Greens Production Workshop

ASAP BFRDP Project

Asap
Local Food
Strong Farms
Healthy Communities

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Greens Workshop Activity

1. Choose a spokesperson for your group.
2. For your pest find the following information to report back to the group.

Problem: _____

A. Symptoms and Signs

B. Disease or Insect Cycle

C. Control

D. Other information (See production, container grown, transplants, seeds, other)

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Smart Gardening

How to grow greens

Nothing says summer bounty quite like the crisp crunch of fresh greens. These vegetable leaves and stems can be used fresh in salads or sandwiches or for cooking. Greens include: Swiss chard, spinach, kale, collards and mustard greens. Turnips and beets also produce roots that can be eaten, but are often grown just for using their tops as greens. All are high in vitamins and minerals and easy to grow.

Types of greens

Swiss chard belongs to the beet family, but does not develop an edible root. Leaves and stems can be harvested all summer. Leaves are glossy green and wrinkled. Stems and veins can be white, yellow or red, depending on the variety. Small leaves and stems can be eaten raw, but larger leaves should be cooked. Leaves grow in rosettes, and it is possible to pick just the outer leaves and keep the plants growing for harvest most of the season. Cut or break leaves about one inch from the ground when harvesting. The optimum soil temperature for seeding is 55 to 75°F.

Spinach is a cool season annual and will grow in partial shade. There are two types of spinach, smooth leaf and Savoy which has crinkled leaves. The smooth leaf spinach is preferred by many because it is easier to clean. Sow spinach as early as the soil can be worked in the spring. Spinach is slow to germinate and grow. It can also be grown as a late fall crop. Once it begins to bolt (when seed heads develop on the stem), the leaves will become bitter and the plants should be removed from the garden.

Kale does best as a fall crop and its flavor is improved by light frosts. Plants can be started in the spring or in mid-July for a fall crop. Thin kale plants to eight inches apart as they begin to grow. The thinned plants may be used as the first kale meal of the season. To harvest, cut or twist off outer leaves when they are eight to 10 inches tall. Keep plants mulched. Ornamental kale varieties are used in fall flower gardens and as a garnish rather than food.

Collards are sometimes called tree cabbage. Although it is a cool season crop, collards handle hot weather well. Seeds can be started in the spring or sown as a fall crop. Start 10 to 13 weeks before the first expected frost for fall harvesting. Roots are shallow, so great care should be used in cultivating around the plants. Mulching will keep weeds down and keep the soil cool. Harvest older outside leaves when they are eight to 12 inches tall.

Mustard grows fast, just 30 to 40 days from planting to harvest. For the best flavor, harvest the leaves before they are fully grown. Mustard goes to seed when days are long and hot, so plant early in the spring or in August for a fall crop. The curly mustard varieties withstand frost well and can be harvested late in the fall. Cut leaves when they are six to eight inches tall. New leaves will provide a continuous harvest until they become strong in flavor and tough in texture from temperature extremes.

Turnip tops and **beet tops**. For growing tops only, grow these close together in rows or scattered in the corner of the garden. The tops can be used as greens when the leaves are three to five inches tall. If bigger roots are desired, plant in rows about 18 inches apart. When new plants are a few inches tall, thin them so that the beets are three inches apart and the turnips are four to six inches apart. The thinned plants may be eaten as greens.

Preparing the soil

A good harvest begins with careful soil preparation. Select a location for the garden that gets at least six to eight hours of sun daily. Follow your soil test recommendation or use one

Originally developed by Lee Taylor and adapted by Gretchen Voyle. Revised by Linda Whitlock and Mary Wilson.

pound of 5- 20-20 per 100 square feet. Apply the fertilizer and then turn over the soil (or till) to work the fertilizer into the soil. Spread another pound of fertilizer per 100 square feet after tilling. Work in compost or well-rotted manure. Three to four inches of the soil surface can be turned in to a depth of 12 inches. All of these plants will benefit from being mulched.

Harvesting

The nutritional content, freshness and flavor of the greens depend on the stage of maturity and the time of day that they are picked. Overly mature greens will be stringy, tough, coarse and sometimes bitter. The best time of the day to harvest greens is during the cool part of the morning. Refrigerate or process as soon as possible. Wash greens in cool, running water and shake to remove excess moisture before use. It is important to remove any soil that is clinging to the leaves. New, small leaves of most greens are tender and can be added to salads. Older outer leaves are cooked.

To preserve the most nutrients in the greens, cook quickly with as little water as possible. This can be done in a microwave oven or a steamer. Greens can be sautéed, too. Cook greens about one to three minutes, until they wilt.

If greens require a long cooking time to be edible, they were picked when overly mature.

Try these varieties:

Swiss chard

- Rhubarb
- Fordhook Giant
- Bright Lights

Beets

- Ruby Queen
- Detroit Dark Red

Mustard

- Green Wave
- Tendergreen

Kale

- Dwarf Blue Curled
- Vates

Turnips

- Tokyo Cross
- Seven Top

Spinach

- America
- Viking

Collards

- Vates

Notes:

UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY — COLLEGE OF AGRICULTURE

Greenhouse-grown Lettuce and Greens

Introduction

Lettuce and greens are well adapted for production in cool or unheated greenhouses and high tunnels in Kentucky. Potential lettuce types for greenhouse production include romaine, Bibb and leaf lettuces. Mesclun can include any mix of baby lettuces, greens and herbs; however leaf lettuces are often a main component. A variety of lettuce leaf textures (smooth to crinkled), as well as colors (green to red), can be added to these bagged salad mixes.

The term "greens" is often used to refer to a number of leafy vegetables which belong to several unrelated plant families. Common greens that could be produced in a greenhouse include spinach, turnip greens, collards and mustard greens. Specialty greens, such as arugula, sorrel, chicory, and Asian greens, also show potential.

Marketing

Lettuces and greens produced in the greenhouse require a specialized niche market that may take some time to develop. Potential growers should talk to restaurant chefs, caterers or to produce brokers, especially those who sell to restaurants. Lettuce and greens are also excellent for early and late season sales at farmers markets. Success for these crops and markets will be limited to those individuals that are really committed to producing and marketing them.

Market Outlook

The demand for lettuce and greens has increased as health-conscious Americans continue to consume more fresh produce. Lettuce is the third largest vegetable item (behind potatoes and tomatoes) in the average American diet. The popularity of salad bars and bagged salad greens has added to the increased demand for these products. Sales at farmers markets and to the food service industry should offer opportunities for growers able to supply a consistent amount of quality products into the market place.

Production Considerations

Production systems

Lettuce and greens can be grown in a cool or unheated greenhouse from September 15 until June. Leaf lettuce, Bibb lettuce and a number of greens may be adapted to the tobacco greenhouse float system. They could possibly be grown on protected outdoor float beds, as well. These crops are grown in typical "float" trays in the same way as tobacco transplants. This involves first sowing seeds in a standard plug (plastic) tray where the seedlings grow for 2 to 3 weeks. Seedlings are then transplanted to the final spacing in float trays for the last 3 to 5 weeks of production.

Lettuce and greens can also be grown in the soil floor of a small

or large greenhouse. These crops, which prefer a sandy loam soil that is high in organic matter, are seeded directly into rows or beds. Seedlings are thinned a 6 inch to 8 inch spacing for heads or young leaves are simply harvested from plants for mixed baby greens. Drip irrigation greatly reduces splashed soil so the leaves are easier to clean.

University of Kentucky researchers continue to evaluate lettuce and greens production. Their main interest is the use of organic fertilizers in the float water. Such a system would make it possible for plants to be sold in the expanding "organic" market. The results have been very promising; however, more information is needed before recommendations can be made. Research is also being conducted using a system similar to the one described on the Cornell CEA Web site.

Pest management
Environmental conditions that favor plant growth also favor the rapid build-up and spread of insects and diseases. There are very few pesticides labeled for greenhouse production of these crops so insect and disease management will be crucial.

Potential insect problems include aphids and thrips. The use of insect screening on the sidewalls will be necessary, if sidewall ventilation is used. Tender, young plants are particularly susceptible to damping-off. Water aeration is necessary to reduce water molds. Tipburn, a physiological disorder, can also occur on greenhouse-grown greens.

Harvest and storage
Leaves or heads of plants are typically washed, carefully drained dry, weighed and packaged. Hydroponic plants are generally harvested and shipped with the roots intact for longer post-harvest life. Greens must be cooled immediately after harvest and stored near freezing in high humidity conditions. Plants are often packaged individually in plastic bags and then boxed as the market requires. Washed greens for mesclun are usually mixed as they are bagged.

Labor requirements
Labor is needed for seed sowing, transplanting, harvest, packaging and shipping.

Economic Considerations
Greenhouse production requires a significant start-up cost, as well as demanding labor and management. Initial investments include greenhouse construction, production system costs and equipment. The cost of a production-ready greenhouse, excluding land costs, can run approximately $10 per square foot. A well-run operation should have gross returns of $5 to $12 per square foot of production space for the season, depending on crop quality and market.

