caterpillar pests. At this stage, the marketed portion of the crop must be almost free of insects, insect parts, and insect frass to meet quality standards. Thus, control of caterpillar larvae at this stage is a quality issue.



*Cabbage at maturity*

© Howard F. Schwarz

## C. Scouting methods

It's important that scouting is done systematically and at regular intervals. In order for a scouting program to be effective, you must be familiar with what a healthy crop looks like. You also must know the key pests and diseases of each crop. This section will help you know what insects and diseases to look for, how to scout for them, and when they are likely to be a problem.

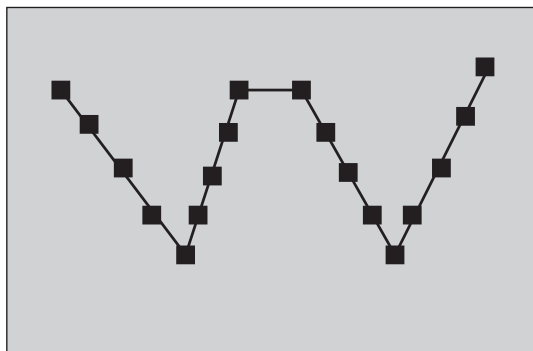
When scouting, you will be visually inspecting the crop for insects such as caterpillars, thrips, flea beetles, and aphids. You will take notes on the number of beneficial insects present and the level of parasitism of insect pests. Plant diseases, environmental injury, or injury due to improper cultural practices should also be observed and noted when you walk the field.



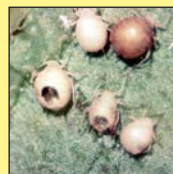
*Scouting with a sweep net*

### Choose plants to inspect

Walk along a W-shaped path through the field and examine a plant every few yards. Choose the plants randomly at a fairly even spacing throughout the field. Don't bias your sample by looking for injured or uninjured plants to inspect. However, do include edges or areas of the field where pests or diseases have been a problem in the past. Examine 25 to 50 plants, depending on the field size. Be sure to cover all quadrants of the field, as aphids in particular, will not be uniformly distributed but rather tend to be clumped in hot spots.



### How to recognize signs of biological control during scouting.



Aphid mummies indicate that parasitic wasps are present. If there are high numbers of aphid mummies, insecticide application may not be necessary.



Parasitized caterpillars are another sign that natural predators are at work.

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.

### Inspect plants and record information

Check young seedlings and transplants twice a week for signs of cabbage maggot, diamondback caterpillar larvae, black rot, and black leg. Check the following pages for specific descriptions of what to look for.

At all stages, look for insects on the upper and lower surfaces of each leaf. Small caterpillars, especially imported cabbageworm and diamondback moth, blend in very well with cabbage leaves and are hard to spot. Be sure to check heart leaves for damage, as small larvae can be easily overlooked. Check plants carefully even if there is no apparent feeding damage. Look for eggs that will hatch into larvae in several days to a week. Eggs of caterpillar pests are often laid singly on the undersurface of leaves along leaf mid-veins.

Record your findings on a scouting form. See an sample scouting form in this section. For a blank scouting form, see the last page of the **Disease Management** section. Count and record the number of insect pests you find. Examine caterpillars and aphids for signs of parasitism and record the



number you find. Wasps that parasitize aphids and diamondback moth larvae are common and may be providing significant control. Note the presence of natural enemies.

Note whether there are any disease symptoms present. If you notice something, determine the extent of the symptoms. Note the location and type of symptoms, how much tissue is affected, and how many plants are affected. If plants appear stunted, dig one to inspect the roots. Do your best to accurately diagnose the cause. Seek diagnostic help if needed.



*Downy mildew*

© Dr. Amanda Gevens, UW-Madison

Record the presence of weeds. Count the number of weeds per 10 feet of row for large infestations or every 100 feet of row for smaller infestations. Mark what you find on a weed map. Scouting regularly for weeds keeps you on top of shifting weed pressures and makes it easier to spot-treat for weed problems and to make plans for off-season weed control.

## D. Information management and field 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 a 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. If several crops are grown in a single field, each plot, row, or bed can be marked and numbered on the map. The field map can be used as an activity log showing

dates of plantings, planting rates, crops planted, varieties planted, seed sources, soil amendments, fertilizer applications, pest control applications, weed management strategies, and other cropping practices and inputs.

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 spacings, general observations made on plant health, specific weed populations or problem locations, and weather conditions such as heavy rains or soil erosion, are useful things to note during the season.

Harvest records can be invaluable in planning for the future, especially to determine what crops were most profitable, which crops or varieties were most affected by pests or diseases, when to plant specific crops, or how much to grow in the future. Harvest records can include crop, variety, date of harvest, amount harvested, quality of harvest, and location where harvested.

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 using field maps and observing 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.

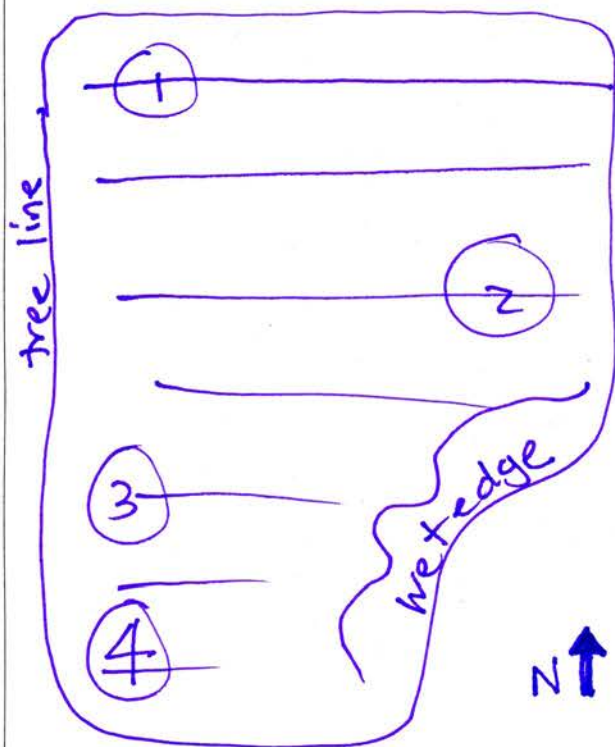
A weed map is particularly effective as a long-term management tool. The weed map should include notes on specific weed species present, the locations of perennial weeds, and any severe infestations of annual weeds. Also note the weeds located in fence rows, near the edges of the field, and along waterways.



# Pest Scouting Form

Date / Time AUGUST 10TH / 10 AM Field # 22 Crop Cabbage  
 Grower HAPPY ACRES Field Location SOUTHEAST 80 Plant Height 17 inches  
 Scout Rick Field Field Size 78 acres Growth Stage heading

**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).

icu ~~||||~~ / 25 plants

looper ||| / 25 plants

dbm ~~||||~~ || / 25 plants

fla beetles 100% damage @ site ④

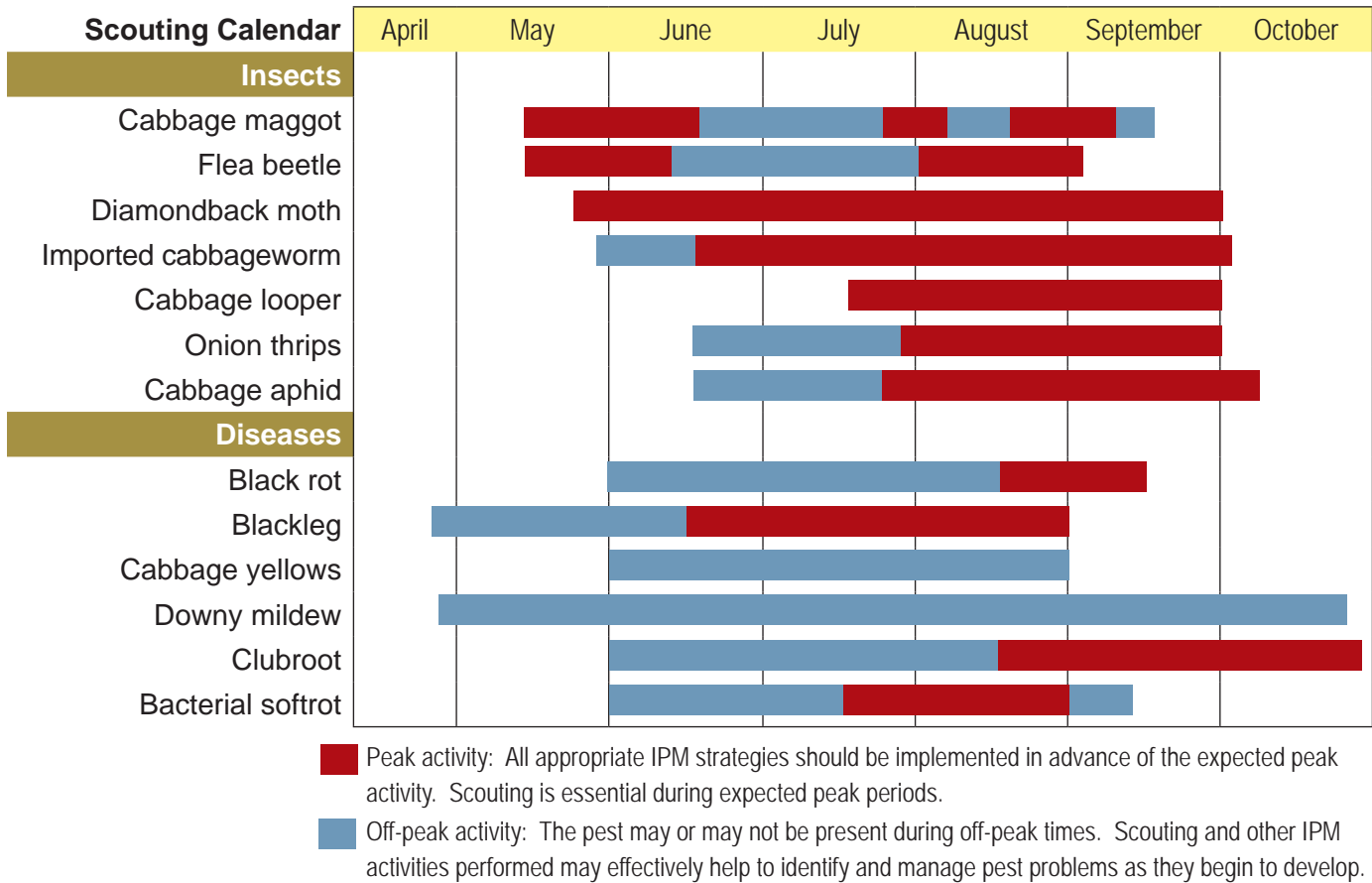
**Weeds:** Count the number of weeds per 10 feet of row for large infestations or every 100 feet of row for smaller infestations. Identify the weed and mark what you find on the map.

wild mustard at North edge / site ①

**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.

Cabbage yellows @ 15% at sites ③ + ④

slight downy mildew at site ①



## Scouting Methods for Key Insect Pests of Cole Crops

### Cabbage maggot

*Delia (=Hylemya) radicum*



After seedling emergence or transplanting, check the crop twice weekly for signs of cabbage maggots. Infected plants might be stunted and yellow and wilt easily. Pull the plant and check the roots. The maggots are tiny, one-fourth inch long white larvae with no legs, and resemble a grain of rice. Brown tunnels in the roots are a sign of maggot feeding, which can create an entry for pathogens.

The adult cabbage maggot fly resembles a house fly but is only half as long. Female flies lay eggs in the soil near the base of the plant, which hatch into the maggots that feed on roots. The peak egg-laying activity can be predicted by monitoring degree-day accumulations. The first generation maggots develop from eggs laid when 300 degree days have accumulated. This corresponds to the blooming time of the common lilac.

**Threshold:** There are no economic thresholds for the cabbage maggot. Once cabbage maggot damage is noticed, it is too late to apply control procedures.

## Flea beetles

*Phyllotreta cruciferae*, *P. striolata*



© Whitney Cranshaw, Colorado State Univ.

Scout direct-seeded and transplanted crops twice per week during the seedling stages for flea beetles. Look for bleached, pitted areas with a shot-hole appearance where adults have chewed holes in the leaves. Heavy feeding on young plants can cause the leaves to drop. Flea beetles are small, hard beetles only one-tenth inch long and may be black, black and yellow, or metallic green-blue. They have long legs and will jump long distances when disturbed.

Flea beetles are most active on sunny, windless days, or during cool weather when plants are growing slowly. They are attracted to fields that are weedy or surrounded by weeds that are drying up. Flea beetles rarely cause serious damage to mature plants. Flea beetle activity normally declines in June.

**Threshold:** Relatively low populations can cause economic damage when plants are in the cotyledon or first-leaf stages. Although no economic thresholds have been established in cole crops, treatment should be implemented to keep insects from reaching 50% infestation on these early, vulnerable stages. Spot treatment of outside rows where overwintering adults are entering the field may be sufficient. Once plants have five leaves they can tolerate a moderate infestation. Older, established plantings are even more tolerant.

## Diamondback moth

*Plutella xylostella*



© Alton N. Sparks, Jr., Univ. of Georgia



© Whitney Cranshaw, Colorado State Univ.

The three caterpillar pests—diamondback moth, imported cabbageworm, and cabbage looper—can be considered together as a single caterpillar complex. Monitor weekly by walking a W-shaped path through the field and examining randomly-selected plants every few yards. Examine 25-50 plants, depending on the field size, and record the number of plants infested. A plant is infested if eggs or caterpillars of any species are present.

The diamondback moth is often overlooked because it is small and blends in well with cabbage leaves. Look for one-half inch long light-green caterpillars that wriggle furiously or drop off the leaves when disturbed. Check for eggs, which are oval, yellowish-white, and tiny. They will be glued to the upper and lower leaf surfaces singly or in groups of two or three, usually along the veins.

Check transplants carefully. Diamondback moth larvae are initially leaf-miners, but later feed on leaf tissue, creating a “windowpane” pattern when viewed from above.

**Threshold:** Thresholds are based on the presence of healthy larvae or eggs of all caterpillar species present, and on the crop growth stage—see Cabbage Looper. Note and record the presence of parasitized larvae and disease-killed larvae, and consider the level of biological control activity when making treatment choices.



## Imported cabbage-worm

### *Pieris rapae*



The three caterpillar pests— diamondback moth, imported cabbageworm, and cabbage looper—can be considered together as a single caterpillar complex. Monitor weekly by walking a W-shaped path as described for the Diamondback moth.

Imported cabbageworms are small green caterpillars (larvae) that grow into 1-inch long velvety green caterpillars with a faint yellow stripe down the back and a row of faint yellow spots on each side. Older larvae are voracious feeders, tending to feed toward the center of the plant near the midribs of leaves. They move sluggishly when poked. Look for their greenish brown fecal pellets and yellow double-pointed eggs on the undersides of leaves.

You may notice the adults, which are day-flying butterflies with white or yellow-white wings tipped with one (male) or two (female) black spots. The adult butterflies do not feed on plants, but they are a clue to the presence of the plant-feeding larvae.

**Threshold:** Thresholds are based on the presence of healthy larvae or eggs of all caterpillar species present, and on the crop growth stage — see Cabbage Looper. Note and record the presence of parasitized larvae and disease-killed larvae, and consider the level of biological control activity when making treatment choices.



© David Cappaert, Michigan State Univ. (egg close-up), Whitney Cranshaw, Colorado State Univ. (egg), Russ Ottens, Univ. of Georgia (adult moth)

## Cabbage looper

### *Trichoplusia ni*

Cabbage loopers are easy to recognize as short (1-2 inch) caterpillars which arch their backs into a loop as they crawl. Look for the presence of round, white eggs that are laid singly or in small numbers on the undersides of leaves, and for greenish brown fecal pellets. The cabbage looper is found mainly in August and September.

**Threshold:** Base treatment on the presence of healthy larvae and eggs of all caterpillar species present. Thresholds depend on the plant growth stage. Note and record the presence of parasitized larvae and consider the level of biological control activity when making treatment choices.

- ▶ Treat seedlings if more than 10% of the plants are infested.
- ▶ Treat broccoli and cauliflower transplants until first flower or curd when 50% of the plants are infested.
- ▶ Treat cabbage between transplant and cupping if more than 30% of plants are affected and between cupping until early heading if more than 20% of plants are infested.
- ▶ Once heads, flowers, or curds are developing, treat cabbage, Brussels sprouts, broccoli, and cauliflower if 10% of the plants are infested.



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## Onion thrips

### *Thrips tabaci*



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Cabbage and Brussels sprouts are the only cole crops affected by thrips. Note the presence and numbers of thrips when scouting weekly for caterpillar pests. Thrips prefer tight spaces on plants, such as the closely pressed leaves of a developing cabbage head or on the underside of leaves. They are often difficult to find, so it is important to look for signs of feeding. After head formation, damage can be detected by peeling off the outermost leaves. Some varieties with tighter heads are less susceptible to injury and should be considered if thrips become a perennial problem. Feeding injury from onion thrips looks like white scratches or blisters on the leaf surface that turn into dark blotches. The insects themselves are very small (less than one-sixth of an inch) and hard to see. Use a 10X magnifying lens.