More Information
- Additional Crops for Greenhouse Tobacco Growers Using the RAFT System (University of Kentucky)
http://www.uky.Edu/Agriculture/HLA/Anderson/raft_veg/home.htm
- Alternative Crops for Greenhouse Tobacco Growers (University of Kentucky, 1997)
http://www.uky.edu/Agriculture/HLA/anderson/raft_veg/intro.htm
- The Greenhouse Business in Kentucky – A Review of Crops and How to Begin a Business (University of Kentucky, 2002)
http://www.uky.edu/Ag/HLA/anderson/greenhousesinkentucky.pdf
- Managing the Greenhouse Environment to Control Plant Diseases, PPFS-GH-1 (University of Kentucky, 2004)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-GH-1.pdf
- Nutrient Analysis of Selected Commercial Organic Fertilizers for Greenhouse Lettuce Production (University of Kentucky, 2002)
http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/pdf/lettuceorgfert.pdf
- Production and Yield of Selected Edible Greens in Hydroponic Ponds (Float Beds) in a Greenhouse (University of Kentucky, 2004)
http://www.uky.edu/Ag/Horticulture/anderson/brassica.pdf

- Selected Resources and References for Commercial Greenhouse Operators (University of Kentucky, 2002) http://www.uky.edu/Ag/Horticulture/anderson/greenhousereferences.pdf
- CEA Grower's Handbooks (Cornell, 2001) http://www.cornellcea.com/handbook_home.htm
- Greenhouse and Hydroponic Vegetable Production Resources on the Internet (ATTRA) http://attra.ncat.org/attra-pub/ghwebRL.html
- Greenhouse Vegetable List of References (North Carolina State University, 2001) http://www.ces.ncsu.edu/depts/hort/hil/hil-32-a.html
- Hydroponic Greenhouse Lettuce Enterprise Budget (Ohio State University, 2003) http://www.oardc.ohio-state.edu/hydroponics/Economics/economics.htm
- Integrated Pest Management for Greenhouse Crops (ATTRA, 1999) http://attra.ncat.org/attra-pub/gh-ipm.html
- Organic Greenhouse Vegetable Production (ATTRA, 2000) http://www.attra.org/attra-pub/ghveg.html
- Specialty Lettuce and Greens: Organic Production (ATTRA, 2002) http://www.attra.org/attra-pub/lettuce.html

UGA extension

Commercial Production and Management **of Cabbage and Leafy Greens**

Reviewed by Timothy Coolong, Extension Horticulturist

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Edited by WilliamTerry Kelley, Extension Horticulturist;
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Foreword

This publication is the result of a joint effort among the seven disciplines in the University of Georgia College of Agricultural and Environmental Sciences that serve the Georgia vegetable industry. The 11 topics covered in this bulletin are all integral parts of a successful cabbage/leafy greens management program. Each topic focuses on a particular aspect of production and provides information on the latest management technology for that phase of production. The authors hope that the information contained in this publication will assist growers in improving profitability. Chemical pest control recommendations are subject to change from year to year; thus, only general pest control guidelines are mentioned in this publication. Growers are urged to consult the current *Georgia Pest Control Handbook* or check with their local county Extension agent regarding the most recent chemical recommendations. Mention of tradenames in this publication is neither an endorsement of a particular product nor a lack of endorsement for similar products.

History, Utilization and Botany

William Terry Kelley and Darbie M. Granberry, Extension Horticulturists

Cabbage and leafy greens, including turnip, mustard, kale and collard, have a long history of production in Georgia. The cabbage and leafy greens industry makes up almost 20 percent of the Georgia vegetable industry's acreage, with almost 30,000 acres under production in a given year. The nature of the industry has changed, however, with more emphasis on shipping and less on locally marketed product. The bulk of all these crops remains in the fresh market, with a growing segment of processed greens.

The botanical classifications of several types of cabbage and leafy greens grown in Georgia are listed in Table 1. *Brassica oleracea* includes all cabbage, collard and kale. This group has long been referred to collectively as "cole crops." This term comes from a Middle English or Norse word that originated from the Latin word *caulis,* which refers to the cabbage stem or stalk. Wild types of these crops have been found along the Atlantic Coast of Europe and cabbage, kale and collard are believed to have originated in Western Europe. Early uses of these crops were for medicinal purposes.

Kale is thought to be the first form to be domesticated and may have been cultivated as early as 2000 BC. Hard-headed types of cabbage were not cultivated until around the ninth century. Traders and explorers spread the crops to other parts of the world, where they were quickly adopted as cultivated crops. Although cabbage is not particularly high in protein, vitamins and minerals, kale is one of the most nutritious vegetables grown, based on fresh weight. Mustard originated in central and eastern Asia, the Mediterranean and the Himalayas.

Uses of cabbage and leafy greens vary widely. All are grown for both the fresh market and processing into any number of products. Cabbage is popular as a fresh item used in slaw, cooked or processed into preserved products such as sauerkraut. Kale is used primarily as a garnish because of its attractive curly leaves. However, kale can be cooked and eaten in much the same fashion as other leafy greens. Collard, turnip greens and mustard are used primarily as cooked fresh vegetables. However, the tendency to find them served in a raw form is increasing. All are grown for the fresh market but also are grown widely for processing both as canned and frozen products.

Collard, kale, turnip and cabbage are dicotyledonous herbaceous plants that are biennial in nature, although the wild form of cabbage is an annual. All are grown commercially as annuals, however. Kale, turnip and collard do not form a head; all have a rosette form of vegetative growth on a short stem. Collard produces a large smooth leaf, and turnip produces smaller leaves that are generally pubescent. Newer varieties of turnip may be smooth-leaved and are more similar in appearance to mustard. Mustard is a cool-season annual that also forms a rosette of vegetative growth. Mustard leaves may be curly or smooth depending on the cultivar. Cabbage forms a head as the leaves mature and become densely packed.

Cabbage and leafy greens are all produced for their leaves. Some types of turnip also produce a

Table 1. *Botanical classification of several types of cabbage and leafy greens*

Common Name	Genus	Species	Group	Subgroup
Green Cabbage	*Brassica*	*oleracea*	Capitata	Alba
Red Cabbage				Rubra
Savoy Cabbage				Sabauda
Kale			Acephala	none
Collard				none
Mustard		*juncea*	Pervirdis	none
Turnip		*rapa*	Rapifera	none

fleshy root harvested for consumption. These roots can vary in shape from flat-round to elongated to spherical. The outer color may be totally white or have shades of red or purple, particularly at the shoulder. Cabbage, collard and kale are hard to distinguish from one another at the seedling stage but soon develop recognizable characteristics.

All of these crops may be subject to bolting (premature appearance of a flower/seed stem). Flowering usually occurs after an extended period of exposure to low temperatures (below 50°F) followed by a period of warmer temperatures. Exposure to temperatures below 40°F or above 70°F after low temperature exposure causes rapid emergence of the seed stem. Losses to bolting in these crops occur almost every year, particularly in overwintered crops that are exposed to severe temperatures. The flowers of the crops are whitish or yellow and are pollinated by insects.

Culture and Variety Selection

William Terry Kelley and George E. Boyhan, Extension Horticulturists

Climatic Requirements

Cabbage and leafy greens are adapted to a wide range of environmental conditions and are grown throughout Georgia. Although the southwestern portion of the state produces the most, several areas contribute significantly, including the southeast and the northeast. Cabbage, collard and kale can tolerate hard frosts, but severe freezes can be damaging. Turnip and mustard can tolerate fairly cold temperatures, but hard frosts can kill the crops or make them unmarketable. All can be grown on a wide range of soil types and are somewhat drought tolerant, although production without irrigation is not recommended.

Most production of cabbage and leafy greens occurs in the spring, fall and winter months, except in the northern reaches of the state where production occurs in spring and summer. Collard production in the summer in South Georgia is generally difficult because of increased disease and insect pressure. However, many producers choose to grow it throughout the year. Mustard and turnip can be grown practically throughout the year in Georgia, but cooler temperatures make winter production unlikely in North Georgia. Heat, disease and insect pressure in the summer reduce production in South Georgia.

Crop Establishment

Turnip and mustard are direct seeded. Kale, collard and cabbage can be either direct seeded or transplanted. Transplanting has some advantages over direct seeding but also involves an increased cost. When purchasing transplants, growers should always buy Georgia-certified plants from reputable growers.

Producers of containerized plants specialize in growing plants in greenhouses that are designed specifically for the production of transplants. To contract with a grower for transplants, specify the cell size desired, the variety to be planted and a specific delivery date of the plants.

Also, determine whether the plant grower or the greens grower is to furnish the seed. The cost to the grower for this type of transplant will vary depending on the volume ordered and the cell size of the tray. Growing containerized transplants is a highly skilled, intensive operation that is usually not economically feasible for the greens producer.

Although some greens are seeded directly in the field, several recommended practices should be considered. Direct seeding has several problem areas that must be addressed:

1. Weed control is usually somewhat more difficult with direct seeding.
2. Direct seeding requires well-made seedbeds and specialized planting equipment adequate to control depth of planting and in-row spacing. Precision seeders that maximize singulation should be considered, although several types of seeders will do an adequate job.
3. Because of the shallow planting depth required, the field must be nearly level to prevent seeds from being washed away or covered too deeply with water-transported soil.

4. Spring harvest dates will be at least four weeks later for direct-seeded greens. At soil temperatures of 59°, 68° and 77°F, cabbage seeds require 15, nine and six days, respectively, for emergence. Turnip will emerge at soil temperatures of 50°, 59°, 68° and 77°F in five, three, two and one day, respectively, from seeding.

Typically, four- to six-week old cabbage, kale or collard seedlings are transplanted into the field. As with most other vegetable crops, field grown (bare-root) or container-grown transplants may be used. Container-grown transplants retain transplant growing media attached to their roots after they are removed from the container (flat or tray). Many growers prefer this type of transplant because it:

1. is less subject to transplant shock,
2. usually requires little, if any, replanting,
3. resumes growth more quickly after transplanting, and
4. grows and produces more uniformly.

Cabbage, collard and kale, like other transplants, should be hardened off before they are transplanted in the field. Hardening off is a technique used to slow plant growth prior to field setting so the plant can more successfully withstand unfavorable conditions in the field.

Cabbage, collard and kale transplants are sensitive to environmental conditions. Any condition that results in a prolonged cessation or checking of vegetative growth during the early stages of plant development can trigger the onset of bolting. Bolting is the development of small, unmarketable heads or flower stalks while the plant is still immature. Flower stalks can form when plants are grown below 50°F in the bed and are exposed to periods of cool weather (35° to 50°F) after field setting. Lack of nitrogen or other nutrient stresses as well as competition from weeds, insects or diseases that slow vegetative growth can promote flowering. Transplants that are older and less vigorous are more likely to flower than young, fast-growing plants. Bare-rooted plants that have been exposed to drying or severe water stress immediately following transplanting are also more likely to flower.

Flowering (heading out) can be prevented by:

1. Maintaining a steady, moderate rate of growth in the plant bed.
2. Setting out young, healthy transplants that have not been stressed.
3. Using transplant water to initiate root growth and remove air pockets from the soil.
4. Setting out plants under favorable conditions for growth and irrigating to relieve moisture stress.
5. Maintaining good vegetative growth, particularly for the first few weeks after field setting.

Cabbage and collard transplants should never have flower buds at transplanting. An ideal transplant is young (4 inches tall with a stem approximately 1/8 inch in diameter), exhibits rapid vegetative growth, and is slightly hardened at transplanting time. Hardening may be indicated in the greens by a slight purpling of the outer part of the leaves. Good growth following transplanting helps assure a well-established plant.

Transplants should be set out as soon as possible after they are removed from their containers or pulled. If greens transplants must be held for several days before transplanting them, keep them cool (around 55° to 65°F, if possible) and prevent the roots from drying out prior to transplanting. When setting out plants, the transplant should be planted deeply enough to completely cover the rootball (slightly deeper than they were grown).

At transplanting, an appropriate fertilizer starter solution should be applied (see the section on fertilizer starter solutions). After transplanting (especially within the first two weeks), it is very important that soil moisture be maintained so that plant roots can become well established.

Plant Spacing and Planting Dates

The optimal plant population per acre depends upon the plant's growth habit (compact, medium or spreading), size (small, medium or large) at maturity, vigor of specific cultivars, climate, soil moisture and nutrient availability, soil productivity and intended use. Table 2 gives planting dates and recommended seeding and planting information for collard, cabbage, kale, turnip and mustard.

Plant spacing for cabbage and kale is usually about 36 inches between rows and 9 to 12 inches in the row. Turnip may be spaced closely (four to six seeds per foot) if no roots are to be harvested or spread to wider in-row spacings (three to four seeds per foot) if grown for roots and tops. One popular arrangement is to grow four rows, each 14 inches apart, on a 6-foot bed. Mustard arrangements are similar to turnip grown for greens only.

Collard spacing will depend on the harvest method. If young collards are to be harvested similarly to turnip, they may be grown in rows 12 to 18 inches apart with plants 2 to 4 inches apart in the row. If they are to be cropped or cut as whole plants, they should be spaced in rows 36 inches apart with plants 12 to 18 inches apart. Kale can be grown in 30- to 36-inch rows or with three rows on a 6-foot bed with plants 9 to 12 inches apart. Cabbage grown for sauerkraut or slaw may be spaced further apart in the row.

Planting dates can vary widely. However, those crops that are planted between late October and mid-February

in South Georgia can come under significant risk of freeze injury. Although successful collard and cabbage production can be achieved with winter plantings, turnip, mustard and kale are more subject to cold damage.

Variety Selection

Numerous varieties of cabbage and leafy greens are available on the market. Several factors should be considered in selecting appropriate varieties. Yield, of course, is important to every grower. However, this should not be the sole factor in determining variety. Disease resistance/tolerance is important in many of these crops and should be critically examined. Buyer preference and market acceptability are probably two of the most important factors to consider. Horticultural characteristics such as product color, growth habit and shape should also be considered. Finally, the variety should be adapted to the area in which it is to be grown.

Local variety trials are a good source of information regarding variety selection. With any new variety, always try a small planting of the variety first before adapting it to your operation. Also, give every new variety at least a couple of tries before making a decision on its use for your production system. Environmental conditions can strongly influence varietal performance. Therefore, conditions in one year may not produce the same results in another year for a given variety. Good varieties are adaptable over a wide range of conditions. Tables 3 and 4 show some recommended varieties for Georgia production of cabbage and leafy greens.

Table 2. *Recommended planting dates and planting information for cabbage, collard, kale, turnip and mustard produced in Georgia*

	Turnip	**Mustard**	**Collard**	**Kale**	**Cabbage**
Planting Dates					
North Georgia	March-Aug.	March-Aug.	Feb.-July	March-Aug.	Feb.-July
South Georgia	Aug.-Oct. Feb.-April	Aug.-Oct. Feb.-April	Aug.-June	Aug.-Oct. Feb.-April	Aug.-March
Planting Information					
Seed/Pound	240,000	240,000	144,000	144,000	144,000
Seed/Acre, Drilled	1-2 pounds	2-3 pounds	1-2 pounds	1-2 pounds	1 pounds
Seed/Acre, Precision	1 pound	1 pound	¼ pound	¼ pound	¼ pound
Seed/Acre, Container Transplants	NA	NA	2-3 ounces	2-3 ounces	2-3 ounces
Field Transplants	NA	NA	6-8 ounces	6-8 ounces	6-8 ounces
In-row Spacing	½"-6"	5"-10"	2"-18"	8"-12"	9"-12"
Between-row Spacing	12"-36"	12"-36"	12"-36"	18"-36"	30"-42"
Seeding Depth	⅛"-¼"	⅛"-¼"	¼"-¼"	⅛"-¼"	
Seed to Harvest	35-50 days	35-50 days	60-90 days	60-80 days	90-140 days
Transplant to Harvest	NA	NA	6-10 weeks	6-8 weeks	70-120 days
Optimum Soil Temperature for Germination(°F)	60-85	60-85	50-85	50-85	50-85
Optimum Air Temperature for Crop Growth (°F)	60-65	60-65	60-65	60-65	60-65

Table 3. *Cabbage varieties recommended for production in Georgia*

Variety	Color	Head Size	Maturity	Shape
A&C No. 5 Plus	blue-green	medium	91 days	flat-round
Blue Bayou	blue-green	medium	78 days	semi-round
Blue Vantage	blue-green	4-6 pounds	72 days	round
Bravo	blue-green	4-8 pounds	85 days	round
Constanza	blue-green	4-6 pounds	90 days	round
Crimson	red	small-medium	82 days	round
Fortuna	green-blue	4-6 pounds	90 days	round
Hercules	blue-green	medium	91 days	flat-round
Izalco	blue-green	medium	105 days	round
Quisto	blue-green	medium	89 days	round
Red Dynasty	red	medium-large	70 days	round-oval
Red Rookie	red	3 pounds	78 days	round
Rio Verde	blue-green		85 days	flattened
Royal Vantage	blue-green	3 pounds	102 days	round
Savoy Acedark	green	2 pounds	80 days	round
Savoy King	green	4 pounds	111 days	semi-flat
Solid Blue No. 780	blue-green	3-4 pounds	78 days	round
Solid Blue No. 790	blue-green	3-4 pounds	79 days	round

Table 4. *Varieties of collard, turnip, mustard and kale recommended for production in Georgia*

Collard	Turnip	Kale	Mustard
Blue Max	Alamo	Blue Armor	Florida Broadleaf
Champion	All Top	Blue Knight	Slobolt
Flash	Just Right	Vates	Southern Giant Curled
Georgia	Purple Top		Tendergreen
Heavi Crop	Seven Top		
Top Bunch	Shogoin		
Vates	White Globe		

Soil and Fertilizer Management

Darbie M. Granberry, William Terry Kelley and George E. Boyhan, Extension Horticulturists

Georgia's climate, stretching from the warm Coastal Plain in the south to the cool mountain area in the northern region of the state, provides a long growing season for producing cabbage and leafy greens. Although these crops grow best in light, fertile, well-drained soils, when production is properly managed, they can be grown successfully in a wide range of soil types throughout Georgia.

Soil Management

Plants depend on the soil for physical support, nutrients and water. The degree to which the soil adequately provides these factors depends upon topography, soil type, soil structure and soil fertility. Under cultivated conditions, soil and fertilizer management are two key factors influencing plant growth and yield.

Tillage is a general term for any operation that disrupts and/or moves the soil, typically within 10 to 12 inches of the soil surface. Land preparation involves one or more tillage operations that loosens, pulverizes, smooths or firms the soil and makes it more conducive to plant establishment and root growth.

Growth of cabbage and leafy green roots is influenced (and in many cases is limited) by the soil profile. Hard pans, clay pans and generally compacted soil restrict root growth. This, in turn, reduces nutrient and water uptake, limits plant growth and reduces yields. Although cabbage and leafy greens are shallow rooted, under favorable conditions and in properly prepared soil, roots will grow to a depth of 18 to 24 inches.