Onion thrips build up on alfalfa and small grains before migrating to cole crops after the small grains mature and alfalfa is cut. Place yellow sticky traps on outer field edges to monitor migrating thrips, especially when nearby small grains are cut. Traps should be examined twice weekly, and more often once an influx of thrips has been detected. Pesticide applications, if necessary, are more effective prior to head formation. Thorough insecticide coverage is essential for good control of thrips, and sprays should be directed at both the top and underside of the leaves. Once thrips are between the leaves in a head, they are difficult to contact with an insecticide.

**Threshold:** No thresholds have been established for thrips in cabbage. Cabbage varieties differ in their resistance to thrip feeding, and resistant varieties should be planted. Heavy rains or overhead irrigation will also reduce thrips numbers by washing them from the plants. Hot and dry conditions tend to favor thrips damage, while cool rainy weather will often delay infestations.

## Cabbage aphid

### *Brevicoryne brassicae*



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The cabbage aphid is usually a pest only in the later part of the season when populations build up and control by natural enemies declines. When scouting, note whether aphid mummies are present, indicating parasitism. Also note and record the presence of natural enemies. Thoroughly check each field weekly, especially after heading and flower formation to avoid contamination of the harvested crop. Aphids occur in “hot spots”, rather than uniformly in a field.

Cabbage aphids are green-gray with a white, waxy coating. Check the youngest, highest, and innermost leaves of young plants. After heading, check the flowering parts of broccoli and cauliflower and pull back wrapper leaves of cabbage. Aphids can be found deep within the heads of cabbages or Brussels sprouts. Transplants of Brussels sprouts can harbor aphids and provide an entry into the field. Check seedlings before transplanting.

**Threshold:** Thresholds depend on the crop growth stage, as follows: Treat broccoli and cauliflower before heading if there are more than 100 aphids/plant; after heading if there are more than 5 aphids/plant. Treat cabbage if 1-2% of the plants are infested. Brussels sprouts can tolerate 40% infested plants from transplanting up until 2 weeks before harvest. At topping, treatment is required if 1 or 2% of plants is infested with one or more aphids (UC-Davis recommendations).

## Black rot

*Xanthomonas campestris* pv. *Campestris*



Black rot is considered the most serious disease of crucifers. Inspect all transplants for black rot before planting because the pathogen can be seed-borne. Do not plant any plants which may have black rot as they will serve as a source of the bacteria that will spread throughout the field.

Seedlings infected from contaminated seed turn yellow, drop lower leaves, and may die. Leaves may be affected on only one side of a seedling. Dark spots and blackened veins sometimes develop on cotyledons. Plants may not develop symptoms for several weeks. Monitor seedlings weekly. Limiting field activities when foliage is wet can help in managing spread.

Older plants can be infected with black rot at any stage of growth, especially when warm, humid conditions follow periods of rainy weather during early crop development. The diagnostic symptom of black rot is a yellow to tan V-shaped lesions at the leaf margin. The veins in infected leaves, stems, and roots may turn black from compounds produced by the bacteria. Blackened veins can be seen in stems and leaf petioles by cutting crosswise. Infected cauliflower curds turn brown, but this symptom is not diagnostic because soft rot bacteria can cause similar symptoms.

**Threshold:** There are no treatments for black rot once the disease is present. Management is prevention-based, using resistant varieties and strict sanitation. Rogue out infected plants to slow the progress of the disease.

## Black leg

*Phoma lingam*



Black leg is caused by a fungus that can infect plants in the seedbed or in the field at any time during the growing season. Inspect transplants for black leg before they are transplanted into the field. Do not plant any plants with signs of black leg.

On seedlings, the first symptom is usually a circular, sunken canker at the base of the stem that eventually girdles the stem. Severely-infected plants will topple over as the pathogen destroys the supportive stem tissue. The fungus can kill seedlings or stunt the growth of surviving plants.

Look for signs of black leg during weekly scouting. Leaves of infected older plants may have yellow to brown circular spots with grey centers and purplish borders. Spots may turn a reddish color. Lesions formed after heading can make cabbage heads unmarketable. With a 10X hand lens, check for tiny, black bodies called pycnidia in the leaf spots. They contain millions of spores of the pathogen which spread during wet weather.

**Threshold:** There are no treatments for black leg once the disease is present. Management is prevention-based, using resistant varieties and strict sanitation. Rogue out infected plants to slow the progress of the disease.



## Cabbage yellows

### *Fusarium*



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Cabbage yellows is caused by a warm-season, soil-borne fungus. The disease develops rapidly at temperatures ranging from 75 to 85 degrees F; little development occurs below 60 degrees F in early season crops. Begin checking for cabbage yellows two to four weeks after transplanting if soil temperatures are warm.

The first sign of yellows is a pale, yellow color overall but often more noticeable on one side of the plant. Lower leaves turn yellow first, then the upper leaves, which eventually turn brown and dry. The yellowing is often more intense on one side of the leaf, which will curl and twist, leaving only one side of a plant stunted. The vascular tissue in the stem turns dark brown, resembling symptoms of black rot, except the veins are brown, not black. Symptoms of cabbage yellows can be so similar to black rot that you may need diagnostic help to distinguish between the two diseases.

The rate of disease development depends on variety resistance and soil temperature. Susceptible varieties growing in warm soils may die within two weeks. Other varieties may continue to decline throughout the season and die slowly. If soil temperatures decrease after infection, the plant may merely lose a few yellow leaves, recover, and make a normal head.

**Threshold:** There is no treatment for cabbage yellows once the disease is present. Management is prevention-based, using resistant varieties and exclusion.

## Downy mildew

### *Peronospora parasitica*



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Scout for downy mildew during cool, wet, humid weather. Downy mildew can develop rapidly when temperatures are 45 to 60 degrees F with a relative humidity near 98%, and when the leaves are wet from fog, drizzling rains, or heavy dew.

Plants may become infected with the downy mildew fungus during any stage of growth, but the disease is more of a problem on early-seeded beds and on late-maturing crops when weather conditions are more likely to favor disease development. Downy mildew can also develop in storage.

Symptoms are typically seen first on lower leaves where the plant canopy maintains higher relative humidity. The first symptoms are discolored spots, especially on cotyledons. Later, discrete yellow areas on the upper surface of leaves develop, and occasionally fluffy, white fungal growth on the under-surface can be seen. Irregular black spots develop on broccoli and cabbage leaves in the field and in storage.

**Threshold:** No thresholds have been set for downy mildew. If severe disease pressure is expected, a fungicide can be applied weekly as a protective treatment. Consult A3422 for registered products.

## Clubroot

### *Plasmodiophora brassicae*



© Robert Wick, Univ. of Massachusetts



© Robert Wick, Univ. of Massachusetts

Clubroot may develop extensively on plant roots before the first sign is noticed above-ground. If the soil is moist, above-ground symptoms may not become apparent until water stress occurs, when infected plants wilt and turn yellow. Infected plants may be stunted. Check the roots of plants if you see these symptoms when scouting. When diseased plants are pulled from the soil, the roots are usually swollen and distorted, hence the name club-root.

Root swelling may vary in size from very small swellings on the tap and lateral roots to large club-shaped roots, depending on when the plants became infected. In addition to reducing the plant's ability to take up water and nutrients, the clubbed tissue is highly susceptible to soft rot bacteria.

Field-grown transplants and movement of soil on machinery are the most common ways through which the fungus enters an uninfested field. The fungus is long-lived in soil once present.

**Threshold:** There is no treatment for clubroot once the disease is present. A fungicide may be added to the transplant water as a preventative treatment. See A3422 for current registered products. Crop rotation and maintaining soil pH at 7.2-7.3 can aid in the management of clubroot.

## Bacterial soft rot

### *Pseudomonas and Erwinia spp.*



© Paul Bachi, University of Kentucky, REC

Bacterial soft rot is a watery decay of plant tissue caused by several kinds of bacteria. The first sign of bacterial soft rot is a moist, mushy appearance of infected leaf, flower, or head tissue. The tissue turns light brown and develops a foul odor. Cole crops are susceptible in the field and in storage.

The bacteria that cause soft rot are secondary invaders that require some kind of wound to enter the plant. Wounds caused by insect feeding, mechanical injury, and hail are most common. Monitor plants for signs of soft rot closely during these conditions.



Broccoli heads with depressions in which water collects can become infected by soft rot bacteria in the field. Tipburn in cabbage heads can also lead to infection by soft rot bacteria. Soft rot can occur below-ground, often associated with an infestation of cabbage maggots. Plants appear wilted, stressed, and stunted. When pulled, the roots show mushy, foul-smelling decay where maggots have been feeding.

**Threshold:** There is no treatment for soft rot once the disease is present. Severe losses can be avoided if the disease is identified quickly and steps are taken to prevent spread.



# Disease Management

## In-Season



Cole crop diseases are more effectively prevented than cured. Planting resistant varieties, sanitation, and excluding pathogens from non-infested fields are important IPM strategies for cole crop 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. *Good growing practices are maintained to support crop vigor and resistance to plant disease.*
- ☐ B. *Targeted scouting for specific diseases occurs during susceptible crop growth stages or during periods of conducive weather conditions.*
- ☐ C. *Cole diseases are managed preventatively, using a combination of crop rotation, host resistance, and sanitation to avoid in-season disease problems.*
- ☐ 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 prevent the disease from occurring. For example, if a pathogen is present, then choosing a resistant variety (the host) can effectively prevent the disease. If the pathogen is not present, taking precautions not to introduce it into uninfested fields is a very effective control strategy. You'll find that exclusion is an important tool in managing cole crop diseases.

Many pathogens are opportunistic and will infect plants that are already stressed by poor soil conditions, inadequate fertility, or insect feeding. Providing good growing conditions, particularly good soil conditions, will promote healthy root growth and more resistance to plant disease.

When starting transplants, provide optimum conditions of ventilation, watering, fertility, temperature, and light for growth. Maintain weed-free seedbeds and cold frames to avoid spreading pathogens from weeds to the crop. Transplant or direct- seed

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.



### Quick Note

Pathogens that cause disease in cole crops are mainly fungi and bacteria. Viruses are less common.

## B. Scouting for diseases

Plant diseases are highly dependent on weather conditions. Moist, humid conditions following periods of rainy weather is especially conducive to disease development. Monitor the crop closely for signs of disease during this kind of weather, or when leaves remain wet during periods of high humidity, fog, drizzling rains, or heavy dew. Black rot, black leg, downy mildew, and bacterial soft rots can all develop quickly under these conditions.

In contrast, cabbage yellows, a soil-borne disease, develops rapidly at warmer soil temperatures ranging from 75 to 85 degrees F. Little development occurs below 60 degrees F in early season crops. The root disease called clubroot is more likely to be noticed during warm, dry weather, when the plants are under water stress.



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**Symptoms of cabbage yellows**

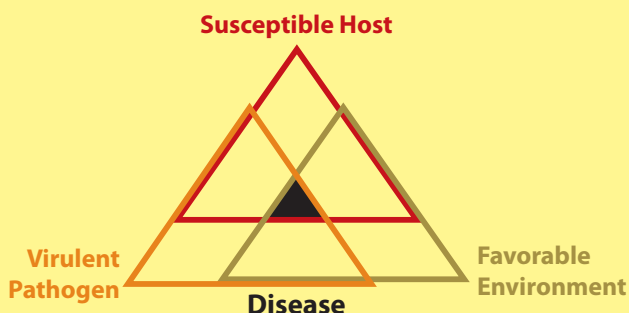
Seedlings are often more susceptible to pathogens than older

plants. Infected seeds can also be the source of infection of serious cole crop diseases such as black rot and black leg. Monitor seedlings closely for signs of these diseases until the crop is well-established.

If purchasing transplants, inspect them carefully for disease symptoms before they are planted. Also look for the presence of diamondback moth larvae and for aphids. Scouting carefully at this stage will

### 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.



prevent spreading these pathogens and pests into uninfested fields. Scout newly-planted fields twice a week. Remove any plants with signs of black rot, black leg, or clubroot.

Soft rot bacteria, black rot, black leg, and clubroot pathogens take advantage of wounds to gain entry into the plant. Be aware of times when wounds might be caused by cabbage maggots or caterpillar feeding, by mechanical injury during field work, or by weather conditions such as cold temperatures or wind-blown soil or hail, and watch carefully for signs of infection.

## C. IPM strategies for cole crop diseases

Diseases of cole crops are much more easily prevented than cured. Fortunately, there are many effective ways to prevent cole crop diseases. Below are the general strategies for disease prevention that should be incorporated into the entire growing season, from pre-plant to harvest. Refer to the table at the end of the section for a summary of IPM strategies for specific cole crop diseases.

### Crop rotation

Crop rotation is one of the most important pest control strategies for cole crops. Most pathogens of cole crops survive in the residues of previous crops. 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 crucifer crop more often than every three years in a field. Plow under debris soon after harvest to allow for rapid and thorough decomposition.

Do not allow volunteer cruciferous crops or cruciferous weeds, such as wild mustards, shepherd's purse, pepper-grasses, or wild radish to grow in rotation years because they can harbor the same pathogens.



*Shepherd's purse*

### Host resistance

Choose resistant cultivars as much as possible, especially if you have had a specific disease problem in the past. Host resistance is the only effective control option for Fusarium yellows. Consult your seed catalogs, seed company representatives, and extension specialists about available resistant cultivars.



*A healthy savoy cabbage*

### Sanitation/Exclusion

Sanitation is the removal of a pathogen from seed, plants, or equipment and is a method of excluding a pathogen from an uninfested field, or preventing it from spreading. It is one of the best ways to prevent disease problems.

Several key pathogens of cole crops such as black rot, black leg, Alternaria leaf spot, anthracnose, cabbage yellows, and downy mildew are spread from field to field on seed. Seedlots should therefore be entirely free of black rot bacteria and other pathogens before planting. Purchase only certified, pathogen-free seed. You can also treat seed with hot water (see section on **Seed Selection**) or buy seed already treated with hot water.

Infected transplants is another way that pathogens enter a field. 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 and for insect pests before planting.



*Transplanting cabbage*

Black rot, black leg, Fusarium yellows, and clubroot are spread from field to field in soil left on equipment. If you know a field is infested with one

### Notes:

There are a few fungicides labeled for cole crops, although not all fungal diseases, such as cabbage yellows or black leg, respond to fungicide application.

If your field has a history of downy mildew and weather conditions are particularly favorable, a protective fungicide may prevent severe disease development. Consult the publication A3422 *Commercial Vegetable Production in Wisconsin* for fungicides currently labeled for downy mildew.




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 in low spots or places where dew dries more slowly. Include insect and weed infestations on the field maps.



Include the variety planted, date 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, how diseases and other pest problems affect your crops, and how to adjust your management practices to minimize damage due to diseases.


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.




## Summary of IPM Strategies for Cole Crop Diseases

Black rot	Preplant	Planting	In-Season/Harvest
<p><i>Xanthomonas campestris</i> pv. <i>Campestris</i></p>  	<p>Use a 3-year rotation away from crucifer crops.</p> <p>Choose a sunny, well-drained location.</p> <p>Eradicate cruciferous weeds.</p> <p>Choose varieties with some level of resistance or tolerance.</p> <p>Buy certified disease-free seed and/or treat seed with hot water.</p> <p>When growing transplants, choose a seedbed or greenhouse at least 1/4 mile from crucifer production fields.</p>	<p>Exclusion is the best way to avoid problems with black rot. Plant only pathogen-free transplants.</p> <p>Do not dip transplants in water prior to transplanting.</p> <p>Maintain balanced soil fertility in both seedbed and field, based on a soil test.</p> <p>Do not share tools between seedbeds and other crucifer crops, or clean carefully.</p>	<p>Be aware that feeding by cabbage root maggots and caterpillars can serve as a point of infection for black rot.</p> <p>Do not work in the fields when plants are wet.</p> <p>Turn under crop debris after harvest so that it decomposes quickly.</p>
Black leg	Preplant	Planting	In-Season/Harvest
<p><i>Phoma lingam</i>: a fungal pathogen</p> 	<p>Use a 4-year crop rotation.</p> <p>Eliminate cruciferous weeds.</p> <p>Buy certified, disease-free seed and/or treat seed with hot water.</p> <p>Choose varieties with some level of resistance or tolerance.</p> <p>Use clean or sterile soil mixes for the seedbed. Use locations free of black leg for outdoor seed beds.</p>	<p>Inspect all greenhouse transplants for stem lesions. Do not plant any plants with signs of disease.</p> <p>Do not dip transplants in water prior to transplanting.</p> <p>Allow for good air movement by planting with wide spacings, in rows parallel to prevailing winds, and not close to hedgerows.</p> <p>Plant later plantings upwind of earlier plantings.</p>	<p>Do not work in the fields when plants are wet.</p> <p>Scout for blackleg. If found, plan preventative strategies for next season.</p> <p>Turn under crop debris after harvest so that it decomposes quickly.</p>


Clubroot	Preplant	Planting	In-Season/Harvest
<p><i>Plasmodiophora brassicae</i></p>  <p>© Robert Wick, Univ. of Massachusetts</p>  <p>© Robert Wick, Univ. of Massachusetts</p>	<p>Eliminate cruciferous weeds in the field and surrounding areas.</p> <p>Use clean or sterile soil mixes for the seedbed. Use clubroot-free locations for outdoor seed beds.</p> <p>Avoid purchasing infected transplants. Buy only from reputable growers as infected transplants cannot always be identified.</p> <p>If compatible with other crops in the rotation, raising the soil pH to 7.2 provides good control in mineral soils.</p> <p>Rotate infested fields out of cole crops for a minimum of 7 years.</p> <p>Discontinue growing in heavily-infested fields.</p>	<p>Use caution to exclude this pathogen from disease-free fields.</p> <p>Discard all plants in a lot if clubroot is found on any seedling. Others may be infected and not yet show symptoms.</p> <p>Do not add hydrated lime in seedbeds, as it may mask the presence of the fungus, and allow it to move with the transplants to the field.</p> <p>A fungicide dip may be used as a preventative treatment for transplants.</p>	<p>In fields with a history of clubroot, scout weekly to determine the level of infection.</p>

Cabbage yellows	Preplant	Planting	In-Season/Harvest
<p><i>Fusarium</i></p>  <p>© Queen's Printer for Ontario, 2009</p>	<p>Choose yellows-resistant varieties.</p> <p>Use clean or sterile soil mixes for the seedbed. Use yellows-free locations for outdoor seed beds.</p> <p>Rotate at least 3 years out of crucifers to prevent buildup of the fungus in the soil.</p>	<p>Use extreme caution to exclude this pathogen from yellows-free fields. Once present it can not be eradicated.</p> <p>Purchase certified, disease-free transplants.</p>	<p>Scout for cabbage yellows. If found, plan preventative strategies for next season.</p> <p>Do not move infested soil into uninfested fields on machinery, tools, or feet.</p> <p>Destroy crop debris after harvest.</p>

Downy mildew	Preplant	Planting	In-Season/Harvest
<p><i>Peronospora parasitica</i></p>  <p>© Dr. Amanda Gevens, UW-Madison</p>	<p>Use a 3-year rotation without crucifer crops.</p> <p>Choose a resistant variety, especially of broccoli and cauliflower.</p> <p>Choose a location with good air circulation and well-drained soil.</p>	<p>Allow for good air movement by planting with wide spacings, in rows parallel to prevailing winds, and not close to hedgerows.</p>	<p>Watch for downy mildew during cool, rainy periods, especially early and late in the season.</p> <p>Fungicides can be applied as a protectant when weather conditions are particularly favorable.</p> <p>Destroy crop debris after harvest.</p>



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Bacterial soft rot	Preplant	Planting	In-Season/Harvest
<p>several bacteria including <i>Pseudomonas</i> and <i>Erwinia</i> spp.</p> 	<p>Choose varieties with some resistance to soft rot. Broccoli varieties with rounded, domed heads are generally less susceptible.</p> <p>Choose a sunny, well-drained location with good air circulation.</p> <p>Rotate with less susceptible crops, such as cereals.</p>	<p>Avoid injury.</p>	<p>Control insect pests. Be aware that insect feeding can lead to soft rot infection.</p> <p>Harvest when heads are tight.</p> <p>Cut stalks at an angle so that water cannot collect on the cut stalk.</p> <p>Remove infected plants from the field or storage areas.</p> <p>Keep storage temperature below 39 degrees F. Provide good air circulation.</p>

# 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.



# Insect Management

## In-Season



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An integrated insect management program is prevention-based. Control strategies are implemented throughout the season—from pre-plant decisions to harvest—and include combinations of 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

Historically, insecticides have been the primary form of insect management for many growers, and many sprays were made according to calendar schedules, not due to the specific presence and populations 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, present at a vulnerable stage of a pest's life cycle, or present during 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.



*Cabbage looper larvae*

© R.J. Reynolds Tobacco Company Slide Set, R.J. Reynolds Tobacco Company

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



*Cabbage maggots*

Chemical controls should only be considered when insect populations have reached or exceeded a level that will cause economic damage if left untreated. This is commonly called the economic threshold level. Economic thresholds have been scientifically established for some pests of cole crops to help commercial growers weigh the costs of their pest management strategies against the potential economic impact of each pest.

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

Quality standards for broccoli, Brussels sprouts, cabbage, and cauliflower vary depending on whether the crop will be used for fresh market or for processing, but in general, very little insect damage is acceptable on the marketed portion of heads (cabbage, Brussels sprouts), flowers (broccoli), or curds (cauliflower). These quality standards make it challenging to manage insect infestations at these critical stages of crop development.

Fortunately, moderate damage or injury from insect feeding can be tolerated if it occurs before cup-

### ★ **Quick Note:**

Selecting cabbage varieties that are tolerant to thrips is the most effective method of controlling thrips.

## B. Determining threshold levels

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

- ▶ cabbage maggot
- ▶ flea beetle
- ▶ three different caterpillar pests (diamondback moth, imported cabbageworm, and cabbage looper)
- ▶ onion thrip
- ▶ aphid

ping, flowering, or curd formation. Thus, there are more options early in the growing season to prevent or reduce populations of pests and to increase the number of beneficial insects before the critical crop growth stages are reached. This is why University of Wisconsin economic thresholds for caterpillar and aphid feeding on fresh market cabbage, broccoli, and cauliflower depends on the growth stage of the plant.



**Diamondback moth larvae feeding**

© Alton N. Sparks, Jr., University of Georgia, Bugwood.org

### UW-recommended treatment thresholds for caterpillar larvae on fresh market cabbage, broccoli, and cauliflower

Crop	Growth stage	Threshold (% plants infested)
<b>Cabbage</b>	Seedbed	10
	Transplant to cupping	30
	Cupping to early head	20
	Mature head	10
<b>Broccoli</b>	Seedbed	10
	Transplant to first flower	50
	Flower bud to harvest	10
<b>Cauliflower</b>	Seedbed	10
	Transplant to first curd	50
	Curd present	10

For aphids, the threshold for broccoli and cauliflower before heading is 100 aphids/plant, and after heading, 5 aphids/plant. Treat cabbage if 1-2% of the plants are infested. Treat brussels sprouts if greater than 40% plants are infested up to 2 weeks before harvest, and at topping, treat if 1 or 2% of plants are infested.

## C. IPM strategies for cole crop 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 controls, and application of insecticides. A summary of current recommended management options for specific insect pests of cole crops is on the following page.

### Cultural control

There are many cultural practices that are effective in keeping insect pests below damaging levels. Choosing varieties with some resistance or tolerance to insect pests, especially onion thrips on cabbage, is highly recommended. Turning under crop residues after harvest and rotating cole crops to different fields each year disrupts the life cycles of many key pests, including cabbage maggots, caterpillar pests, and aphids. The most damaging first generation of the cabbage maggot can be avoided by timing planting for when the adult egg-laying flies are not prevalent. In smaller plantings, row covers are effective in excluding cabbage maggots, flea beetles, and caterpillar larvae.



**Healthy cabbage plant**

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

### Biological control

Biological control occurs regularly in Midwest fields and can be highly effective in controlling populations of insect pests that feed on cole crops. The three caterpillar pests (diamondback moth, imported cabbageworm, and cabbage looper) as well as aphids are all susceptible to parasitism and predation by natural enemies throughout the growing season. To be aware of biological control activity and implement practices



**Lady beetle**

© Frank Pearis



that do not disrupt the activity of natural enemies is an important part of insect management. 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 after crop heading. Selection of treatments depend on the pest species present and their developmental stage.

Bt is often recommended in cole crop production because of its excellent control of caterpillar pests, lasting even through harvest if only small caterpillars are present. *Bacillus thuringiensis*, commonly called Bt, is a naturally-occurring, soil-inhabiting bacterium that is safe for humans but toxic to many insects. There are more than 20 types of Bt, most of which are highly selective against caterpillars. Bt does not directly affect predators or adult wasp parasites and therefore does not disrupt the activity of these beneficial insects. Since the 1950s Bt has become the most widely used microbial insecticide with many different registered products. It is applied in a manner similar to chemical insecticides and is generally most effective on younger, smaller caterpillar larvae. The target insect must ingest Bt for it to be effective.

Another excellent example of a reduced-risk insecticide option in cole crops are the spinosans, classified in the naturalyte class of pest management tools. These products are a mixture of two fermentation-derived products produced by *Saccharopolyspora spinosa*, a bacterial species discovered from a Caribbean soil sample. This material exhibits such a favorable environmental and mammalian toxicity profile that it has been designated a reduced-risk pesticide by the EPA. Spinosad is rapidly degraded in sunlight but stabilized on leaf surfaces. These compounds are quite selectively active on caterpillar pests as well as thrips. Spinosans, with their unique characteristics, fit a product class of their own and offer pest management alternatives with respect to resistance management. These biologically based materials have an excellent combination of contact and residual efficacy on target pests and safety to beneficials, aquatic organisms, and mammals, making them an ideal fit into an Integrated Pest Management program.



### Quick Note:

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

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## D. Impact of insecticides on beneficial species

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



### Quicknote:

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**Insecticide Timing.** Avoid insecticides or choose a reduced-risk material such as Bt earlier in the season when the crop is not greatly affected by insect feeding. This gives natural enemies time to build populations and contribute to control. The more fast-acting, highly effective, broad-spectrum materials should be saved for those applications closer to harvest when strict control may be needed to prevent damage to crop quality.

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## Summary of IPM Strategies for Insect Pests of Cole Crops

Pest	Cultural control	Mechanical control / Exclusion	Host plant resistance	Biological control	Chemical control/ Reduced-risk products
<b>Cabbage maggots</b>	Crop rotation  Time planting to avoid peak adult emergence  Destroy crop residues  Well-drained soil, soil temp 50 degrees F or higher.	In smaller plantings, barriers around transplants to prevent egg-laying  Row covers to exclude adults	Varieties with tolerance are available	Ground beetles feed on eggs and larvae but not enough for complete control.  The commercially-available nematode <i>N. carpocapsae</i> has potential against cabbage maggot.	Soil insecticides applied at planting  Resistant to many insecticides
<b>Flea beetles</b>	Early planting  Weed control	Row covers	None	Not important	Soil and foliar insecticides
<b>Diamond-back moth</b>	Reduced tillage  Control cruciferous weeds	Be cautious that purchased transplants do not harbor larvae	Varieties with thick, glossy leaves are more resistant	Important	Bt and foliar insecticides  Resistance
<b>Imported cabbage-worm</b>	Early planting  Control cruciferous weeds  Residue destruction	Be cautious that purchased transplants do not harbor larvae  Row covers  Handpick in small fields	None	Important	Bt and foliar insecticides
<b>Cabbage looper</b>	Early planting  Cruciferous weed control	Be cautious that purchased transplants do not harbor larvae	None	Somewhat important	Foliar insecticides
<b>Thrips</b>	Field location away from alfalfa, oats, or wheat		Important control strategy	Not important	Foliar insecticides
<b>Aphids</b>	Residue destruction	Rogue infested transplants	None	Important—see Biological Control section	Soil and foliar insecticides Soap

**Notes:**

# Weed Management

## In-Season



© D. Brinard

Weeds can be one of the most challenging problems that a vegetable grower will face. Previous weed history in the field is a good guide with which 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.



© Joseph LaForest

**Wild Mustard**

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. Complete reliance on herbicides, however, can lead to control failure and concerns about weed resistance. Current bioIPM recommendations are to



© Howard F. Schwartz

**Weed competition in cabbage**

combine multiple management strategies that will minimize the risk of control failure and non-target effects of herbicides. Using multiple strategies prevents weed seed build-up and provides season-long control.

If a pre-emergence herbicide is part of your weed management program, use the information you have on previous weed history in that field to help you select an appropriate pre-emergence herbicide. Be aware that herbicide options for cole 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.

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. Weeds that are resistant to an herbicide grow normally even after an application that usually kills the weed. To avoid this problem, rotate herbicides by choosing products with a different mode of action each year.

To help growers choose herbicides with different modes of action, the Environmental Protection Agency (EPA) and the Herbicide Resistance Action Committees (HRAC) have developed a voluntary pesticide labeling proposal that groups pesticides with similar modes of action and designates them with a number. You will also find this information on the herbicide label. Herbicides are each also given a rating on their relative toxicity to mammals, beneficial organisms, bees, and the environment in general.



### Quick Note

Consult A3422 for herbicides currently labeled for cole crops.

## 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

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

## B. Preventative strategies

By far the best management strategy for any weed is to prevent its introduction and dispersal. There are ways in which 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 the how you might reduce the entry of weeds 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 free of weed seed.

Prevention is also important in minimizing the spread of weeds already present on the farm. There are steps you can take before, during, and after the growing season to minimize weed seed production in the field and surrounding field margins. These include:

- ▶ Select sites where weed seed numbers have been reduced through crop rotation, and that are free of very difficult to control perennial weeds such as quackgrass, Canada thistle, or yellow nutsedge.
- ▶ Identify weeds before you till them. Are they annual weeds or perennial weeds? Perennial species can be spread by cutting below-ground tissue.

- ▶ Consider planting and managing a boundary strip around the field margins. Use a non-invasive mix of species that will be highly competitive with weeds and provide habitat for beneficial insects. You might also harvest this boundary strip for hay.
- ▶ Help the crop suppress weeds by partitioning the resources to the crops and not the weeds. For example, band fertilizer near the crop, use drip irrigation rather than broadcast irrigation, and choose vigorous, well-adapted cultivars that can compete with weeds through rapid early season growth.
- ▶ Mulch with synthetic and/or organic materials.
- ▶ Till or mow any remaining weeds after crop harvest but before weeds go to seed.
- ▶ Prevent weed seed production along irrigation canals, reservoirs, and other open water sources.



*Cabbage mulched with straw*

## 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 will be listed on the label. Some products are a combination of more than one active ingredient.
- ▶ Follow herbicide label instructions carefully.
- ▶ 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

Timely cultivation is one of the most effective ways to control annual weeds. 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 small 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.

When planning your cultivation, pay special attention to soil stewardship practices, and never till when the soil is wet and susceptible to compaction. Cultivation is not a good way to control perennial weeds, which have underground plant parts that are cut and spread by tillage.

Many different types of cultivation implements have been developed to control weeds in and/or between rows. Between-row cultivators range 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. The rod weeder is a simple, affordable design of two steel rods, one



**Brush hoe**



**Finger weeder**

© D. Brainhard

© D. Brainhard

on either side of the crop row, that uproots small weeds while pushing the soil into the row.

## D. Weed suppression with mulches

Mulching is covering the ground in between the crop rows with natural or synthetic materials to suppress weeds. When the ground is covered by a mulch, weeds are deprived of light and die out.

Examples of natural, organic materials used to mulch vegetables are wood chips, pine needles, yard waste and leaf debris, and straw. A benefit of using a natural material for mulch is that it adds organic material to the soil and it helps to hold and regulate soil moisture. This can be very beneficial for cole crops as they require a good water supply.

Plastic or polyethylene can also be used as a mulch. These synthetic materials provide excellent control of weeds, except in the hole in which the crop plant is transplanted. Dark plastic will also tend to raise the soil temperature, which promotes crop growth early in the season. A disadvantage is that they need to be removed at the end of the growing season and generally can't be reused.

Living mulches, also known as intercropping, inter-seeding, or strip-mulching, are cover crops planted to out-compete the weeds between the rows of the crop plant. Living mulches are very effective in long-term perennial crops such as fruit orchards or bramble fruit plantings, where the main crop has an advantage of age and size. For small vegetable crops, however, the advantages are not so clear. Sometimes the living mulch deprives the main crop of nutrients, light, and water to such an extent that crop yield suffers.

### Weed control for insect and disease management

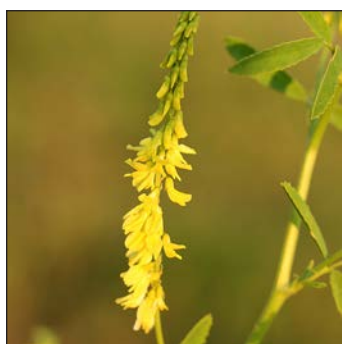
Many cruciferous weeds host the same disease pathogens as cole crops, as well as flea beetles and caterpillar pests. Break pest and disease life cycles by removing weed and volunteer crucifers from fields and surrounding areas during the season and in rotation years. Cruciferous weed include wild mustards, shepherd's purse, and wild radish.