Tillage with a moldboard ("bottom") plow provides the greatest soil volume conducive to vigorous root growth. Disking after moldboard plowing recompacts soil.

Compaction pans are present in many Georgia soils. They are usually formed by machinery and, when present, are normally at or just below plow depths. Even though compaction pans may be only a few inches thick, their inhibitory effects on root growth can significantly reduce yields of greens and cabbage.

If a compaction pan exists just below or near moldboard plow depth, disrupting this hard pan by subsoiling to a depth of 16 to 18 inches will allow the development of a more extensive root system and increase water infiltration.

If a lot of plants or plant residue is on the soil surface, disking (or mowing, then disking) is helpful before moldboard plowing. Immediately prior to seeding or transplanting, final soil preparation (to ensure a crust-free, weed-free friable soil) can be accomplished with a rotary tiller, bed press, bedding disk or double disk hiller with a leveling board.

Cabbage and leafy greens may be planted or transplanted on flat or raised beds. A raised bed will warm up more quickly and enhance earlier growth. Cabbage and leafy greens do poorly in excessively wet soils. Raised beds facilitate drainage and help prevent "wet feet" in low or poorly drained soils. Keep in mind, however, that cabbage or leafy greens planted on raised beds may require more irrigation during drought conditions.

Lime and fertilizer management refers to the application of optimal amounts of lime and fertilizer (or nutrient-containing materials) at the most appropriate time(s) and by the most effective method.

Fertilizer Management

Recommendations based on soil tests result in the most effective lime and fertilizer management program possible. However, recommendations can be accurate only if valid soil sampling procedures are used to collect the samples submitted for analysis. To be beneficial, a soil sample must reliably represent the field or "management unit" from which it was taken. Improperly collected, compiled or labeled soil samples are of dubious benefit and may even be detrimental. If you have questions about soil sampling, please contact your county Extension office for more information. Recent technological advances have made it possible to use quadrant sampling or global positioning techniques to tune fertility recommendations more finely, which can result in more uniform fertility throughout a given field.

Recommending a specific fertilizer management program that has universal application for all cabbage

and leafy greens fields is impossible. In addition to crop nutrient requirements and soil types, fertilizer recommendations should take into consideration soil pH, residual nutrients and inherent soil fertility. Therefore, fertilizer recommendations based on soil analysis have the greatest potential for providing cabbage and leafy greens with adequate, but not excessive, fertility. Apply only the needed amounts of fertilizer for optimum growth and yield. Excessive fertilizer application wastes fertilizer, encourages luxury consumption of plant nutrients and may cause fertilizer burn.

Soil pH

Soil pH influences plant growth, the availability of nutrients and the activities of microorganisms in the soil. Keeping soil pH in the proper range is important for production of the best yields of high quality cabbage and leafy greens. Soil test results indicate soil pH levels and are used to recommend the amount of lime required to raise the pH to the desired range.

The optimum pH range for cabbage and leafy greens production is 6.0 to 6.5. Coastal Plain soils, which predominate in South Georgia, become strongly acid (pH 5 or less) with time if lime is not applied. A soil test is essential for determining how much lime should be applied.

Calcium (Ca) has limited mobility in soil; therefore, lime should be broadcast and thoroughly incorporated to a depth of 6 to 8 inches to neutralize the soil acidity in the root zone. To allow adequate time for neutralization of soil acidity (raising the pH), lime should be applied and thoroughly incorporated two to three months before seeding or transplanting. However, if application cannot be made this early, liming will still be beneficial if applied and incorporated at least one month prior to seeding or transplanting.

Generally, maintaining a soil pH of 6.0 to 6.5 will provide adequate soil test Ca levels. When soil test Ca levels fall below 350 to 400 pounds per acre, calcium deficiency problems may develop. Because calcium levels can vary considerably in a field, soil test calcium levels on Coastal Plain soils should be maintained at 500 pounds per acre or slightly above. If the soil pH is between 6.0 and 6.5 and the soil test Ca level drops below 500 pounds per acre on Coastal Plain soils, apply 800 to 1,000 pounds of calcium sulfate (gypsum) per acre.

Two liming materials commonly available in Georgia are calcitic and dolomitic limestone. In addition to calcium, dolomitic limestone contains 6 percent to 12 percent magnesium. Because Coastal Plain soils are inherently low in magnesium, dolomitic limestone is usually the preferred liming material.

Phosphorus and Potassium Recommendations

The following chart indicates the pounds of fertilizer nutrients recommended for varying soil fertility levels according to University of Georgia soil test ratings of residual phosphorus (P) and potassium (K).

Fertilizer Recommendations for Cabbage and Leafy Greens

Ratings	Low	Medium	High	Very High
Recommended P	160	110	60	0
Recommended K	160	110	60	0

P – pounds of P_2O_5 recommended per acre
K – pounds of K_2O recommended per acre

NOTE: If soil testing is done by a lab other than the University of Georgia Soil Testing Laboratory, the levels recommended above may not apply.

All the recommended phosphorus should be applied during or near the time of transplanting. One-third to one-half of the potassium should either (1) be applied in two bands, each 2 to 3 inches to the side and 2 to 3 inches below the level of plant roots or (2) be incorporated into the bed prior to seeding or transplanting. Broadcasting over the entire field is usually less effective than banding. An acceptable alternative to field broadcasting is the "modified broadcast" method by which a preplant fertilizer containing one-third to one-half of the nitrogen and potassium and all the recommended phosphorus and micronutrients is broadcast in the bed area only. For example, on a 72-inch-wide bed, a swath (60 to 72 inches wide) of fertilizer is uniformly applied centered over the bed. Incorporation by rotary tilling will help reduce water and wind movement of the fertilizer and will also place some fertilizer in the root zone. The remainder of the recommended nitrogen and potassium should be applied in one to three applications as needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. On sandy soils, the maximum number of applications is usually more effective.

Nitrogen Recommendations

For production of cabbage and leafy greens, Coastal Plain soils require 175 to 225 pounds of nitrogen (N) per acre. Extremely sandy soils may need additional N or an

increased number of applications. Increasing the number of applications may prove beneficial because it will cut down on the amount lost to leaching from adding too much fertilizer at one time. Piedmont, Mountain and Limestone Valley soils usually require 150 to 180 pounds of N per acre for cabbage and greens production.

Required N rates will vary depending on season rainfall, soil type, soil temperature, irrigation, plant population, and method and timing of applications.

For typical Coastal Plain soils, one-fourth to one-third of the recommended nitrogen should be incorporated in the bed prior to seeding or transplanting. Broadcasting over the entire field is usually less effective than banding.

An acceptable alternative to field broadcasting is the "modified broadcast" method (described under "Phosphorus and Potassium Recommendations"). Incorporation by rotary tilling will help reduce water and wind movement of the fertilizer and will place some fertilizer in the root zone. Apply the remaining recommended N in one to three applications as needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. For heavier Piedmont, Mountain and Limestone Valley soils, one or two applications are usually sufficient.

Magnesium, Sulfur, Zinc and Boron Recommendations

If the soil test indicates magnesium is low and if lime is recommended, apply dolomitic limestone. If magnesium is low and lime is not recommended, apply 25 pounds of elemental magnesium per acre. Apply a minimum of 10 pounds of sulfur per acre, 1 pound of actual boron per acre, and, if soil test indicates zinc is low, 5 pounds of actual zinc per acre. Sulfate of potash magnesia (Sul-Po-Mag or K-Mag) may be used to supply a portion of the recommended K_20 and to supply magnesium (Mg) and sulfur (S).

Starter Fertilizer Solution

Liquid fertilizers applied to the soil around plant roots are called starter solutions. They promote rapid root development and early plant growth. Starter solutions for cabbage and leafy greens transplants should contain a high rate of phosphorus (an approximate ratio of 1 nitrogen: 3 phosphorus: 0 potassium is common) and should be mixed and applied according to the manufacturer's directions. Most starter solutions consist of 3 pounds of a formulated material (such as 10-34-0, which weighs approximately 11 pounds/gallon) mixed in 50 gallons of water. Approximately ½ pint of the starter solution is normally applied per plant. Application of about 100 to 150 pounds per acre of a starter fertilizer promotes earlier growth, particularly in cool/cold soils. For early growth stimulation, pop-up fertilizer should be banded 2 to 3 inches to the side of the plants and 2 to 3 inches below the roots. In addition to supplying phosphorus, which has limited availability in cold soils, the starter solution supplies water and firms the soil around roots (eliminating air pockets, which cause root drying). However, a starter solution is no substitute for adequate rainfall or irrigation after transplanting.

Mix and apply starter fertilizer according to the manufacturer's recommendations. If it is too concentrated, a starter solution can kill plant roots and result in dead or stunted plants. When mixing and applying from a large tank, mix a fresh solution only after all the previous solution is used from the tank. This helps prevent the gradual increase in concentration that occurs when a portion of the previous mix is used for a portion of the water component in subsequent batches.

Foliar Fertilizer Application

The fact that plants can absorb a number of fertilizer elements through their leaves has been known for some time. However, leaves of many vegetable plants are not especially well adapted for absorbing nutrients because they have a waxy cuticle. In fact, plants may appear to benefit from foliar uptake when the actual cause of improvement may be from the component of the nutrient spray that reaches the soil and provides essential nutrients for subsequent root uptake.