# Soil Fertility and Plant Nutrition

## In-Season



Cole 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. Follow the University of Wisconsin research-based nutrient recommendations for cole crops.



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

- ☐ **A. Fertilizer 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. Long-season crops such as cabbage and Brussel sprouts receive split applications of nitrogen.**
- ☐ **D. Practices that maintain or build soil organic matter levels are implemented.**

# A. Plant nutrition & fertilization

Cole crops are high nutrient demand crops and do best when soil fertility is high. Proper fertilization is essential for vigorous early season growth. Proper fertilization also improves plant resistance to pests and diseases and provides a competitive advantage for the crop against weeds. The University of Wisconsin provides guidelines for nutrient applications for cole 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 does not only represent an economic loss to your cropping system, but can also cause unneeded nutrients to enter surface and groundwater. Over application of fertilizer can also damage the crop. For example, excessive nitrogen can cause tip burn in cabbage.

The University of Wisconsin has produced research-based fertilizer recommendations for cole crops. University of Wisconsin guidelines for P and K applications on cole crops are based entirely on soil test P and K levels. Soil testing every 2 to 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 only a general indication of how much N the soil will supply (<2%, typical on sandy soils; 2-10%, common for most mineral soils; <10% for muck, peat, or organic soils). Research has been conducted across these soil organic matter concentration gradients.



## Quick Note

UW fertilizer recommendations are based on the crop demand for P and K in a single season, minus the amount already in the soil and the amount expected to be supplied by the subsoil of your soil type. In this way, just the right amount of fertilizer is added each year.

# B. Using soil tests and nutrient recommendations

Inorganic (or commercial) and organic fertilizers (or manures) can be used for cole crop production. Inorganic fertilizers are sometimes called chemical fertilizers because they are produced in an industrial manufacturing process. Inorganic fertilizers often contain higher concentrations of nutrients compared to organic fertilizers, thus, 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 micro-

**Annual Phosphorus fertilizer application rate guidelines for cole 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

Soil Test Level						
Crop	Yield goal	Very low	Low	Optimum	High	Excessively High
Broccoli	4 - 6 t/a	85	60	10	5	0
Brussels sprouts	4 - 6 t/a	90	65	15	10	0
Cabbage	8 - 12 t/a	90	65	15	10	0
Cauliflower	6 - 8 t/a	95	70	20	10	0



organisms 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 from species to 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.

### Micronutrients

Cole crops have medium to relatively high boron requirements and medium requirements for copper and manganese. Biologically active soils with adequate organic matter usually supply enough of these nutrients. Have the soil tested for these elements when growing cole crops for the first time. If the boron test level is very low or low, consult A3422 *Commercial Vegetable Production in Wisconsin* for current recommendations.

### Annual Nitrogen (N) recommendations for cole 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

	Organic matter (%)	Amount to apply
<b>Broccoli</b>	Less than 2	100
	2.0 – 9.9	80
	10 – 20	60
	> 20	25
<b>Brussels sprouts</b>	<2	100
	2.0 – 9.9	80
	10 – 20	60
	> 20	25
<b>Cabbage</b>	<2	180
	2.0 – 9.9	140
	10 – 20	100
	> 20	40
<b>Cauliflower</b>	<2	120
	2.0 – 9.9	100
	10 – 20	80
	>20	40

### Annual Potassium fertilizer application rate guidelines for cole 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

Crop	Yield goal	Soil Test Level					
		Very low <sup>1</sup>	Low <sup>1</sup>	Optimum	High	Very High	Excessively High
Broccoli	4 - 6 t/a	140,165	100,125	40	20	10	0
Brussels sprouts	4 - 6 t/a	145,170	105,130	45	25	10	0
Cabbage	8 - 12 t/a	170,195	130,155	70	35	20	0
Cauliflower	6 - 8 t/a	150,175	110, 135	50	25	15	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.

## C. Split-season applications of nutrients

On long-season crops such as cabbage grown for storage and Brussels sprouts, split the nitrogen applications. Apply half at planting, and side-dress the remainder in midseason.



*Maturing brussels sprouts*

The other cole crops have relatively short growing seasons and should receive all their nitrogen at planting. If the soil is sandy, however, split the nitrogen into two or more applications during the season. Split-applying nutrients, especially N, will improve the nutrient use efficiency of the system. More N will be taken up by the plant per unit N applied.

## D. Organic soil amendments and cover crops

### Manure and composts

Cow, sheep, horse, 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 main nutrients N, P, K as well as micronutrients.

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 becomes more fertile.



*Spreading manure*

The nutrient contribution of organic amendments can and should be calculated towards the total nutrient budget for the cole 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 would become excessive. These materials should there-

fore 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.

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 sowing a cover crop, often a legume, in early spring and tilling it in the next spring. It was once the conventional method of supplying nitrogen to crops and was widely practiced before inexpensive commercial nitrogen fertilizer became available. It is a more balanced way to provide nitrogen to the subsequent crop than the application of composted manure or other organic materials, and is also an excellent soil builder. 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



*Sweet clover flowerhead*

(*Trifolium alexandrinum*) are other legume cover crops well-adapted to Wisconsin conditions. Grass and grain crops such as ryegrass or oats are productive soil builders because of their extensive root system, and they can capture excess nitrogen in the soil at the end of the season, thereby minimizing nitrogen leaching over the winter.

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 comparatively little time to grow than 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*. The UW soil testing lab 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 insure 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 soil/seed contact. Legume seed needs good soil/seed 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.

### 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.

**Notes:**



# 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 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 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 organism then has the genetic potential to pass along the resistant traits to future generations.

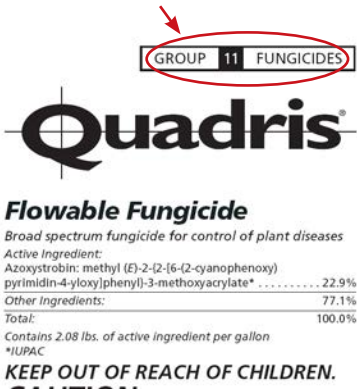
Pesticides all have a specific way in which they affect pests. This is known as the pesticide's mode of action. When resistance develops, it is to the particular mode of action of that pesticide. The genetic alterations that create resistant populations occur most rapidly when pesticides with similar modes of action are applied in consecutive sprays, in a single season, over successive generations, or over several seasons. Therefore, it is essential to not 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-resistant biotypes.

Notes:

# 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:** Cabbage maggot, diamondback moth, cabbage looper, imported cabbage-worm, onion thrips

**Diseases:** Downy mildew

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

## C. Resistance management strategies

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
- ▶ 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.



### Quick Note

Diamondback moth populations have developed resistance to synthetic pyrethroids, organophosphates, carbamate, spinosyns, and Bt products in some southern states. This is thought to be due to frequent use of single insecticide classes or insecticides over time, coupled with nearly continuous production of cabbage in isolated areas, especially in Florida and Georgia.



*Diamondback moth larvae*

## 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:**



# 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 cole 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 cole 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 cole 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 occur abundantly in cropland and provide a significant amount of 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 them at levels where they cause 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 treated, the outcome can be a secondary pest outbreak. 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*

You may want to consider augmenting the natural population of beneficial insects by purchasing and releasing additional beneficial insects into the field. There are companies that grow and supply natural enemies, including some specifically for cole crop pests.



*Commercially packaged Green lacewing larvae*

© Joseph LaForest, University of Georgia

### Conserving the natural enemies in your fields

- Reduce the impact of insecticide sprays by spot-treating, banding, timing treatments carefully, and choosing compounds with low toxicity and short persistence.
- Avoid or minimize the use of broad-spectrum insecticides, especially early in the season.
- Plant or preserve early-flowering species with a high pollen load to provide a food source during late spring before the build-up of aphids.
- Maintain plantings that provide nectar, pollen, alternate hosts, and humid resting places in or near the field. Any noninvasive mix of plants that include flowering plants and will be competitive with weeds will be beneficial.
- Maintain overwintering sites for beneficials on the border of fields.



*Goldenrod in bloom*

© Mary Ellen Harte

## B. Common beneficial insects

Natural enemies of insect pests fall into three categories: general predatory insects, parasitic insects, and insect pathogens (fungi, bacteria or nematodes).

**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, and lady beetles are examples of predatory insects. Most predators are fairly mobile and can search for their prey. Many predators are active in their immature larval or nymph stage and adults. You and your scout will learn to recognize common predatory insects in both their immature and adult stages.



*Damsel bug*

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.

Some of the most effective natural enemies, however, are tiny and easily overlooked.

These are the **insect parasites**, also called parasitoids, which are often tiny, non-stinging wasps. Parasitic wasps are free-living in the adult stage, but are parasitic on specific insects in the larval stage. Eggs are laid in the host, and the parasitic larvae eat their hosts 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*

© Ken Gray, Oregon State University

populations in check, especially those of aphids and caterpillar pests. For example, a tiny stingless wasp called *Diadegma insulare* parasitizes older larvae of the diamondback moth and causes a high mortality rate of diamondback moths in the upper Midwest. In Wisconsin, they parasitized 53-88% of caterpillars collected from cabbage in a four-year study.

**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.



*A fungal-parasitized aphid*

© Bill Stoneman

Fungi that attack insect pests are called entomophagous fungi and are fairly common. Under rainy, humid conditions, death caused by fungal infection can be a mortality factor for caterpillar larvae and aphids. Under some conditions, entire aphid populations can be wiped out. Most of the time, however, infection does not occur early enough or often enough to be an important control agent. Fungicide sprays may kill insect-infecting fungi.

Insect-specific viruses can be effective natural controls of caterpillar pests, including the cabbage looper and imported cabbageworm. In some years, the combination of virus diseases and predation or parasitism can deplete the pest population.

### Biological control information

Much of the information in this chapter is from the comprehensive manual called *Biological Control of Insect Pests of Cabbage and Other Crucifers* (NCR 471). This research-based manual describes in detail, with color photos, the natural enemies of cole crop pests in the upper Midwest and how to make effective use of them. Another excellent reference is *Biological Control of Insects and Mites: An introduction to beneficial natural enemies and their use in pest management* (A3842).

Parasites often prefer a specific host insect. Their activity can be very effective in keeping pest



## Common Predators of Insect Pests in Cole Crops

Most predatory insects are called generalist predators because they feed on a wide variety of insects, rather than on a few specific species. Aphids; diamondback moth eggs, and larvae; imported cabbageworm eggs, larvae, and pupae; cabbage looper eggs, and young larvae; and the eggs, larvae, and pupae of the cabbage maggot are important prey for generalist predators.

You and your scout should learn to recognize the presence of these beneficial insects. Note that some of them are active in both the larval and the adult stages.

### 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 cole crops in the upper Midwest. Other common species include the twelve-spotted lady beetle, *Coleomegilla maculata*, and the seven-spotted lady beetle, *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 lady beetle as well as the adult. Larvae are active, black, elongate 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**

© David Cappaert, Michigan State Univ.



**Hover fly larvae**

© Clemson University - USDA Cooperative Extension Slide Series

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 cole 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 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



**Green lacewing larvae**

© Whitney Cranshaw, Colorado State Univ.

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 actually 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.

Lacewings are usually supplied as eggs, but also larvae or adults. Eggs are shipped in a carrier material, which makes it easier to distribute 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.

## Spined soldier bug

### *Podisus maculiventris*



© Russ Ottens, University of Georgia

The spined soldier bug is reddish brown with two short spines sticking out from the middle edges of its shield-like body. It is a common predator of caterpillars and caterpillar eggs in cole crops. The nymphs look similar to the adults, and are also active predators. One nymph may consume as many as 360 host eggs during its development.

**Availability for release:** The spined soldier bug is available commercially. The suggested release rate is five nymphs for every foot of row. Release when caterpillar larvae are peaking.

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

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



**Damsel bug**

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 bug**

© Bradley Higbee

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 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.



**Minute pirate bug**

© John Ruberson, University of Georgia

**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.

## Parasites of Cole Crop Pests

One of the most important groups of natural enemies are the parasitic wasps. Because they are so tiny (some are the size of a pinhead), you will probably never notice them in the field. You can, however, learn to recognize the signs of their activity. Learn to tell the difference between healthy and parasitized eggs, larvae, or pupae of insect pests, which may mean that biological control is active and working. Be aware of these signs when you scout.

### *Diadegma insulare*



**Parasitized diamondback moth pupae**

© Ken Gray, Oregon State University

*Diadegma insulare* is the most important parasitoid of the diamondback moth in the upper Midwest. It parasitizes older larvae of the diamondback moth by laying a single egg in the caterpillar. When the caterpillar pupates, it turns black instead of light-colored. Look for parasitized pupae when scouting. Parasitism is often greater than 75% in the field and is often sufficient to keep diamondback moth populations in check unless disrupted by the use of a broad spectrum insecticide.

**Availability for release:** Pre-fed fertile adults are available commercially. Weekly releases should begin early in the season when moths are present and pest egg laying is occurring.

### *Diaeretiella rapae*



**Aphid mummy**

© Dan Mahr, UW-Madison

This tiny wasp is the most important parasite of the cabbage aphid. 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.

### *Trichogramma*



***Trichogramma* parasitizing an egg**

© Ties Huigens and Hans Smid

These almost microscopic wasps parasitize the eggs of the cabbage looper, imported cabbageworm, and other caterpillars. They are particularly effective because they kill their hosts before the insects can cause plant damage. Adult wasps are too tiny to be noticed, but the parasitized caterpillar egg turns black as the larval parasite grows in it. Natural parasitism is thought to be about 20% in this area, but this can be increased greatly by timed introduction of commercially available *Trichogramma* species. The short life cycle of 8-10 days allows the wasp population to increase rapidly.

**Availability for release:** *Trichogramma* is available inexpensively from suppliers. The most suitable species available for release is probably *T. pretiosum*, although results can vary with species and strains. Releases should begin at the time of the first moth flight, before the pest population builds up. Regular scouting to determine the presence of caterpillar eggs is an accurate method to determine when hosts for *Trichogramma* are present. Frequent releases over several weeks result in better parasitism and control than a single large release.

**see parasitized egg photo in section D.**



## Biological control of key cole crop pests

In crucifers, four key pests (diamondback moths, cabbage loopers, imported cabbage worms, and aphids) have natural enemies in the field that are capable of keeping them below economic levels for much of the growing season.

**Cabbage aphid:** The cabbage aphid has numerous natural enemies, including parasitic wasps, fungal pathogens, and generalist predators such as ladybird beetles, syrphid fly larvae, and lacewing larvae. Natural enemies are often numerous enough to keep cabbage aphid infestations below economic levels. The most effective control agent varies according to environmental conditions. In some cases wasp parasites are the most effective, at other times predators, especially syrphid fly larvae, weather conditions, or fungi might cause the most mortality. In general, predators and fungal pathogens are favored by wet weather, which is unfavorable to the aphid.



**Cabbage aphids**

© Dr. Amanda Gevens, UW-Madison

### Diamondback moth:

Natural parasitism by parasitic wasps is often sufficient to suppress diamondback moth populations, especially later in the season. Releases of the most important parasite *Diadegma insulare*, can suppress caterpillar populations if natural populations provide insufficient control. The microbial pesticide Bt is very effective in controlling diamondback moths. Predatory insects feed on diamondback moth larvae each year but are generally not important in reducing populations of this pest.



**Diamondback moth larvae**

© Russ Olfens, University of Georgia

**Imported Cabbageworm:** Eggs, larvae, and pupae of the imported cabbageworm are susceptible to predation by common beneficial insects. The caterpillars are also parasitized by several native species of parasitic wasps, though none are

present in high enough populations to provide economic control of the pest. Practices to conserve natural enemies might improve natural control, and augmenting natural control with carefully-timed supplemental releases of parasites can be effective. Insect-specific viruses can be highly effective natural controls, and in some years the combination of naturally-occurring viruses and other natural enemies will maintain imported cabbageworm populations at acceptable levels.



**Parasitized imported cabbageworm pupae**

### Cabbage Looper:

Predation by lady beetles, as well as syrphid fly larvae, lacewing larvae, minute pirate bugs, and ground beetles, provides control of the cabbage looper, except when the preferred aphid is present. Natural parasitism of looper eggs by the parasite



**Cabbage looper**

© David Cappaert, Michigan State Univ.

Trichogramma and other parasitic species occurs each year, but the parasitism rate usually remains below 20%. Supplemental releases may be effective in increasing parasitism rate. Naturally-occurring virus diseases can be highly effective natural controls of cabbage looper in some years, especially in combination with other natural enemies.

**Cabbage Maggot:** Numerous parasites and predators also attack cabbage maggots, though control of this pest is usually moderate in the upper Midwest. Still, careful consideration of pesticide use for this insect is important in order to preserve natural enemy abundance and activity. Thrips and flea beetles have few natural enemies and are not appreciably controlled by beneficial insects in the field.