The effectiveness of applying macronutrients such as nitrogen, phosphorus and potassium to plant leaves is questionable. It is virtually impossible for greens (waxy leaved cabbage, collard and kale) to absorb enough N, P or K through their leaves to meet their nutritional requirements; furthermore, they are unlikely to absorb sufficient amounts of macronutrients to correct major deficiencies. Although nitrogen may be absorbed within 24 hours after application, up to four days are required for potassium uptake, and seven to 15 days are required for phosphorus to be absorbed from foliar application.

The crucial question is whether foliar N, P or K actually increases yield or enhances quality. Although some growers feel that foliar fertilizer should be used to supplement a soil-applied fertilizer program, research findings do not support this practice. If proper fertilizer management of soil-applied nutrients is

used, supplementation by foliar fertilization is not usually required.

Foliar nutrients often are expected to cure a variety of plant problems, many of which may be unrelated to nutrition, such as reducing stress, aiding in healing frost- or hail-damaged plants or increasing plant resistance to various stresses and pests. Nutrients are effective as long as they are supplying a nutritional need; however, neither soil-applied nor foliar-applied nutrients are capable of performing miracles.

After frost or hail occurs, some cabbage and leafy greens growers apply foliar nutrients to give the plants an "extra shot" to promote rapid recovery. However, if a proper fertilizer program is being used before foliage damage occurs, the plants don't need additional fertilizer. What they do need is time and the proper environment for the normal recovery processes to occur. The likelihood of deriving significant nutritional benefits from a foliar application of fertilizer to plants that have lost some of their leaves (or have a large proportion of their leaves severely damaged) is questionable.

Foliar application of sulfur, magnesium, calcium and micronutrients is helpful in correcting deficiencies. To alleviate boron deficiency, apply water-soluble boron (l lb/boron per acre). Magnesium sulfate (3 lb/acre) can be applied to correct a magnesium deficiency. CaB, a commercially available formulation containing 2 percent boron and 6 percent calcium, can be applied at the rate of 2 quarts per acre to help alleviate calcium and boron deficiencies. Other acceptable foliar fertilizer formulations may also be available. When using foliar fertilizers (1) check the label for percent active ingredients — know what and how much fertilizer you are applying — and (2) apply according to label instructions. Apply foliar fertilizers only if a real need for them exists and only in quantities recommended for foliar application. Application of excessive amounts can cause fertilizer burn and/or toxicity problems.

Tissue Analysis

Fertilizer recommendations provide general guidelines for the application of fertilizers to crops. Actual amounts needed will vary depending on soil type, the amount of leaching and crop growth. Routine tissue analyses (tables 5 and 6) and sap tests (Table 7) are excellent tools for fine tuning fertilizer management.

Presently we do not have tissue and sap tests recommendations for all vegetable crops. We will provide recommendations for other vegetable crops when they are developed.

Table 5. *Plant tissue analysis critical values for cabbage*

Nutrient	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)	Cu (ppm)	Mo (ppm)
Status	***Five Weeks After Transplanting[1]***											
Deficient	<3.2	<0.3	<2.8	<0.8	<0.25	–	<30	<20	<30	<20	<3.0	<0.3
Adequate Range	3.2-6.0	0.3-0.6	2.8-5.0	1.1-2.0	0.25-0.6	0.3-0.6	30-60	20-40	30-50	20-40	3.0-7.0	0.3-0.6
High	>6.0	>0.6	>5.0	>2.0	>0.6	–	>100	>40	>50	>40	>10	–
	Eight Weeks After Transplanting[1]											
Deficient	<3.0	<0.3	<2.0	<0.8	<0.2	<0.3	<30	<20	<30	<20	<3.0	<0.3
Adequate Range	3.0-6.0	0.3-0.6	2.0-4.0	1.0-2.0	0.25-0.6	0.3-0.8	30-60	20-40	30-50	20-40	3.0-7.0	0.3-0.6
High	>6.0	>0.6	>4.0	>2.0	>0.6	>0.8	>100	>40	>50	>40	>10	0.6
	Heads One-half Grown[2]											
Deficient	<3.0	<0.3	<1.7	<0.8	<0.25	–	<20	<20	<20	<30	<4.0	<0.3
Adequate Range	3.0-4.0	0.3-0.5	2.3-4.0	1.5-2.0	0.25-0.45	0.3	20-40	20-40	20-30	30-50	4.0-8.0	0.3-0.6
High	>4.0	>0.5	>4.0	>2.0	>0.45	–	>100	>40	>40	>50	>10	–

1 Most recently mature leaf sampled.

2 Wrapper leaf sampled.

Adapted from *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida Publication SS-Vec-42. January 1991.

Table 6. *Injection schedule for N and K for cabbage and collard planted two rows per 6-foot bed on soils testing medium for K*

	Total Nutrients (lb/A)		Crop Development		Injection (lb/A/day)[1]	
Crop	**N**	**K_2O**	**Stage**	**Weeks[2]**	**N**	**K_2O**
Cabbage	175	110	1	3	1.5	1.0
Collard	175	110	2	7	2.5	1.5
			3	2	1.5	1.0

1 Actual amounts may vary depending on preplant fertilizer and soil test K.
2 Starting from seeding or transplanting. First two weeks may be omitted if 25 percent of total N and K were applied preplant.
Adapted from *Vegetable Production Guide for Florida*. Pub. No. SP 170. University of Florida Cooperative Extension Service. April 1999.

Table 7. *Plant tissue analysis critical values for collard*

Nutrient	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)	Cu (ppm)	Mo (ppm)
Young Plants[1]												
Deficient	<4.0	<0.3	<3.0	<1.0	<0.4	–	<40	<40	<25	<25	<5	–
Adequate Range	4.0-5.0	0.3-0.6	3.0-5.0	1.0-2.0	0.4-1.0	–	40-100	40-100	25-50	25-50	5-10	–
High	>5.0	>0.6	>5.0	>2.0	>1.0	–	>100	>100	>50	>50	>10	–
At Harvest[2]												
Deficient	<3.0	<0.25	<2.5	<1.0	<0.35	<0.3	<40	<40	<20	<25	<5	<0.3
Adequate Range	3.0-5.0	0.25-0.5	2.5-4.0	1.0-2.0	0.35-1.0	0.3-0.8	40-100	40-100	20-40	25-50	5-10	0.3-0.8
High	>5.0	>0.5	>4.0	>2.0	>1.0	>0.8	>100	>100	>40	>50	>10	>0.8

1 Tops of young plants sampled.
2 Most recent mature leaf sampled.
Adapted from *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida Publication SS-Vec-42. January 1991.

Table 8. *Sufficiency ranges for petiole sap testing in collard*

	Fresh Petiole Sap Concentration (ppm)	
Crop Development Stage	**NO_3-N**	**K**
Six-leaf Stage	800-1,000	NR
One Week Prior to First Harvest	500-800	NR
First Harvest	300-500	NR

NR – No recommended ranges have been established.
Adapted from *Vegetable Production Guide for Florida*. Publication No. SP 170. University of Florida Cooperative Extension Service. July 1996.

Cabbage Disease Management

David B. Langston, Jr., Extension Plant Pathologist

Cabbage and leafy greens are susceptible to a number of diseases that may seriously injure or even destroy the crop. Some diseases may cause only minor spotting, but because the leaves are consumed, the quality may be reduced below market standards. Prevention is the key to controlling all diseases affecting crucifers. Some of the diseases can be controlled with timely fungicide applications and others must be prevented altogether. This section will aid in the identification of diseases and discuss environmental conditions that favor disease development. Sources of infection are discussed relative to specific diseases on specific crops.

Black-rot (Figure 1)

Black-rot, caused by the bacterium *Xanthomonas campestris* pv. *campestris*, is the most serious disease of crucifers in Georgia. The bacterium attacks many species of the mustard family. Among these are cabbage, collard, kale, mustard and turnip. Plants may be affected at any stage of growth. This disease is seedborne and is often introduced by contaminated seeds or infected transplants. In some areas of the country, the disease is of minor importance; however, under Georgia conditions, the disease becomes serious and many growers sustain severe economic loss. In some cases, the crop may be destroyed. In the field, the disease is easily recognized by the presence of large yellow to yellow-orange V-shaped lesions extending inward from the margin of the leaf.

When infected seeds germinate, the resulting young plants usually die quickly; however, these plants serve as an inoculum source for other plants. If infection occurs in young seedlings, the disease is much more severe because the main stem becomes infected and the disease becomes systemic and moves throughout the plant. These plants remain stunted and the veins in the stem are black. Heads developed from these plants deteriorate rapidly after harvest.

The bacterium enters the vascular system of the plant principally through natural openings and injuries on the leaf. In time, the bacterium spreads in the vascular system of the leaf and stem. The disease spreads and causes most damage in wet, warm weather. It does not usually spread in dry weather and is inactivated at temperatures below 50°F. The bacterium can survive in the soil for 14 to 42 days, depending on the season, and in old cabbage stems for 244 days. The disease is also carried over on weed hosts such as “pepper grass” and with wild species of mustard, radish and turnip. The bacterium is spread by splashing rain, irrigation and running surface water as well as insects and other movement in the field while the plants are wet. Disease management strategies such as crop rotation away from

Figure 1. *Black-rot*

Figure 2. *Wirestem, bottom rot and head rot*

contaminated land for two years and use of certified seed or transplants are effective. There is no remedial control for this disease

Wirestem, Bottom Rot and Head Rot (Figure 2)

Wirestem, bottom rot and head rot are caused by *Rhizoctonia solani*. This fungus also is a common cause of damping-off. Wirestem is normally more serious in transplant beds; however, it can be a serious problem after plants are transplanted to the field. Cabbage, collard and kale planted in early fall are more vulnerable to *Rhizoctonia* injury than spring plantings. Wirestem infected plants are first infected near the soil surface. The initial infection site may be as small as a pinpoint or extend an inch up the stems. This area shrivels and becomes reddish brown; outer tissues slough off, leaving the woody inner stem exposed. The infected plant may be bent or twisted without breaking — hence the name.