**Cabbage maggot larvae**



## C. Scouting for beneficial species

When scouting, examine caterpillars and their eggs, larvae, and pupae for signs of parasitism and disease. Learn to recognize the difference between healthy and parasitized or diseased pests. Parasitized eggs and pupae generally look dark from the parasite larvae rather than the healthy light color. Diseased caterpillars that are infected by viruses may turn white and granular or very dark. Some may stop feeding, become limp, and hang from the upper leaves or stems, hence the common name “caterpillar wilt”.

Check for and count aphid mummies (parasitized aphids) on the undersides of the leaves. Parasitized aphids slowly decline, turning tan or brown. The presence of 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 the dead bodies.



*Aphid mummies*

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



*Adult lady beetle*

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 carefully timed chemical controls.

## D. Conserving and releasing beneficial species

Providing food, water, and shelter for natural enemies will encourage them to stay in the crop area to feed and reproduce. Beneficial insects often need an alternate food supply in addition to the pest prey. Many natural enemies, including the adult lacewing and minute pirate bug, must have a source of nectar, pollen, or honeydew on which to feed in the general vicinity of the pest. This will stimulate egg laying in the crop.

A more diverse landscape tends to harbor many more natural enemies than a large-area monoculture because it offers more food, water, and shelter to beneficials. Consider how you might supply these resources near your fields. Small patches of unmowed grass and flowering plants can provide a food source as well as sheltered, humid spots where beneficial insects can hide during the day without dehydration. A managed boundary around fields is also a good way to control weeds and provide overwintering sites for beneficials.



*A meadow offers diverse habitat for beneficials*

### Augmentation biological control (release)

You may want to consider augmenting the natural population of beneficial insects by purchasing and releasing additional beneficial insects into the field. There are companies that grow and supply natural enemies, including some specific for cole crop pests.

For example, timely releases of the caterpillar egg parasites *Trichogramma pretiosum* or *Cotesia marginiventris* have provided effective control of imported cabbageworm and the cabbage looper as long as releases are made



*Trichogramma parasitized egg*

Green lacewings are available from many commercial suppliers and can be extremely effective predators of aphids and caterpillar larvae under certain conditions. Lacewings are usually supplied as eggs, but they can also



or adults. 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.

### Notes:

[illegible]

# Harvest and Storage

Harvest

Post-harvest



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



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 injury.**
- ☐ **C. Optimal storage temperatures and humidity are maintained to maximize shelf life and avoid post-harvest diseases.**
- ☐ **D. Storage conditions are managed to prevent injury from ethylene.**



## A. Signs of crop maturity

Harvesting vegetables at the proper maturity greatly influences their market quality and shelf life.

Learn to recognize the signs of a mature, quality crop. Generally, cole crops are harvested by judging the feel and the size of the head. Instruct pickers how to select for maturity, and caution against rough handling of the crop during harvesting.

### Broccoli

Broccoli is harvested when the heads are firm and well-developed, but the individual florets have not yet begun to open. The average head size should be about 4-6 inches in diameter. Good quality broccoli should have dark or bright green closed florets. Harvest the heads with about four inches of stem attached. Cut sprouting broccoli just below the head to stimulate the growth of new shoots.



*Well-developed broccoli head*

### Brussels sprouts

Brussels sprouts are the compact vegetative buds that develop along the stem of the Brussels sprouts plant. They should be harvested when the buds are about 1 to one and three quarter inches in diameter and firm, but not over-mature, which is indicated by splitting of the outer leaves. Good quality Brussels sprouts should be bright green, without yellowing or discoloration, and should have a firm texture. Brussels sprouts become sweeter and more flavorful if harvested after frost. If you want to prolong the harvest, cut the top three inches off the top of the plants about three weeks before harvest.



*Mature Brussels sprouts*

### Cabbage

Cabbage is ready for harvest when the heads are firm. A compact, mature head can be only slightly

compressed with moderate hand pressure. A very loose head is immature. Quality cabbage heads should be firm, heavy for their size, and free of insects, decay, or any seed stalk development. The leaves should be crisp and turgid.

Cut the cabbage stalk flat and as close to the head as possible, yet long enough to retain two to four wrapper leaves. The extra leaves act as cushions during handling. Remove leaves that are yellowed, damaged, or diseased. Discard heads that are damaged by insects. Cabbage fields may be harvested several times. Be careful not to damage the unharvested cabbage.



*Cabbage ready for harvest*

### Cauliflower

Mature cauliflower curds are firm, white to creamy white, and surrounded by a crown of turgid green leaves. Loose or protruding floral parts, creating a 'ricey' appearance, are a sign of over-maturity. Harvest when the curds are tight and compact and still surrounded by healthy wrapper leaves. Harvest with enough wrapper leaves to keep the head intact.



*Harvested cauliflower*

©Doug Wilson

### Kohlrabi

Kohlrabi should be harvested when the stems are one and one-half to 2 inches in diameter with a bright green or purple color. The flavor is mild and sweet when harvested before the bulb gets tough. Cut the kohlrabi stem just below the bulb. The lower leaves should be healthy and remain on the tuber after harvest.



*Mature kohlrabi bulb*



## B. Harvesting procedures

Harvest broccoli, cabbage, cauliflower, and kohlrabi by bending the head to one side and cutting it with a sharp knife. Keep harvesting knives sharpened to reduce effort and lessen fatigue. The head should not be removed by snapping or twisting it because this practice can damage the head and create an uneven stalk length. Broken stalks are more susceptible to decay than cleanly-cut stalks.

Brussels sprouts, broccoli and cabbage can be harvested in one harvest or over several harvests. Cut the Brussels sprout plants at the base and transfer to a shed where the sprouts can be removed, or market the entire stem with the buds attached.



*Harvested broccoli*

Harvest cole crops with care—rough handling at harvest can damage the florets, heads, and buds and increase decay. Cauliflower in particular should be harvested with great care to prevent damage to the highly-sensitive curds. Bruising occurs easily with cauliflower and can lead to rapid browning and decay. Do not handle by the curd portion of the head. Cabbage that has been handled carefully can be stored for weeks or even months longer than badly-bruised cabbage.

Keep the crop in the shade during harvesting to prevent moisture loss. Hydrocool the crop by submerging in a cool water bath for a few minutes immediately after harvest. This helps the crop retain its fresh, crisp taste. Dry the crop on screen tables and pack into waxed cardboard boxes. Maintain high humidity and provide evaporative cooling by lining the box with a clean, damp cloth. Because Brussels sprouts are harvested in cool weather, they generally do not require hydro-cooling. Get all crops into cooled storage facilities as soon as possible.



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### 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.

## 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. Broccoli, cauliflower, and Brussels sprouts have the highest respiration rates. Cabbage’s respiration rate is slightly lower. Storing produce under refrigeration helps to slow respiration rates, which is why hydrocooling 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

Most cole crops are susceptible to decay caused by a number of common pathogens. These pathogens are common in the environment, but many of them need an entryway through a wound or injury to infect the plant. Therefore, avoiding injury is a good way to prevent post-harvest decay. Trimming outer leaves, keeping the crop cool during and after harvest, and maintaining low storage temperatures are other good prevention methods.

The most common decay-causing pathogens of cole crops are bacterial soft rots caused by various bacterial species including *Erwinia*, *Pseudomonas*, and *Xanthomonas*.



Soft rot on broccoli

Bacterial soft-rots cause a slimy breakdown of the infected tissue. The fungi *Botrytis cinerea* (gray mold), and *Alternaria spp* (alternaria leaf spot) can also cause a mold or leaf spot decay on harvested produce. 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. 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.

Broccoli and cauliflower are extremely sensitive to exposure to ethylene. Floret yellowing is the most common symptom in broccoli. Exposure to 2 parts per million ethylene at 50 degrees F reduces the shelf-life of broccoli by 50%. In cauliflower, ethylene causes a discoloration of the curd and yellowing and detachment of the wrapper leaf stalks. Cabbage is also sensitive to ethylene which will cause the leaves to yellow.



©Doug Wilson

Cauliflower is extremely sensitive to ethylene

Adequate ventilation during storage is important to maintain very low ethylene levels. Tomatoes, apples, melons, and bananas are examples of fruit that produce high amounts of ethylene. Do not mix loads of apples, melons, or tomatoes with cauliflower, broccoli, or cabbage.

Optimum storage conditions for harvested cole crops

Crop	Temp degrees F	Relative humidity	Storage time	Notes
Broccoli	40	95 -100%	14 days	Broccoli must be rapidly cooled after harvest. Heads can yellow if temperatures are too high. Some broccoli cultivars store better than others.
	50	95 -100%	5 days	
Brussels sprouts	40	95 -100%	10 days	Brussels sprouts will remain in good condition for 1-2 days in cool weather without hydrocooling or refrigeration. If stored too long, the outer leaves become yellow and bitterness develops.
Cabbage	40	95 -100%	5 days	With hydrocooling but no refrigeration, cabbage will keep for one day.
Cauliflower	40	95 -100%	5 days	Cauliflower is prone to post-harvest diseases, particularly in combination with rough handling and poor temperature control.
Kohlrabi	40	95 -100%	5 days	Kohlrabi keeps in good condition for one day without refrigeration.

# Bacterial Soft Rot

*Pseudomonas, Erwinia & other bacteria*

peak activity

April

May

June

July

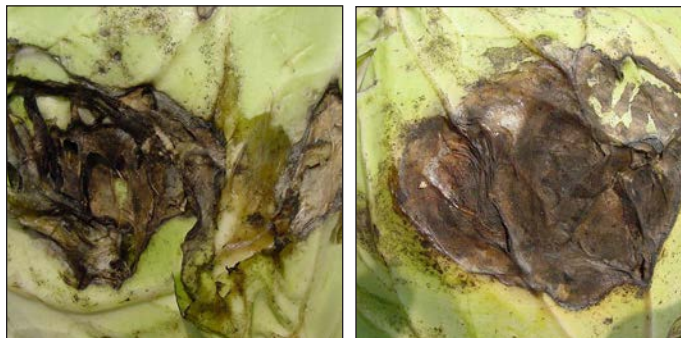
August

September

October

Bacterial soft rot is a common disease that affects many vegetables and can cause serious losses in the field, in transit, and in storage. The bacteria that cause soft rot are secondary invaders that require some kind of wound to enter the plant. Wounds caused by insect feeding, mechanical injury, or hail are most common. In cole crops, soft rot bacteria can infect below-ground plant parts and is often found together with an infestation of cabbage maggots. Infected plants appear wilted, stressed, and stunted. When dug, the roots have a mushy, foul-smelling decay along the maggot tunnels.

Soft rot bacteria survive in plant residues, in the soil, on contaminated equipment and containers, and on insects such as the cabbage maggot. They are spread by direct contact, hands, tools, splashing rain or irrigation, and insect feeding. Once the bacteria gain entry to plant tissue, they multiply rapidly and liquefy all surrounding tissue. Severe losses can be avoided if the disease is identified quickly and steps are taken to prevent spread.



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**Bacterial soft rot can cause serious losses in the field, in transit, and in storage.**

**Scouting:** When walking fields, look for signs of soft rot. Monitor closely during periods of insect feeding and disease outbreaks, or if mechanical injury or hail has occurred, as these can provide the wounds needed for the bacteria to enter the host. Broccoli heads with depressions where water collects can become infected by soft rot bacteria in the field.

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

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

## Management Strategies

### Cultural control

- ▶ Choose varieties with some resistance to soft rot and other cole crop diseases. Broccoli varieties with rounded, domed heads are generally less susceptible to soft rot.
- ▶ Grow crucifers in a sunny, well-drained location with good air circulation.
- ▶ Rotate with less susceptible crops, such as cereals.
- ▶ Avoid plant injury.
- ▶ Control other insects and diseases that provide a source of entry.
- ▶ Harvest when heads are tight.
- ▶ Cut stalks at an angle so that water cannot collect on the cut stalk.
- ▶ Discard plants that have been bruised or wounded, or have signs of soft rot.
- ▶ Keep storage temperature below 39 degrees F. Provide good air circulation.
- ▶ Practice good sanitation in storage facilities. Remove all debris from the warehouse, and disinfect walls and containers.

### Chemical control

- ▶ None recommended.



# Black Leg *Phoma lingam*

peak activity

April

May

June

July

August

September

October

Black leg is caused by a fungus that can infect plants in the seed bed or in the field at anytime during the growing season. Once a very destructive disease, black leg can now be controlled by crop rotation and using disease-free transplants and seed.

The most serious symptom of black leg occurs on the stem near the soil line where elongated, sunken, brown lesions form. These lesions may girdle the stem, resulting in stunting, wilting, and general poor growth of the plant. Later, leaf spots and root rot can develop.

The black leg fungus survives in seed, crop debris, and weeds, especially cruciferous weeds. It is commonly introduced into a field on contaminated seed or transplants. Cool, moist conditions favor disease development and spread. Spores are spread with splashing water and can be blown long distances on wind currents.



**Black leg is a fungal disease that causes leaf spots, girdling of the stems, and root rot. The fungus survives in crop debris or infected seed.**

**Scouting:** Inspect seedlings and transplants twice weekly, removing and destroying plants with signs of infection. On seedlings, the first symptom is usually a circular, sunken canker at the base of the stem that eventually girdles the stem.

Leaves of infected older plants may have yellow to brown circular spots with grey centers and purplish borders. More important are the stem lesions or cankers formed just below the soil line. If the stem lesions enlarge, the stem may break and cause the plant to fall over. The fungus damages the water-conducting tissue, and blackened streaks can be seen by cutting open the stem.

With a 10X hand lens, you may find tiny, black bodies called pycnidia in the leaf or stem lesions. They contain millions of spores of the pathogen which spread during wet weather.

**Threshold:** There are no treatments for black leg once the disease is present.

## Management Strategies

### Cultural control

- ▶ Choose a sunny site where dew dries quickly. Allow for good air movement by planting with wide spacing, in rows parallel to prevailing winds, and not close to hedgerows.
- ▶ Practice crop rotation; rotate fields out of cruciferous crops for at least 2 years.
- ▶ Plow under debris after harvest to allow for more rapid and thorough decomposition.
- ▶ Remove cruciferous weeds and volunteer plants that may harbor the pathogen.
- ▶ Buy only certified pathogen-free seed.
- ▶ Soaking seeds in hot water at 122 degrees F (50 degrees C) for 25-30 minutes can reduce seed-borne blackleg. However, seed may be damaged and germination rates reduced by hot water treatment.
- ▶ Plant resistant varieties if available.
- ▶ Inspect all greenhouse transplants for stem lesions before transplanting to the field. Do not plant any seedlings with signs of blackleg.
- ▶ Plant later plantings upwind of earlier plantings.
- ▶ Do not work in the fields when plants are wet.
- ▶ Rogue out infected plants to slow the progress of the disease.

### Chemical control

- ▶ None recommended.



# Black Rot *Xanthomonas campestris*

peak activity

April

May

June

July

August

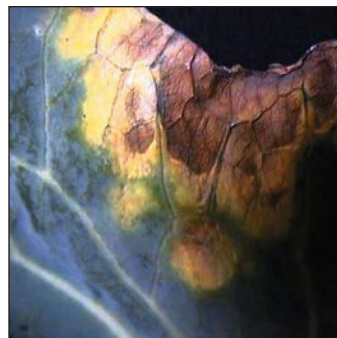
September

October

Black rot is a destructive bacterial disease that can infect all crucifers, but cabbage and cauliflower are the most common hosts. Losses from black rot are typically less than 10% in the upper Midwest, but under ideal conditions, when warm, humid weather follows periods of rain, the disease can spread quickly and is capable of destroying an entire crop. As little as one infected plant in 10,000 can result in a field epidemic.

Black rot is mainly a disease of above-ground plant parts, which can become infected at any stage of growth. Seedlings infected from contaminated seed turn yellow and may die. Infections later in the season provide wounds that other rot organisms use to enter the plant and cause significant damage during storage.

The bacterial pathogen is introduced into fields on contaminated seeds or infected transplants. Once present, the bacteria survive in the soil, on infested plant debris, and on weed seed and weed plants. Black rot spreads rapidly during warm, humid weather when temperatures are greater than 80 degrees F and the humidity is high, and can spread up to 100 feet from an infected to a healthy plant. That is why identifying and removing infected plants and providing good weed control within fields and around fields is good preventative strategy.



**Any yellowing plants or plants with V-shaped lesions should not be transplanted, as they could be a source of bacteria that can spread throughout the field.**

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**Scouting:** Monitor seedlings carefully for signs of black rot. Leaves may be affected on only one side of a seedling. Dark spots and blackened veins sometimes develop on cotyledons. Rogue out infected plants. Infected seedlings grown in the greenhouse under cool conditions (below 60-65 degrees F) often do not show any symptoms of the disease, but will worsen when the weather warms up.

A diagnostic symptom to look for in older plants is the presence of "V"-shaped yellow or brown lesions or patches along the margins of leaves. As the lesion develops, the tissue turns brown and the small veins become blackened. If the leaf is held up against the light and the veins stand out black, it is probably black rot.

In cauliflower, the water conducting vessels of the stem and head can become blackened, leaving the head small and unmarketable. Infected cauliflower curds turn brown, but this symptom is not diagnostic because soft rot bacteria can cause similar symptoms.

**Threshold:** There are no treatments for black rot once the disease is present.

## Management Strategies

### Cultural control

- ▶ Choose a well-drained site in a sunny location. Select fields that will not receive run-off water from areas or fields where crucifers have been grown previously.
- ▶ Use a 3-year rotation away from crucifer crops.
- ▶ Practice good weed control in fields, ditches, and field margins, particularly cruciferous weeds.
- ▶ Plant resistant cabbage cultivars if available.
- ▶ Plant only certified, pathogen-free seed (no more than 1 in 30,000 seeds is infected).

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- ▶ Soaking seeds in hot water at 122 degrees F (50 degrees C) for 25-30 minutes can reduce seed-borne black rot. However, seed may be damaged and germination rates reduced by hot water treatment.
- ▶ Grow transplants in seed beds or greenhouses at least one-quarter mile from crucifer production fields. Practice excellent greenhouse sanitation. Disinfect all surfaces. Do not share tools between seedbeds or clean them carefully.
- ▶ Do not transplant any yellowing plants or plants with V-shaped lesions to the field.
- ▶ Do not dip transplants in water prior to transplanting.
- ▶ Be aware that feeding by cabbage root maggots and caterpillars can serve as a point of infection for black rot.
- ▶ Do not work in the fields when plants are wet. Avoid overhead irrigation.
- ▶ Turn under crop debris after harvest, and allow it to decompose completely before planting to a cole crop.

#### **Chemical control**

- ▶ None recommended.



***Black rot bacteria can spread to nearly 100 feet from infected plants (including weed hosts) to healthy plants.***



***Black rot is usually introduced to a farm through infected seed or transplants. Use disease-free seed and inspect all transplants for black rot before planting.***

# Cabbage Yellows *Fusarium oxysporum* f.sp.conglutinans

peak activity occurs during period of hot, dry weather

April	May	June	July	August	September	October
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Cabbage yellows, also known as Fusarium wilt, is a wilt disease that affects all cole crops, but tends to be the most serious on cabbage. It is caused by a fungus that is spread easily through the movement of soil adhering to farm equipment, tools, and feet. Use caution not to introduce the pathogen into fields free of cabbage yellows. Once present, this fungus survives indefinitely in the soil.

Plants may be affected by cabbage yellows at any age. The fungus infects the plant through small roots or wounds in older roots. Once inside the root, it moves up to the stem and leaves, causing the plant to wilt. Symptoms are most severe when the weather is warm. Where the disease is present, a high degree of crop loss can be expected if susceptible varieties are planted. Resistant varieties have been developed for cabbage yellows and are the only effective control of this disease.



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**Cabbage yellows, also known as Fusarium wilt, is a persistent soil-borne disease.**

**A major symptom of Fusarium wilt is yellowing of the lower leaves, often on one side of the plant.**

**Scouting:** When walking fields, look carefully for signs of wilting, stunting, or yellowing. Outbreaks of cabbage yellows often follow periods of crop stress, especially hot, dry weather. The disease will not develop below 60 degrees F, with the most rapid disease progression occurring when soil temperatures are between 65 and 75 degrees F.

Infected seedlings will turn yellow and die within 2 to 4 weeks after transplanting in warm soil. Affected plants of all ages are stunted, lopsided and yellowed, lose most of their lower leaves, and have a brown to black discoloration in the veins. The lower leaves are affected first. The yellowing is often more intense on one side of the leaf, which will curl and twist, often leaving only one side of a plant stunted. As the disease progresses, the older leaves drop off the plant.

Cabbage yellows can be confused with black rot and water stress. If the crown is cut lengthwise at the soil level, a brown stain caused by the fungus can be seen in the water-conducting tissue of the stem.

**Threshold:** There is no control for cabbage yellows once the plant is infected. Management is preventative.



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**A brown discoloration of the water-conducting tissues (xylem) is characteristic of this disease. With time the entire plant may yellow, wilt, and collapse.**

## Management Strategies

### Cultural control

- ▶ Rotate at least 3 years out of crucifers to prevent buildup of the fungus in the soil.
- ▶ Plant yellows-resistant varieties.
- ▶ Start transplants in disease-free soil, or buy disease-free transplants from a reliable source.
- ▶ Prevent spread of infested soil carried on farm equipment, tools, feet, or in water.

### Chemical control

- ▶ None recommended.



# Clubroot *Plasmodiophora brassicae*

						peak activity	
April	May	June	July	August	September	October	

Clubroot is a disease caused by a widespread and persistent soil fungus. All wild and cultivated crucifer plants are susceptible hosts. The pathogen infects plant roots, causing swellings that vary in size from very small swellings to large club-shaped roots. Severely infected roots have difficulty absorbing water and minerals from the soil. Affected plants may have no above-ground symptoms or may show signs of wilting, stunting, and other signs of root dysfunction.

The clubroot fungus prefers wet, slightly acidic soils. Once in a soil, it can persist for 10 years or more, and special management guidelines must be followed if crucifers are to be grown in that field again. Losses can be heavy and the economic importance is increased by the persistence of the fungus once established in the soil.

The fungus is spread from field to field on diseased field-grown transplants and movement of infested soil on machinery and surface water. Clubroot surveys in Canada have found that almost all new infestations of clubroot begin near the field access, which indicates that contaminated equipment is the main way this pathogen is spread.

The clubroot pathogen overwinters in the soil as hardy resting spores. In the spring, the presence of host plant roots stimulates the resting spore to germinate by releasing swimming zoospores. Soon after, a second generation of zoospores is released which re-infects the roots of the initial host or of nearby plants, causing the galling and clubbing symptoms. If a suitable host is not present in the spring, the resting spore remains dormant in the soil.



© Robert Wick, Univ. of Massachusetts



**Clubroot is a soil fungus that can persist in soil for 10 years or longer.**

**Field-grown transplants and movement of soil on machinery are the most common ways the clubroot fungus enters a non-infested field.**

**Scouting:** Clubroot may develop extensively on plant roots before the first sign is noticed above-ground. If the soil is moist, above-ground symptoms may not become apparent until water stress occurs, when infected plants wilt and turn yellow.

When walking fields, look carefully for signs of wilting, stunting, yellowing, and premature ripening. Dig up the plant and inspect the roots. New clubroot infections cause small knot-like galls, while more developed infections appear as long spindle-shaped clubs on primary and lateral roots. If you suspect clubroot, bring a sample to a disease diagnostic laboratory for confirmation.

Some hosts, such as turnips and radishes, do not form clubs when infected. These hosts have black sunken lesions along the root surface. Galled and clubbed roots are often invaded by secondary rot organisms such as soft rot bacteria; this results in the rapid decay of roots.

**Threshold:** There is no treatment for clubroot once the disease is present. Management is preventative.

## Management Strategies

### Cultural control

- ▶ Grow crucifers in well-drained, warm soil. Eliminate cruciferous weeds in the field and surrounding areas.
- ▶ Use clean or sterile soil mixes for the seedbed.
- ▶ Use clubroot-free locations for outdoor seedbeds. Do not add hydrated lime in seedbeds, as it may mask the presence of the fungus, and allow it to move with the transplants to the field.
- ▶ Avoid purchasing infected transplants. Buy only from reputable growers as infected transplants cannot always be identified.
- ▶ Discard all plants in a lot if clubroot is found on any seedling. Others may be infected and not yet show symptoms.

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- ▶ If compatible with other crops in the rotation, raising the soil pH to 7.2 provides good control in mineral soils.
- ▶ Rotate infested fields out of cole crops for a minimum of 7 years. Discontinue growing in heavily-infested fields.
- ▶ Restrict the movement of soil on farm implements or field boots from infested to non-infested fields. Minimize all equipment traffic into infested fields. Do not use water from infested fields to irrigate non-infested fields.
- ▶ Research is currently under way in Canada to determine if bait crops could be used to draw down the population of resting spores in infested fields. Bait crops are allowed to grow long enough to stimulate germination of the clubroot resting spores, and then plowed down before the clubroot pathogen completes its life cycle. This strategy may shorten the rotation time needed between crucifer crops.

### Chemical control

- ▶ A fungicide dip may be used as a preventative treatment for transplants.



© Robert Wick, Univ. of Massachusetts

***If clubroot is found in a field, the goal is to prevent the introduction of the spores into new fields.***

# Downy Mildew *Peronospora parasitica*

peak activity can occurs in wet, cool weather

April	May	June	July	August	September	October
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Downy mildew is a fungal disease that can be a problem on early-seeded plant beds or on late-maturing crops when the weather is cool and wet. Nearly all cultivated and weed plants of the crucifer family can be infected by the downy mildew fungus.

Cole crops are susceptible to downy mildew at all stages of development, although young tissue is the most susceptible. Early season infections can kill or stunt seedlings, while late season infections can cause internal discoloration of the heads. It also leaves the heads more susceptible to soft rot bacteria and other storage rots, especially in cabbage.

The fungus overwinters in soil or on crop debris, where it produces masses of spores that are disseminated by wind and rain. Plants grown in infested soil can become infected before they emerge. After emergence, the fungus develops on the leaves, and spores are produced, which are readily spread by wind. Temperature and moisture are very important to the development of this disease. Cool temperatures between 50-60 degrees F are ideal, especially if fog, drizzling rain, or heavy dews are present.



© Dr. Amanda Gevens, UW-Madison



*The downy mildew fungus spreads easily from undecomposed crop debris to nearby crucifer plantings by wind-blown spores.*

**Scouting:** Inspect seedlings at least weekly when weather conditions are cool and wet. The first symptoms of downy mildew are seen as discolored spots on the cotyledons, which can be a source of spores and new infections. Once the leaves turn yellow they usually drop off.

Late season infections are primarily on the older leaves. The diseased parts of the leaf turn dry and papery, but the leaves rarely drop. The downy white growth of the fungus on the lower side of the leaves is visible in cool, damp weather. If the infection moves into the stem, it can travel up to the head.

Look for black spotting on florets or heads when inspecting mature plants. In cauliflower, dark grey spots may appear on the curd. When such curds are cut open, grey streaking is noticeable on the branches beneath the florets. Irregular black spots may develop on broccoli. There could also be no spotting on the outside of the head, but grey streaking could occur beneath the beads all the way back to the main stem. In cabbage, black spots will be evident on the head, one-fourth to three-fourths of an inch in diameter.

**Threshold:** Treatment should be considered if weather conditions are favorable and a susceptible variety is grown. Begin treatment at the first signs of infection.



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*The disease can become severe during conditions of high humidity, fog, drizzling rains, and heavy dew, especially if the leaves stay wet until mid-morning.*

## Management Strategies

### Cultural control

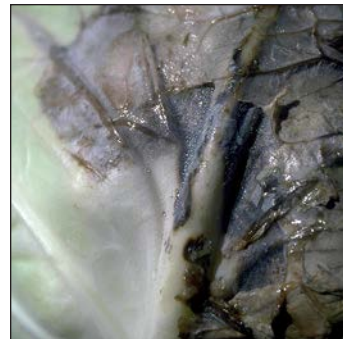
- ▶ Choose a sunny, well-drained planting site that dries out quickly in the morning.
- ▶ Plant resistant varieties if available.
- ▶ Allow for good air movement in the crop by planting in wide spacings, in rows parallel to prevailing winds, and not close to hedgerows.
- ▶ Rotate out of crucifers for at least 2 years.
- ▶ Remove volunteer crucifers and cruciferous weeds.

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- ▶ Avoid overhead irrigation.
- ▶ Plow under crop debris promptly after harvest

#### **Chemical control**

- ▶ Fungicides that are effective for downy mildew are available. Begin application at the first sign of disease
- ▶ Development of resistance is a concern. Avoid consecutive use of products with a similar mode of action.



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***Peronospora parasitica* requires cool, moist weather for infection and disease development to take place.**

# Cabbage Aphid *Brevicoryne brassicae*

peak activity

April

May

June

July

August

September

October

The cabbage aphid occurs every year in the upper Midwest but is usually a pest only late in the season as the numbers of parasites and predators decrease. Cabbage aphids tend to occur in dense colonies on the undersides of the leaves, around the youngest leaves and flowering parts, and in the center of cabbage heads or Brussels sprouts. Several other aphid species may feed on cole crops, such as the green peach aphid (*Myzus persicae*) or turnip aphid (*Lypaphis erysimi*), but these species tend to be more randomly dispersed around the plants than the dense colonies of the cabbage aphid. Cabbage aphids feed only on cruciferous plants, both wild and cultivated.

With the exception of very young seedlings, most cole crops are not affected by aphid feeding and can tolerate a moderate aphid population until heading begins. After heading and flower formation, aphids become more important as potential contaminants of marketed vegetables. Aphid bodies, cast-off skins, and the sooty mold that can develop on colonies are difficult to remove from broccoli or cauliflower heads, even with washing.

The cabbage aphid does not infest non-cruciferous crops but can survive on related weed species when cole crops are not in the field. When adult females find suitable hosts, they produce wingless offspring that are capable of reproducing without mating, resulting in 'colonies' of wingless aphids. These colonies will remain in place on the host until the aphids become crowded, or the host plant begins to deteriorate, when winged forms are produced that can migrate to new fields. Wingless, summer forms of the cabbage aphid are green gray with a white, waxy coating. The winged adults have a black abdomen and lack the waxy coating.



© Dr. Amanda Gevens, UW-Madison



© Whitney Cranshaw, Colorado State University, Bugwood.org

**Aphids are a serious problem during the heading and flower formation stages. They can seriously reduce the quality of the harvested crop.**

**Scouting:** Check seedlings for aphids before transplanting, and rogue out infested plants. After planting, monitor fields weekly for cabbage aphids, especially after heading and flower formation, as the most serious problem with aphids is contamination of the harvested crop. Walk the field in a "W" pattern, and be sure to cover all parts of the field thoroughly. Aphids occur in "hot spots" rather than uniformly in a field. Note whether aphid mummies are present, indicating parasitism. Also note and record the presence of aphid natural enemies.

Check the youngest, highest, and innermost leaves of young plants. After heading, check the flowering parts of broccoli and cauliflower, and pull back wrapper leaves of cabbage. Aphids can be found deep within the heads of cabbages or Brussels sprouts.

**Threshold:** Thresholds depend on the crop growth stage, as follows: Treat broccoli and cauliflower before heading if there are more than 100 aphids per plant. Once heads begin to form, cabbage aphids must be controlled, even if only a few are present. After heading, treat if there are more than 5 aphids per plant. Treat cabbage if 1-2% of the plants are infested.

## Management Strategies

### Cultural control

- ▶ Transplants should be examined for aphids and treated or removed before placing in the field.
- ▶ Control alternate hosts, including mustards and related weeds, around field borders.
- ▶ Aphids are less attracted to mulched plantings than bare ground between plants.
- ▶ Destroy crop remnants immediately after harvest to remove overwintering sites and to prevent aphids from moving into later plantings.

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### Biological control

- ▶ Cabbage aphids have many natural enemies which can control low populations. However, short crop life, use of pesticides for other pests, and the tendency for the aphids to be deep within the head make it difficult for natural enemies to keep up with aphid populations.
- ▶ Important natural enemies include lady beetles, syrphid fly larvae, and the parasitic wasp, *Diaeretiella rapae*. Protect habitat for natural enemies so that they can survive and increase their population levels.
- ▶ Aphid numbers often increase dramatically after broad-spectrum insecticides are applied. Use Bt rather than a broad-spectrum product if insecticide control is needed for caterpillar control.
- ▶ During periods of humid, wet weather, naturally-occurring fungal diseases can wipe out entire aphid colonies.



***Diaeretiella rapae* are natural enemies of cabbage aphids.**

### Chemical control

- ▶ Try to delay using insecticides for as long as possible while maintaining yield and quality. Delaying insecticide applications will save the expense as well as protect the natural enemies that keep caterpillar pests below threshold levels.
- ▶ Spot treatments can be effective when “hot spots” occur with high numbers though the field average remains below threshold.
- ▶ Good plant coverage is essential when using any type of insecticide.
- ▶ Resistance is a key concern. Avoid consecutive use of products with a similar mode of action.

# Cabbage Looper *Trichoplusia ni*

peak activity						
April	May	June	July	August	September	October

The cabbage looper is a common late-season pest of cole crops. Together with the diamondback moth and imported cabbageworm, it is one of three major caterpillar pests of cole crops. Looper caterpillars can be distinguished from other caterpillars by their distinctive looping movement when they crawl. The cabbage looper feeds on cabbage, broccoli, Brussels sprouts, and cauliflower, as well as other non-cruciferous crops such as beets, celery, lettuce, spinach, peas, tomatoes, and potatoes.