The wirestem fungus is common to most Georgia soils. The amount of *Rhizoctonia* present is greatly influenced by the cropping history. Wirestem damage may be suppressed by adding a fungicide to the transplant water. Frequent irrigations during hot dry periods will reduce the incidence of the disease; water evaporation cools the soil surface.

Rotating with grain crops, deep turning and using a fungicide in the transplant water will greatly reduce the incidence of disease.

Black Leg

Black leg, caused by the fungus *Phoma lingam*, is another disease that can cause serious loss to cabbage. Plants are usually infected in seedbeds. Usually the first symptom is an oval, depressed, light brown canker near the base of the stem. The canker enlarges until the stem is girdled. Circular light brown spots also appear on the leaves. Soon after cankers or spots begin to form, they are marked with numerous black dots that are the fruiting bodies of the fungus. The fungus lives for at least three years in the soil and is carried on and in the seeds. Black leg is influenced by environmental conditions, with the severity of the disease in direct proportion to the amount of rainfall received. The fungus grows well at all temperatures suitable to cabbage.

Alternaria Leafspot (Figure 3)

Alternaria leafspot, caused by the fungus *Alternaria brassicae*, may cause severe damage if left uncontrolled. The first symptom is a small dark spot on the leaf surface. As the spot enlarges, concentric rings, which are common to this disease, develop. Blight spots enlarge progressively and can defoliate a plant if left uncontrolled. Alternaria leafspot is best controlled by applying a fungicide on a schedule throughout the entire growing season.

Downy Mildew of Cabbage, Collard and Kale (Figure 4)

Downy mildew, caused by the fungus *Peronospora parasitica*, can be transferred from the transplant bed; however, it also can be introduced to new field plantings by windblown spores. Plants can be infected at any time during their growing period. Young plants infected early show a white mildew effect mostly on the underside of the leaf; later, a slight yellowing can be observed on the corresponding upper surface. The young leaf, when yellow, may drop off. Older leaves enlarge as they turn tan

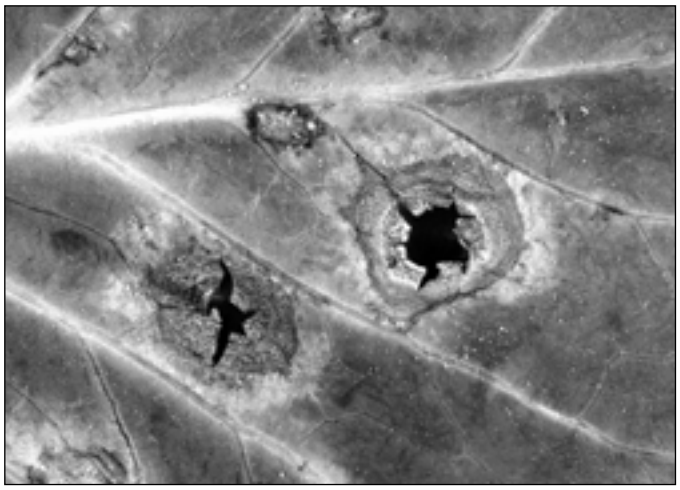

Figure 3. *Alternaria leafspot*

Figure 4. *Downy mildew*

Figure 5. *Sclerotinia sclerotiorium*

Figure 6. *Cabbage yellows*

in color and papery in texture. The fungus produces a mass of gray growth, conidia, on the undersurface of the leaves. The conidia, or seed bodies, are able to float long distances in cool moist air. With favorable weather, they may germinate in three to four hours and produce a new crop of seed bodies on a susceptible host in as few as four days.

Moisture and temperature are very important to the reproduction of this disease. Drizzling rains and cool weather are very favorable for disease development. The fungus grows best and disease develops most rapidly when the night temperatures are about 46°F for four or more consecutive nights and the day temperature does not rise much above 75°F. A preventive spray schedule will help control downy mildew.

Downy mildew can infect turnip and mustard at any stage of growth. A grayish mold forms in spots and on the undersurface of the leaf. Later, a slight yellowing shows on the upper surface. Infected spots enlarge as they turn tan in color and papery in texture. When the disease is severe, the entire leaf dies. Heavily infected leaves may have a watery appearance, wilt and die before the mold growth is evident. Occasionally, affected leaves will show hundreds of very small, darkened specks.

Downy mildew overwinters in turnip roots or on old tops left in the field. The fungi form thick-walled resting spores in the turnip stem. These tiny bodies become mixed with seed at harvest and can be shipped to new locations.

Downy mildew can destroy a field of greens within three to four days after it is first noticed. Usually, damage is most severe on cabbage and leafy greens grown in the spring because conditions favoring its development are more likely to occur at this time.

Sclerotinia sclerotiorium (Figure 5)

Sclerotinia sclerotiorium is becoming more prevalent in cabbage fields as well as transplant beds and greenhouses. Recently this disease has also been identified on turnip, mustard and kale. The disease usually begins on the lower stem, causing a watery soft rot followed by white, cottonlike growth. Black sclerotia, overwintering structures that give rise to the spore-producing apothecia, develop later. The disease is favored by cool, wet weather, which may result in a massive steamlike cloud of spores being spread throughout an area. The disease can infect cabbage from the seedling stage to maturity. On mature cabbage, the entire head is often covered with the white mycelium and black sclerotia, sometimes referred to as “raisin head.” The entire heads melt down, basically leaving a pile of sclerotia. The remarkable thing about this disease is that it does not cause any odor during the destructive process unless other saprophytic organisms invade, which do cause odor.

The best defense against this disease is to transplant disease-free transplants and cultivate to cover any sclerotia. No chemical fungicides are recommended. Good rotation practices are usually all that is needed to manage the disease.

Cabbage Yellows (Figure 6)

Cabbage yellows is caused by *Fusarium oxysporum* f.sp. *conglutinans*. The cabbage strain severely attacks many varieties of kale, cabbage and collard, and moderately affects turnip. The disease is often confused with black rot because of the similar symptoms. Both diseases cause leaf drop, curving stalks and the formation of buds on leafless stems. Yellows is

Figure 7. *Cercospora leafspot (left), cercosporella leafspot (center) and anthracnose*

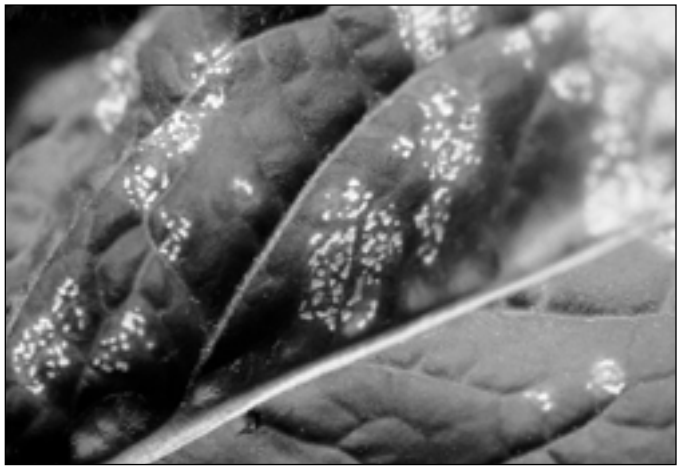

Figure 8. *White rust of spinach*

more likely to produce a curve in the midrib or cause the leaf to grow on only one side. *Fusarium* can live for several years in the soil without being associated with any plant parts. After the pathogen becomes established, it spreads by rain and by equipment moving from one field to another. The fungus enters root hairs, and spores are produced inside and outside of affected stems. Most currently recommended varieties are resistant to yellows.

Leafspots of Mustard and Turnip

Leafspot of mustard and turnip is most often caused by downy mildew *(Peronospora parasitica*), white spot (*Cercosporella brassicae*), anthracnose (*Colletotrichem higginisianum*) and cercospora leafspot (*Cercospora brassicicola*).

Cercospora Leafspot *(Figure 7, left)*

Cercospora leafspot is also a major problem on mustard and turnip. This disease is sometimes called frog-eye leafspot. Both *Cercospora* and *Cercosporella* develop under similar environmental conditions. The disease is most prevalent in a temperature range of 55° to 65°F, with plenty of moisture.

Cercosporella Leafspot *(Figure 7, center)*

This fungus is primarily a problem on turnip and mustard. The spots caused by *Cercosporella* are white and much larger than those caused by *Cercospora*, and are referred to as pale-spot.

White spot causes pale green to grayish white circular to angular spots on leaves. Each spot has a yellowish to brown halo or border around it. Numerous spots may occur on one leaf and merge, killing the entire leaf.

White spot overwinters on such plants as turnip, mustard, collard, cabbage and kale. The fungus produces numerous spores in each infected spot on the leaf. The spores are blown long distances by the wind. White spot reproduces and spreads at a temperature of 71° to 86°F. This disease is usually more damaging to the fall greens crop.