Loopers damage cole crops by eating large holes in the leaves, boring into heads, and contaminating the heads with frass. Smaller larvae feed mainly on the undersides of leaves, while older larvae move deeper into the plant, especially if the weather is hot and dry, to feed on the heart leaves of cabbage or the heads of cauliflower. Damaging populations of cabbage looper occur mainly in August and September. Because this is a critical growth stage when the marketable parts of cole crops are forming, looper feeding can significantly reduce the quality and value of the crop.

Cabbage loopers do not overwinter in large numbers in the upper Midwest, but adult moths migrate into the area from southern states in mid-July to September. Adults are brown, night-flying moths with a distinctive silvery figure-8 on the front wings. The female moths lay white eggs singly on lower leaf surfaces in July. Four to five weeks after hatching, the mature larvae spin silken cocoons and pupate, usually attached to leaves. Moths emerge 10 to 14 days later, mate, and lay eggs which give rise to a second generation. This generation causes the most damage to cole crops in Wisconsin.



© David Cappaert, Michigan State Univ.

*The cabbage looper gets its name from the way it arches its body when it moves. Cabbage loopers are pale green caterpillars up to one and one-half inch long with a light stripe down each side.*

**Scouting:** The three important caterpillar pests on cole crops all cause the same type of damage and are considered together as a single caterpillar complex. Scout weekly for caterpillars to determine which species are present. Cabbage looper activity commonly begins in August. Other pests, such as aphids, can be sampled at the same time.

Walk along a W-shaped path and examine randomly selected plants every few yards (about 25-50 plants total). Look for feeding damage on the leaves or greenish-brown frass as clues to the presence of caterpillar pests. Check carefully for the presence of caterpillars even if no feeding damage is present, and look for eggs that can hatch into larvae in a few days. Check the heart leaves for damage, as small larvae are easily overlooked. Record if any egg or caterpillar of any species is present. Although feeding damage and fecal material are signs of activity, it is better to rely on larvae counts to determine the level of infestation. Examine the caterpillars for parasitism or disease.

Cabbage loopers are easy to recognize as one and one-half inch long green caterpillars which arch their backs into a loop as they crawl. Look for round, white eggs that are laid singly or in small numbers on the undersides of leaves and greenish-brown fecal pellets.

**Threshold:** Treatment thresholds are well established for caterpillar pests and are based on the presence of healthy larvae or eggs of all caterpillar species present and on the crop growth stage. Plants in the seed bed are susceptible to damage, and treatment is warranted when 10% of the plants are infested with diamondback moth larvae or other caterpillars. Avoid the use of broad-spectrum insecticides early in the season, however, to preserve natural enemies.

Between thinning or transplanting and heading, cole crops can tolerate considerable damage from caterpillar feeding. During this period, sample frequently enough to assess caterpillar populations accurately, but avoid unnecessary insecticide treatments. Natural populations of parasitic wasps and flies, as well as generalist predators, are common and active during this time and may keep caterpillar populations at tolerable levels.

Heading to maturity is the most vulnerable stage, when caterpillars could feed

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on the developing cabbage or Brussels sprout heads, broccoli flowers, or cauliflower curd. These are the marketed portions of the crops which must be almost free of insects, insect parts, and frass in order to meet quality standards. On cabbage, a few caterpillars may be present, but only on the outer leaves and not numerous. There is no tolerance for caterpillars on broccoli, so control during this time must be excellent. If large caterpillars of imported cabbageworm or cabbage loopers are present, a botanical or chemical insecticide may be necessary to maintain a marketable crop.

**UW-recommended treatment thresholds for caterpillar larvae on fresh market cabbage, broccoli, and cauliflower** (diamondback moth have slightly higher thresholds)

Crop	Growth stage	Threshold (% plants infested)
<b>Cabbage</b>	Seedbed	10
	Transplant to cupping	30
	Cupping to early head	20
	Mature head	10
<b>Broccoli</b>	Seedbed	10
	Transplant to first flower	50
	Flower bud to harvest	10
<b>Cauliflower</b>	Seedbed	10
	Transplant to first curd	50
	Curd present	10

## Management Strategies

### Cultural control

- ▶ Locate fields away from previous cole crops—the further away the field, the longer it will take for the caterpillar pests to find and infest the current crop.
- ▶ Remove alternate hosts, including mustards and related weeds, around field borders. Cruciferous weeds can support populations of all three caterpillar pests during the crop season.
- ▶ Be sure to purchase transplants that are not harboring any pests. Caterpillar larvae are often imported on transplants from southern regions. Consider growing your own transplants in clean greenhouse settings in order to avoid all three species.
- ▶ Enclose the seed beds or young transplants with a row cover to exclude egg-laying adults.
- ▶ Handpick larvae in small plantings or remove infested plants if early in the crop cycle.
- ▶ Bury crop debris to destroy potential overwintering pupae.

### Biological control

- ▶ Natural enemies can be an effective and cost-effective way to keep caterpillar pests below threshold level. Several general predators feed on looper egg and larval stages.
- ▶ *Trichogramma*, a non-stinging parasitic wasp, is a major parasite of looper eggs. Natural parasitism can be increased by timed introduction of commercially available, inexpensive *Trichogramma* spp. The most suitable species commercially available is *Trichogramma pretiosum*.
- ▶ A naturally-occurring virus disease is also important under certain condi-

tions; the bodies of diseased caterpillars turn into shapeless sacks of dark liquid and can often be spotted hanging from leaves.

### Chemical control

- ▶ Avoid using broad-spectrum insecticides early in the season, when caterpillars are present in low numbers and cole crops can tolerate some feeding. This preserves parasitoids and predators so they can help suppress caterpillar numbers later in the season.
- ▶ The microbial insecticide Bt is very effective in controlling caterpillar pests of cole crops and is widely used. The use of Bt rather than a chemical insecticide early in the season allows parasites to survive and exert greater control of the pest population later in the season.
- ▶ Bt sprays can be effective through harvest, but only if smaller (one-half inch) caterpillars are present. Good coverage of the lower leaf surfaces is important, and the use of a sticker can improve the effectiveness of Bt.
- ▶ Cabbage loopers are also controlled by the more toxic materials recommended for use against other caterpillar pests. If significant numbers of cabbageworms, diamondback moths, or other insects are also present, choose a treatment based on which species is present and their developmental stage.
- ▶ Spot treatments can be effective when “hot spots” exhibit high numbers and yet the field average remains below threshold.
- ▶ Natural enemies may be declining in September. If so, then more disruptive insecticides can be used. Pyrethroids are more effective in cool temperatures and tend to be effective for cabbage looper. Loopers tend to move into the head in cooler weather.
- ▶ Good plant coverage is essential when using any type of insecticide.
- ▶ Resistance is a key concern. Avoid consecutive use of products with a similar mode of action.

# Cabbage Maggot *Delia platura*

peak activity

April

May

June

July

August

September

October

Cabbage maggot is an important early-season pest of all cole crops, especially young transplants. Cole crops are most susceptible to damage by cabbage maggot larvae if they are in the seedling stage when the first generation of adults are laying eggs.

Cabbage maggots feed on roots and lower stems, riddling the roots with tunnels when infestations are heavy, stunting plant growth, and causing plants to wilt easily. The wounds produced by cabbage maggot feeding can provide an entry point for soft rot bacteria, the black leg pathogen, and other diseases. Once established, plants can tolerate a moderate maggot infestation.

Adult flies emerge from overwintering pupae (the cocoon-like resting stage in the soil) in early to mid-May in Wisconsin. The adult cabbage maggot is an ash-gray, bristly fly that resembles a housefly but is half as long and has black stripes. Adult flies are attracted to decomposing organic matter and freshly plowed fields, where females lay small white eggs in cracks in the soil at the base of plants. After hatching, the larvae burrow down into the soil to the root. Cabbage maggot larvae are typical fly maggots: legless and white with one-third inch long bodies that taper toward the head, resembling a grain of rice.



*The cabbage maggot flies are most attracted to recently-tilled fields with high organic matter or where animal or green manure has recently been applied.*

**Scouting:** Peak fly emergence and egg-laying will be at different calendar dates each year but will always occur at the same time that lilacs and yellow rocket are flowering, around early May in Wisconsin. Transplanted crops are most susceptible during the first 2 to 3 weeks after planting. After seedling emergence or transplanting, check the crop twice a week for signs of cabbage maggots.

Areas in the field where seedling emergence is poor or transplants are wilting may indicate cabbage maggot injury. Affected plants appear stunted and off-color. Examine 5 to 10 seedlings in these areas. Signs of cabbage maggot are brown tunnels in the roots and the presence of the maggots themselves. If roots are tunneled but no maggots are present, maggots have left roots to pupate.

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.

**Thresholds:** There are no thresholds established because cabbage maggot damage cannot be detected until it is too late to take control action. Management of this pest is preventative.



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

## Management Strategies

### Cultural control

- ▶ Rotate crops. If you have the land available, do not plant a crucifer crop more often than every three years in a field.
- ▶ Promote rapid seed germination and vigorous seedling growth by planting the crop into well-drained soil when the soil temperature reaches 50 degrees F or higher.
- ▶ Schedule planting to avoid the peak fly emergence and egg-laying periods. This way the crop will be protected from the largest and most damaging population. The ideal time to seed is after the peak emergence (300 DD), which is towards the tail end of the yellow rocket bloom period. Plant transplants at least one week before or after the peak. For direct-seeded crops, begin planting at least 3 weeks before the peak, or 1 week after the peak.

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- ▶ Do not plant in fields where animal manure has been freshly applied. Plow in weeds, animal or green manure, and cover crops at least 3 to 4 weeks before planting.
- ▶ If cole crops are direct-seeded, use a drag chain behind the planter to eliminate any moisture differences in the soil between the seed row and the adjacent soil. Moisture from newly planted seed rows can attract cabbage maggots.
- ▶ In smaller plantings, barriers that fit snugly around the stems of transplants can prevent egg-laying by adult flies. Barriers could be tar-paper disks, pie plates, or other circular objects that can be cut to fit snugly around the stem of the plant.
- ▶ Flexible row covers can be used effectively to exclude the egg-laying adult in smaller plantings. The barriers will not, however, exclude the adults emerging from pupae that overwintered in the soil.
- ▶ Disk crop residues immediately after harvest to reduce overwintering populations.



**Late plantings are usually less affected than early plantings.**

### Biological control

- ▶ Many parasites and predators feed on cabbage maggots, but natural enemies are usually not active enough in early spring to prevent some damage when maggot populations are high. The use of pesticides will interfere with natural enemy abundance and activity.
- ▶ The commercially-available nematode *Neoaplectana carpocapsae* has potential for control of cabbage maggot.

### Chemical control

- ▶ If the crop must be planted at a particular time, regardless of the cabbage maggot fly population, and if there is a history of cabbage maggot infestation in a field, insecticides may be necessary to prevent crop damage.
- ▶ Directly apply insecticides at the base of the plants to avoid disruption of beneficial, soil-inhabiting insects.
- ▶ There are cabbage maggot populations resistant to many insecticides. Avoid consecutive use of products with a similar mode of action.

**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 each have their own specific base temperature. Most plants use a base temperature of 50 degrees F. Cool-season cole crops have a base temperature of 40 degrees F. Begin recording degree day accumulations for Wisconsin on March 1.

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 cabbage maggots and other 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 1 degree above the developmental base temp) for 24 hours, one degree-day (DD) is accumulated. The first generation cabbage maggots develop from eggs laid when 300 DD have 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/>

# Diamondback Moth *Plutella xylostella*

peak activity

April

May

June

July

August

September

October

The diamondback moth is one of three major caterpillar pests—diamondback moth, imported cabbageworm, and cabbage looper—of cole crops. Diamondback moth larvae are small, light-green caterpillars that blend in well with cabbage leaves. They will wriggle or drop off the leaves when disturbed. All wild and cultivated cruciferous plants, especially cabbage, cauliflower, Brussels sprouts, broccoli, and collards are hosts to the diamondback moth.

Feeding by young diamondback caterpillars causes small incomplete holes or a “windowpane” effect; mature larvae chew larger complete holes in the foliage. The entire plant may become riddled with holes under moderate to heavy populations. Damage is typically sporadic and dependent on heavy flights of southern moths reaching Wisconsin. Favorable warm weather conditions and increasing resistance to insecticides, however, have recently elevated the diamondback moth to major pest status.

The adults are small, night-flying moths, whose wings produce a pattern of three diamonds along the top of the narrow body. Adult moths either overwinter in field debris or, more commonly, migrate to the upper Midwest in spring. Adults lay tiny eggs individually on upper and lower surfaces of crucifer weeds, volunteers, or cultivated crucifer crops. After completing four larval stages, they spin white silk cocoons on the lower surface of plant leaves. Three to five generations occur each season in the upper Midwest.



**Diamondback moth larvae are increasingly imported on transplants from southern states.**



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**The larvae are small (1/2-inch), light-green caterpillars that blend in well with cabbage leaves and are hard to find.**

**Scouting:** Monitor fields weekly by walking a W-shaped path through each field and examining randomly-selected plants every few yards. Monitor recently-emerged or transplanted fields twice weekly. Examine 25-50 plants, depending on the field size, and record the number of plants infested. A plant is infested if eggs or caterpillars of any species are present. The three caterpillar pests can be considered together as a single caterpillar complex.

The diamondback moth is often overlooked because it is small and blends in well with cabbage leaves. Look for one-third to one-half inch long light-green caterpillars that wriggle furiously or drop off the leaves when disturbed. Check for eggs, which are oval, yellowish-white, and tiny. They will be glued to the upper and lower leaf surfaces singly or in groups of two or three, usually along the veins.

Cool, windy weather reduces adult activity, and females often die before they lay all their eggs. Heavy rainfall can drown small larvae and reduce numbers by more than half.

**Threshold:** Treatment thresholds are well established for caterpillar pests and are based on the presence of healthy larvae or eggs of all caterpillar species present and the crop growth stage. Plants in the seed bed are susceptible to damage and treatment is warranted when 10% of the plants are infested with diamondback moth larvae or other caterpillars. Avoid the use of broad-spectrum insecticides early in the season, however, to preserve natural enemies.

Between thinning or transplanting and heading, cole crops can tolerate considerable damage from caterpillar feeding. During this period, sample frequently enough to assess caterpillar populations accurately, but avoid unnecessary insecticide treatments. Natural populations of parasitic wasps and flies, as well as generalist predators, are common and active during this time and may keep caterpillar populations at tolerable levels.

Heading to maturity is the most vulnerable stage, when caterpillars could feed on the developing cabbage or Brussels sprout heads, broccoli flowers, or cauliflower curd. These are the marketed portions of the crops which must be almost free of insects, insect parts, and frass in order to meet quality standards. On cabbage, a few caterpillars may be present, but only on the outer leaves and not numerous. There is no tolerance for caterpillars on broccoli, so

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control during this time must be excellent. If large caterpillars of imported cabbageworm or cabbage loopers are present, a botanical or chemical insecticide may be necessary to maintain a marketable crop.

#### Thresholds for Diamondback Moth (50% infestation of at least 5 caterpillars per plant)

Crop	Growth stage	Threshold (% plants infested)
<b>Cabbage</b>	Seedbed	10
	Transplant to cupping	30
	Cupping to early head	20
	Mature head	10
<b>Broccoli</b>	Seedbed	10
	Transplant to first flower	50
	Flower bud to harvest	10
<b>Cauliflower</b>	Seedbed	10
	Transplant to first curd	50
	Curd present	10

## Management Strategies

### Cultural control

- ▶ Rotate fields with non-cruciferous crops. Locate fields away from previous cole crops.
- ▶ Remove cruciferous weeds in or near crop fields.
- ▶ Purchase transplants free of pests. Caterpillar larvae are commonly imported on transplants from southern regions. Consider growing your own transplants in clean greenhouse settings.
- ▶ Enclose seedbeds or young transplants with lightweight row covers to exclude egg-laying adults.
- ▶ In smaller plantings, inspect plants every few days, and destroy any eggs or larvae.
- ▶ Remove crop residue after harvest to reduce migration to younger plants. Bury crop residue to eliminate overwintering sites.

### Biological control

- ▶ Naturally-occurring parasites and predators are often sufficient to keep diamondback moth populations in check, especially later in the season. Flies, wasps, lacewings, plant bugs, pirate bugs, ground beetles, syrphid fly larvae, spiders and birds prey on the diamondback moth larvae.
- ▶ Three native species of parasitic wasps provide effective control of diamondback moths. *Diadegma insulare* and *Microplitis plutellae* parasitize the larval stages, while the third species, *Diadromus subtilicornis* parasitizes pupae.
- ▶ In smaller fields, the commercially-available parasites *Diadegma insulare* or *Trichogramma* spp. may be released to supplement natural populations.
- ▶ Rainfall and high humidity promotes infection by fungi that cause natural disease outbreaks in diamondback moth populations, usually late in the season when populations are high.