Anthracnose *(Figure 7, right)*

Anthracnose is often a serious problem on turnip and mustard and can infect kale and collard. The leafspots are small, pale gray desiccated circular spots. The same fungus infects turnip roots when spores fall from the leaves to the roots. The infected areas begin as small sunken dry spots. Under moist conditions, bacterial soft rot develops, destroying the entire root. The fungus overwinters on crop debris and in volunteer plants. The disease is most severe at temperatures of 79° to 86°F, with plenty of moisture. The disease is prevented by rotation, deep turning and fungicide sprays.

White Rust (Figure 8)

White rust is most often seen on spinach and is caused by *Albugo* sp. White rust affects other crucifers. It has been observed on mustard in a few instances. The disease overwinters by means of oospores. In perennial hosts, such as horseradish, it persists in crowns and roots. Secondary spread is by conidia (spores), which are carried by air currents. Moisture on the host surface is essential for germination. White rust is recognized by a white growth, usually on the underside of the leaves. White rust is controlled by soil and foliar applied fungicides.

Figure 9. *Root-knot nematode*

Figure 10. *Viruses*

Figure 11. *Viruses*

Root-knot Nematode (Figure 9)

Root-knot nematode is the only nematode of economic importance that affects crucifers. All species of root-knot are considered pests of crucifers. Cabbage, turnip, mustard and spinach are the main crops affected. Stunted growth and chlorosis are the above-ground symptoms. Classic galling of the root system is key for diagnosing root-knot nematode damage. Rotation and chemical treatment are the control practices.

Viruses (figures 10, 11)

Turnip mosaic virus disease is caused by any of many strains of turnip mosaic. These strains infect almost every crucifer, including weeds such as shepherd's purse and charlock.

Infected cabbage plants have mottled, distorted leaves. The production of leaf bloom is reduced, and the whole plant is stunted, especially when infected early in the season. Some strains show a darkened ring effect, especially on the older foliage, and irregular dead areas between the veins. This virus may be responsible for a stippling symptom on the outer and inner leaves of cabbage heads. The virus overwinters in perennial weeds. It is carried by many species of aphids.

Cauliflower mosaic virus disease is found more frequently on turnip. Plants infected are rarely stunted, but most express a mosaic pattern. The most distinctive symptom is vein clearing. On cabbage, a black stippling symptom develops on the outer leaves of the mature heads.

Cabbage mosaic causes black specking of cabbage heads at harvest or during storage. This mosaic is caused by a single or dual infection of viruses. A strain of turnip or cauliflower mosaic virus may be responsible. Infections late in the season cause minor losses, and early infections cause serious losses. The turnip and cauliflower mosaic viruses are transmitted principally by cabbage aphids and green peach aphids. Neither virus is seedborne.

Tomato spotted wilt virus (TSWV) can infect cabbage at any stage of growth. The virus is transmitted by thrips and has been identified in Georgia since 1989.

Insect Management

David B. Adams, Extension Entomologist

On-farm Components of Insect Management

Researchers, farmers and agricultural consultants often overlook the basic principles of on-farm insect management when faced with insecticide-resistant pests that attack cabbage and leafy greens. Although theoretical principles may not always apply when working on the farm, certain fundamental practices can greatly enhance the chances of effectively controlling these insects.

For example, diamondback moth caterpillar (DBM) resistance to insecticides has been documented for all major insecticide classes: carbamates, organophosphates and pyrethroids. Although very few currently registered insecticides for cabbage or other leafy greens are effective against diamondbacks, the pests can be controlled in cabbage on Georgia farms. Various formulations of *Bacillus thuringiensis* (BT), occasionally tank-mixed with certain organophosphate insecticides, have had continued success. On-farm tests have consistently yielded 85 percent or more marketable cabbage where these compounds have been used with the following basic practices:

- use of specially designed high pressure/high volume application equipment;
- application of insecticides at delivery speeds of no more than 4 mph;
- early, close-interval applications (every five days or less) of BT;
- the addition of adequate spreading/sticking agents;
- use of an organophosphate insecticide tank-mixed with BTs only as needed when DBM populations begin to increase;
- avoidance of insecticides that have proven to antagonize efforts to control DBM; and
- pest population monitoring so that other insecticides can be used only when necessary.

Although these measures will not eliminate insecticide resistance, they will help to reverse it. After several years of this method of management, DBM can develop strains that will again be susceptible to currently ineffective insecticides.

Foliage-feeding Caterpillars

Foliage feeders are the most important pests of cabbage and always pose a serious threat to quality and yield. Even though resistance to insecticides is a major concern, the single most significant problem in control of these pests is the difficulty in maintaining adequate coverage of the plants with insecticidal spray. Most of the eggs of the caterpillar pests are laid either in masses or singly on the underside of the foliage. The larvae, until mature, generally feed on the underside of the foliage or in the bud, making control very difficult.

Another significant problem is that different species of caterpillars are susceptible to different insecticides. When several species are infesting cabbage and greens at the same time, several insecticides may be necessary for adequate control. This increases the cost of production and also creates antagonistic effects in the control of certain pests. Identifying the species complex of a given infestation, maintaining control of the primary species and making judicious insecticide applications for the less significant pest as its population begins to increase are extremely important.

Diamondback moth caterpillar

(figures 12, 13, 14, 15)

The diamondback moth caterpillar (DBM), *Plutella xylostella*, is the single most destructive pest to cabbage and leafy greens worldwide. Insecticide resistance has been documented in every corner of the globe; DBM is the key pest in most crucifer cultures. By definition, a key pest is the species whose presence triggers the initial, often early, insecticide applications. These early applications often destroy the natural enemies of both the key pest and secondary pests. Secondary pests may then become economically important. Biorational compounds that are "soft" on natural enemies and provide adequate control of DBM have found a solid niche in our current management strategies.

Except for the adult stage, DBM completes its whole life cycle on the plant. DBM moths lay eggs singly on the underside of leaves. The larvae hatch in a

Figure 12. *Diamondback moth caterpillar (adult)*

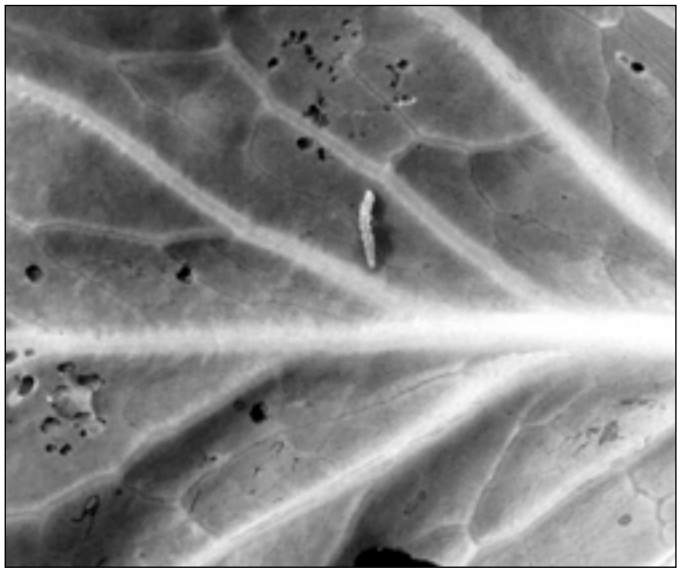

Figure 13. *Diamondback moth caterpillar (young larva)*

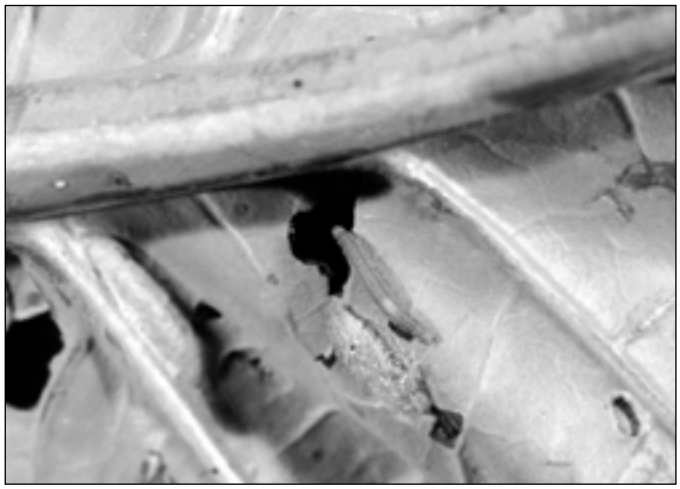

Figure 14. *Diamondback moth caterpillar (mature larva)*

day or so and feed on the underside. The larvae grow as large as $^{5}/_{8}$ inch. The larvae are green and hang by silken threads when disturbed. They are very active when disturbed. Initial damage is small incomplete holes caused by young larvae and larger complete holes caused by mature larvae. The holes become larger as the leaf develops. The entire plant may become riddled with holes under moderate to heavy populations. Larvae also feed in the developing heads of cabbage, causing deformed heads and encouraging soft rots. The pupae of DBM are green and encased in a netlike cocoon attached to the foliage. Pupae reduce quality as a contaminant.

DBM attacks all types of leafy greens and cole crops during all parts of the growing season. DBM is a cold-hardy species, so it can survive cold temperatures in the caterpillar stage. During temperatures below approximately 50°F, larvae cease to feed. As the temperature rises above this mark, feeding resumes. The life cycle is retarded during cooler temperatures. In contrast to this, DBM populations may increase dramatically at temperatures above approximately 80°F. The life cycle may be as long as 50 days at low temperatures and as short as 15 to 20 days during high temperatures. There may be 10 or more generations during warm years.