- ▶ Eliminating diamondback moths entirely is not necessary because plants can tolerate low levels of feeding, which offers the potential for effective biological control to operate.

### Chemical control

- ▶ Avoid using broad-spectrum insecticides early in the season when caterpillars are present in low numbers and cole crops can tolerate some feeding. This preserves parasitoids and predators so they can help suppress caterpillar numbers later in the season.
- ▶ The microbial insecticide Bt is very effective in controlling caterpillar pests of cole crops and is widely used. The use of Bt rather than a chemical insecticide early in the season allows parasites to survive and exert greater control over the pest population later in the season.
- ▶ Bt sprays can be effective through harvest, but only if smaller (one-half inch) caterpillars are present. Good coverage of the lower leaf surfaces is important, and the use of a sticker can improve the effectiveness of Bt.
- ▶ Diamondback moths are controlled by the more toxic materials recommended for use against other caterpillar pests. If significant numbers of loopers, imported cabbageworms, or other insects are also present, choose a treatment based on which species is present and the insects' developmental stage.
- ▶ Diamondback moth populations have developed resistance to pyrethroids, organophosphates, carbamate, and Bt products in some southern states. Avoid consecutive use of products with a similar mode of action.



## PEST PROFILES

# Crucifer Flea Beetle *Phyllotreta cruciferae*

## Striped Flea Beetle *Phyllotreta striolata*

April

May

June

July

August

September

October

peak activity

Flea beetles are very small, hard beetles with large hind legs that allow them to jump long distances when disturbed. The most preferred hosts of the crucifer flea beetle are those in the genus *Brassica*, which include the major agricultural cole crops, as well as canola and oil rapeseed. The striped flea beetle will feed on cabbage.

Adult flea beetles feed on leaves, creating small pits and a shot-hole appearance. The greatest damage occurs during the spring when flea beetles feed on cotyledons and first true leaves in the first weeks after emergence. Flea beetles rarely cause serious damage to mature plants.

Flea beetles overwinter as adults in crop debris, hedgerows, and wooded areas adjacent to fields and emerge in the spring to feed on cruciferous weeds and early-planted or volunteer crops. During the summer, females lay very small white eggs in the soil near plants. The thin, white, brown-headed larvae feed on roots and later form white pupae enclosed in earthen cells. A second and sometimes third generation of adults feed from July to September, but the crops are usually mature enough that feeding damage is minimal.



**Adult flea beetles feed on leaves, creating small pits and a shot-hole appearance. Heavy feeding on young plants can cause the leaves to drop and uneven stand development.**

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**Scouting:** Scout direct-seeded and transplanted crops twice per week during the seedling stages until plants are well-established. Begin scouting at the field margins and walk into the field, selecting plants at various random intervals. Most flea beetle damage is distinctive in appearance and looks like small, ragged holes or pits in the foliage.

Flea beetles become active when spring temperatures are over 50 degrees F, especially on calm, sunny days. They are less active during rainy or windy weather. The beetles can be black, black and yellow, or metallic blue-green, depending on the species, and about one-quarter inch long.

**Threshold:** Relatively low populations can cause economic damage when plants are in the cotyledon or first-leaf stages. Consider treatment if you find several damaged rows. Once plants have 5 leaves, they can tolerate several beetles per plant without damage. Older plants are even more tolerant.

## Management Strategies

### Cultural Control

- ▶ Cauliflower is often the most preferred crop, followed by turnip, radish, and cabbage. Some cultivars of broccoli and cabbage have more resistance than others. Check with your seed supplier.
- ▶ Rotate crops to include non-hosts.
- ▶ A trap crop may work in some situations. Plant a highly favored crop such as radish before the main crop. Adult flea beetles will be attracted to the tallest, earliest crops available. Once beetles are actively feeding in the trap crop, remove the trap crop or treat with a labeled insecticide.
- ▶ Plant early in the spring to avoid high populations during the most susceptible seedling stage. By the time flea beetles appear in large numbers, the crop will be large enough to tolerate feeding.



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

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

### Biological control

- ▶ Predators such as lacewing larvae, big-eyed bugs, the western damsel bugs and northern field crickets feed on flea beetles, but their impact is not well known.
- ▶ Parasitic wasps, especially *Microtonus vittate*, are thought to impact the striped flea beetle populations significantly in the eastern U.S. and Canada, but parasitism in the Midwest is low.
- ▶ No parasite or predator is currently available.

### Chemical Control

- ▶ Foliar insecticides can be effective for quick control of large populations feeding on vulnerable seedlings.
- ▶ Choose a product with a short residual life that will not harm natural enemies of diamondback moths or aphids. Unintended injury to beneficials may cause other insect problems to appear later in the season.
- ▶ Spot treatment of outside rows or borders may be sufficient to control flea beetles. One insecticide treatment should be all that is required.



***Flea beetles are a sporadic pest in the upper Midwest, especially in fields that are weedy or surrounded by weeds, especially cruciferous weed like wild mustard.***

# Imported Cabbageworm *Pieris rapae*

peak activity

April

May

June

July

August

September

October

The imported cabbageworm is the most common of the three caterpillar pests—imported cabbageworm, diamondback moth, and cabbage looper—of cole crops in the upper Midwest. Cabbageworm larvae are velvety green caterpillars, about an inch long, that move sluggishly when touched. The imported cabbageworm feeds on leaves of all cruciferous crops and weeds throughout the growing season.

Cabbageworms chew large, irregular holes in leaves, causing damage similar to the cabbage looper. They feed on both the outer and inner leaves, often along the midrib. Older larvae may bore into the head. Their greenish brown fecal pellets may contaminate the marketable parts of the plant.

The adult cabbageworm, also known as the cabbage butterfly, is a day-flying white butterfly with black spots on its wings. Adults emerge in early May from pupae that overwintered in plant debris, and begin laying eggs on any above-ground plant part. Eggs hatch into larvae that develop on cruciferous weeds and early-planted cole crops. The second generation butterflies emerge in mid-July, and larvae feed almost entirely on cultivated cole crops. This generation develops much more quickly because of the warmer weather and tends to cause the most damage.



**Imported cabbageworms may be hard to find because of their small size and inconspicuous coloring; their presence is often signaled by their frass.**



**Cabbageworms are slow and sluggish, but they feed voraciously on both the outer and inner leaves, often along the midrib. Pupae are usually found on the underside of leaves.**

**Scouting:** Scout weekly by walking a W-shaped path through the field and examining randomly-selected plants every few yards. Examine 25-50 plants, depending on the field size, and record the number of plants infested. The three caterpillar pests can be considered together as a single caterpillar complex. A plant is infested if eggs or caterpillars of any species are present.

The imported cabbageworm is a small velvety-green caterpillar about 1 inch long that moves sluggishly when poked. Cabbageworms may be harder to find than cabbage loopers because of their smaller size and their inconspicuous coloring. The single, bullet-shaped eggs can be found on the undersides of leaves. Good clues to cabbageworm presence are their greenish brown fecal pellets and the fluttering presence of white adult butterflies.

Although feeding damage and fecal material are signs of activity, it is better to rely on larvae counts to determine the level of infestation. Caterpillars cause varying amounts of damage depending on the maturity of the plant, so the need for treatment changes as the crop grows. Keep a record of the percentage of plants infested. This information will be useful to determine whether the population is increasing or decreasing.

**Thresholds:** Treatment thresholds are well established for caterpillar pests and based on the number of plants infested by any caterpillar species and on the stage of crop development. Plants in the seed bed are susceptible to damage, and treatment is warranted when 10% of the plants are infested with cabbage loopers, diamondback moths, or imported cabbageworms. Avoid the use of broad-spectrum insecticides early in the season, however, to preserve natural enemies.

Between thinning or transplanting and heading, cole crops can tolerate considerable damage from caterpillar feeding. During this period, sample frequently enough to assess caterpillar populations accurately, but avoid unnecessary insecticide treatments. Natural populations of parasitic wasps and flies, as well as generalist predators, are common and active during this time and may keep caterpillar populations at tolerable levels.

Heading to maturity is the most vulnerable stage, when caterpillars could feed on the developing cabbage or Brussels sprout heads, broccoli flowers, or cauliflower curd. These are the marketed portions of the crops which must be almost free of insects, insect parts, and frass in order to meet quality stan-

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dards. On cabbage, a few caterpillars may be present, but only on the outer leaves and not numerous. There is no tolerance for caterpillars on broccoli, so control during this time must be excellent. If large caterpillars of imported cabbageworm or cabbage looper are present, a botanical or chemical insecticide may be necessary to maintain a marketable crop.

#### UW-recommended Treatment thresholds for Caterpillar Larvae

Crop	Growth stage	Threshold (% plants infested)
<b>Cabbage</b>	Seedbed	10
	Transplant to cupping	30
	Cupping to early head	20
	Mature head	10
<b>Broccoli &amp; Cauliflower</b>	Seedbed	10
	Transplant to first flower or curd	50
	Flower bud/curd to harvest	10

## Management Strategies

### Cultural control

- ▶ Rotate fields with non-cruciferous crops. Locate fields away from previous cole crops.
- ▶ Remove cruciferous weeds in or near crop fields that can support populations of caterpillar pests.
- ▶ Early planting and early harvesting, especially of broccoli and cauliflower, may avoid the peak population of the second generation of imported cabbageworm.
- ▶ Purchase transplants free of pests. Caterpillar larvae are commonly imported commonly on transplants from southern regions. Consider growing your own transplants in clean greenhouse settings.
- ▶ Enclose seed beds or young transplants with lightweight row covers to exclude egg-laying adults.
- ▶ In smaller plantings, inspect plants every few days, and destroy any eggs or larvae.
- ▶ Remove crop residue after harvest to reduce migration to younger plants. Bury crop residue to eliminate overwintering sites.

### Biological control

- ▶ Imported cabbageworm is heavily parasitized in its native Europe, where it only occurs only as a sporadic pest. Naturally-occurring parasites are abundant in the Midwest, and usually reduce cabbageworm populations each year, though not enough to prevent damage until late in the season. Viruses and bacterial diseases are also sometimes important control factors.
- ▶ Practices to conserve natural enemies might help improve natural control. In Russia, a few mustard plants are planted among cabbages to provide food for parasite adults.
- ▶ Predators are an important cause of mortality of cabbageworm eggs, pupae, and larvae. There are no species that feed on cabbageworm exclusively. Generalist predators known to feed on cabbageworm eggs are ants, lacewing larvae, ladybird beetle adults and larvae, and tarnished plant bug adults and nymphs. Predators known to feed on cabbageworm larvae are damsel bugs, green lacewings, paper wasps, and spined soldier bugs.

- ▶ The commercially available parasitoid *Trichogramma* has potential as a control agent in mass releases. The tiny stingless wasp parasitizes the eggs of the imported cabbageworm as well as other caterpillar pests. In smaller fields, timely releases of *Trichogramma* adults may prevent caterpillar populations from reaching damaging levels.
- ▶ The bacterium *Bacillus thuringiensis*, commonly called Bt, is a microbial insecticide that provides adequate control of the imported cabbageworm when applied regularly.

### Chemical control

- ▶ Avoid using broad-spectrum insecticides early in the season when caterpillars are present in low numbers and cole crops can tolerate some feeding. This preserves parasitoids and predators so they can help suppress caterpillar numbers later in the season.
- ▶ The microbial insecticide Bt is very effective in controlling caterpillar pests of cole crops and is widely used. The use of Bt rather than a chemical insecticide early in the season allows parasites to survive and exert greater control of the pest population later in the season.
- ▶ Bt sprays can be effective through harvest, but only if smaller (one-half inch) caterpillars are present. Good coverage of the lower leaf surfaces is important, and the use of a sticker can improve the effectiveness of Bt.
- ▶ Imported cabbageworms are also controlled by the more toxic materials recommended for use against other caterpillar pests. If significant numbers of loopers, diamond-back moths, or other insects are also present, choose a treatment based on which species are present and their developmental stage.
- ▶ Resistance is a concern, avoid consecutive use of products with a similar mode of action.

# Onion Thrips *Thrips tabaci*

peak activity

April

May

June

July

August

September

October

Thrips are small winged insects with rasping mouthparts that leave whitish scratches or brown blisters on plant tissue. Onions, garlic, and related plants are the preferred hosts. On cole crops, thrips are most damaging to cabbage and cauliflower, especially during hot, dry weather. Thrips often invade cabbage plantings in June and July as they leave maturing or harvested wheat, oat, or alfalfa fields. Adult thrips are small, slender insects, about 2 mm long, pale yellow or brown, and with fringed wings. The nymphs resemble the adults, but are smaller and lack wings.

Both adults and nymphs damage tissue by their rasping and feeding. They start the feeding by piercing and rasping the leaf surface with their mouth parts to release the liquids from the plant cells, and later suck up the plant content. Severe damage can occur when thrips multiply rapidly inside a developing cabbage head without being noticed. On cauliflower, thrips feeding can cause tan or brown streaks, which are susceptible to soft rot bacteria and reduce acceptability for the fresh market.

Adults and nymphs overwinter on plant debris, along field margins, or in clover, alfalfa, or wheat fields. In late spring and early summer the thrips will move to vegetables. This often occurs when a wheat field is drying down or is harvested. Thrips are not good fliers, but they move long distances on the wind. Female thrips can reproduce without mating and insert their eggs into plant tissue. There are generally 5 to 8 generations per year in the upper Midwest.



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**Onions, garlic, and other related plants are the preferred hosts of thrips.**

**On cole crops, thrips tend to be most damaging to cabbage and cauliflower.**

**Scouting:** Scout when wheat is maturing or when mid-season cutting of alfalfa is taking place. Pay special attention to the part of the field closest to the wheat or alfalfa field. Thrips cannot fly well, but they are active and readily dispersed by wind. Hot, dry weather favors outbreaks, while heavy rains reduce thrip populations. Thrips are attracted to yellow and white colors; adults can be monitored by the use of yellow or white sticky traps.

Detection of thrips in a cabbage planting is difficult because of their small size and preference for tight hiding places, such as the close leaves of a developing cabbage head, where they may be found several layers deep. Look for thrip feeding, which appears as silvery patches or shiny streaks on plant tissue.

**Threshold:** There is no economic threshold for thrips on cole crops.

## Management Strategies

### Cultural Control

- ▶ The key to control of thrips on cabbage is variety selection. Many cabbage varieties have high levels of tolerance or resistance. Although tolerant varieties may be injured during hot, dry summers, their injury will be far less than on more susceptible varieties.
- ▶ In general, thrips prefer cabbage varieties with very tight heads rather than those with looser heads.
- ▶ Avoid planting cole crops next to or downwind from wheat, oat, or alfalfa. Thrips tend to build large populations on these crops and will migrate to cole crops when the alfalfa or grains are harvested.
- ▶ Avoid planting onions close to cole crops because the same species of thrips feeds on both crops.

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- ▶ Younger plots should be planted upwind of older plots, relative to prevailing winds, to make it harder for the thrips to find the new plantings.
- ▶ Harvesting cabbage prior to its full maturity will decrease the amount of thrips injury in an infested crop. This can be a useful management strategy on very susceptible varieties.

### Biological Control

- ▶ The minute pirate bug (*Orius tristicolor*) and the tiny predaceous mite *Neoseiulus barkeri* are the most common predators of onion thrips. Both the nymphs and adults of *N. barkeri* feed on thrips, and are found on the plant in the same places that thrips prefer.
- ▶ *N. barkeri* and *N. cucumeris* are available commercially for thrips control on greenhouse and field crops. Both species must be applied to the crop as soon as the thrips are present, as the mites do not reproduce as fast as the thrips. In experimental releases on cabbage, the mites colonized mature cabbage heads, survived, and reduced thrips population in proportion to the number of mites released. These releases did not achieve commercially acceptable control of thrips, but release methods may be developed to improve control.
- ▶ The minute pirate bug is distributed abundantly in North America and feeds on thrips and mites. It is not known if natural populations occur in high enough numbers to provide natural control of thrips on cabbage. The minute pirate bug is available commercially.

### Chemical Control

- ▶ Consider insecticide treatment if thrip populations are increasing at cupping or curd formation. Control is difficult once plants are heading. Treat during the afternoon when thrips are most active.
- ▶ The insecticides registered for thrips are non-selective and will kill beneficial insects that may be suppressing other insect populations.
- ▶ Thrips populations resistant to insecticides have been reported. Avoid consecutive use of products with a similar mode of action.



**The key to control thrips on cabbage is variety selection.**



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**Thrips infestations tend to be worse in hot, dry weather. Heavy rains reduce thrips populations by washing the insects off the plants.**