Suppression of DBM populations with preventive treatments is the most efficient control method. Preventive treatments with biological compounds should be made on a five-day interval. A seven-day interval may be used if no worms are found, especially during cool winter weather. Cleanup sprays may be necessary periodically. Heavy rain showers may reduce populations dramatically. Monitor crops two to three times per week and make decisions on changes in control strategies.

Note: Transplant beds should be kept free of infestation.

Figure 15. *Diamondback moth caterpillar damage*

Cabbage Looper *(figures 16, 17, 18)*

The cabbage looper, *Trichoplusia ni*, is the second most destructive pest to cabbage and leafy greens, and at times is the key pest in Georgia. Biological insecticides are moderately effective, and other insecticides often are needed for adequate control.

The cabbage looper is most destructive in early summer and fall. The larvae are large worms (up to 1½ inches) that feed on leaves, creating large holes. Larvae are sluggish and hold on to the plants tenaciously when attempts are made to remove them. This is the only caterpillar pest that has only three pairs of fleshy prolegs near the rear. Except for the adult, the cabbage looper is like the DBM, spending its entire life cycle on the plant. The eggs are laid on the underside of the leaves, and larvae hatch and feed on the underside, with the pupae attached to the underside in a protective cocoon. The pupae are green and two to three times as large as DBM pupae.

Controls should be initiated at the first signs of moth activity, whether this is eggs or young larvae. Monitoring the crop two or three times per week helps in making control decisions.

Cabbage Webworm *(Figure 19)*

The cabbage webworm, *Hellula rogatalis*, is occasionally a serious pest of cabbage, collard and kale. When it occurs, growers are usually caught off guard. Because it has a habit of feeding in the bud area, producing moderate to heavy webbing, growers have difficulty controlling it.

Mature larvae are about ¾ inch long and have five dark stripes on a dirty gray body. The head capsule is black with a distinct, white V-shaped mark.

Control for the webworm should be initiated at the first signs of an infestation. Some of the same insecticides used against the cabbage looper give good control if coverage in the bud area is excellent.

Figure 16. *Cabbage looper (adult)*

Figure 17. *Cabbage looper (larva)*

Figure 18. *Cabbage looper (pupa)*

Figure 19. *Cabbage webworm*

Figure 20. *Imported cabbage worm (adult)*

Figure 21. *Imported cabbage worm (larva)*

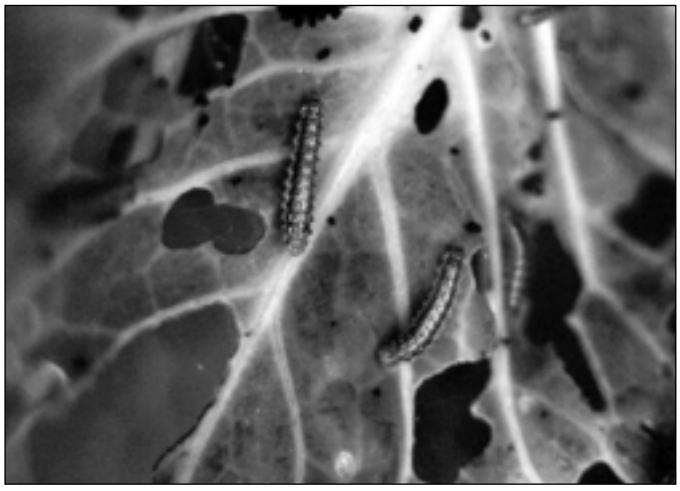

Figure 22. *Cross-striped cabbageworm*

Figure 23. *Beet armyworm*

Imported Cabbageworm *(figures 20, 21)*

The imported cabbageworm, *Pieris rapae*, is rarely an economic pest on cabbage and leafy greens if controls for other worms are being applied. The adult is a common butterfly that lays eggs singly on the leaf surface. The larvae are green and have a velvety appearance. Larvae have a narrow, light yellow stripe down the back. Initiate controls when a buildup of larvae occurs.

Cross-Striped Cabbageworm *(Figure 22)*

The cross-striped cabbageworm, *Evergestis rimosalis*, is occasionally a pest in the cooler, northern part of Georgia. It is usually not too difficult to control if the crop is being monitored and timely controls are initiated.

The larvae may be slightly longer than ¾ inch and have black and white transverse stripes down the back. Below the transverse stripes on each side is a black and yellow stripe along the length of the body. Initiate controls when larvae are observed.

Beet Armyworm *(Figure 23)*

The beet armyworm, *Spodoptera exigua*, may be a pest to fall plantings of cabbage, collard, kale, mustard and turnip. Heavy populations that have increased on other crops move to greens crops when food sources become scarce. Diseases during this period often suppress populations below an economic level, but occasionally the beet armyworm can devastate a crop. The beet armyworm is one of the most difficult caterpillars to control. It is naturally resistant to most commonly used insecticides. If it develops into very large populations, control might not be regained.

The moth lays masses of eggs on the undersides of leaves. The mass may have up to 150 eggs and is covered with scales off the moth's body, giving the mass a cottony appearance. The larvae are light green to dark olive green and sometimes have stripes of these colors down the back. Above the second pair of legs near the head end is a black spot. Larvae may be 1¼ inches long.

Initiate controls if egg masses or larvae are found on 2 percent to 3 percent of the plants. To suppress small populations, apply pesticide every five days. A three- to four-day spray interval may be necessary to bring moderate to heavy populations under control.

Corn Earworm *(Figure 24)*

The corn earworm, *Helicoverpa zea*, formerly *Heliothis zea*, can be a pest of almost any crop but creates the most serious threat to cabbage. The larvae tunnel into the buds of young plants and the heads of older plants. The larvae are common on many plants and are easily recognized when extracted from the tips of ears of field corn.

Make treatments when small larvae are observed on 4 percent to 5 percent of the plants or if large larvae are found on 2 percent or more on the plants.

Figure 24. *Corn earworm*

Cutworm *(Figure 25)*

The granulate cutworm, *Feltia subterranea*, is the most common species in Georgia's cabbage and leafy greens production areas. Cutworms may survive the winter in the larval stage, so large larvae may be present at the time of planting, especially when planting is made into previous crop residue. Cutworms are recognizable by their greasy dingy gray color and C-shaped posture when at rest. Cutworms feed at night, causing damage to stems and foliage, and retreat into the soil during the day. Treatments for cutworms should be anticipated by inspecting the soil during land preparation so insecticides can be incorporated at planting.

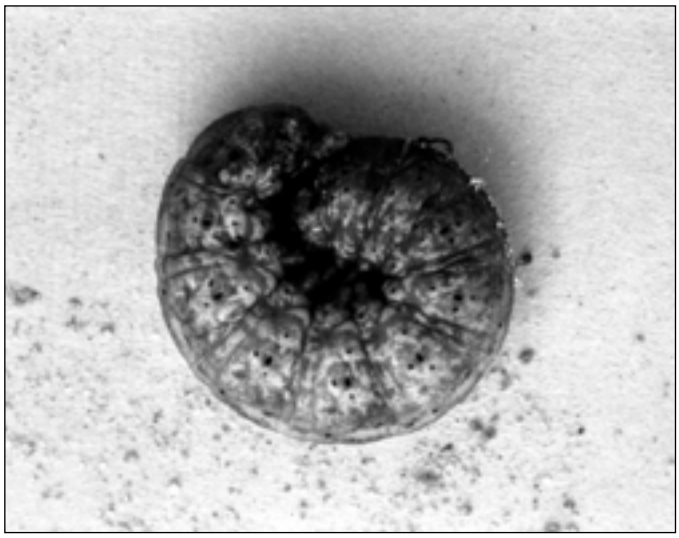

Figure 25. *Cutworm*

Other Pests

Seedcorn Maggot *(Figure 26)*

The seedcorn maggot, *Delia platura*, is a secondary pest that attacks many types of plants. The maggot is a general feeder that is attracted to decaying organic matter. When seedlings are placed under stress, they are most subject to attack by the seedcorn maggot. This occurs most often during the cooler months of planting when transplants are developing slowly.

The immature stage is the maggot, which eventually becomes a small housefly-like adult. The maggot damages the plant by entering the roots and stem. Usually, the plant is weakened beyond recovery. Many plants can be killed.

The most effective control is to anticipate the conditions that create a favorable environment for maggot attacks and apply the preventive, soil-applied insecticides. Cabbage and collard are the most susceptible to attack.

Figure 26. *Seedcorn maggot*

Figure 27. *Cabbage aphids*

Figure 28. *Green peach aphids*

Figure 29. *Turnip root aphids*

Aphids

Several species of aphids attack cabbage and leafy greens. Aphids may be present in fields all year, but they do not always cause significant damage. Aphids are subject to control by several diseases and insect parasites. If broad-spectrum pesticides are used sparingly during the early stages of plant development, aphids usually pose very little threat. However, under conditions that favor rapid development, aphid populations can explode to damaging levels. Cool, dry weather during the spring or fall is ideal for the development of high populations.

Cabbage Aphid (Figure 27)

The cabbage aphid, *Brevicoryne brassicae*, is found throughout Georgia. Its appearance differs from other species, with a powdery, waxy covering over its body. Its body is grayish-green. This aphid feeds primarily on cabbage, collard and kale, and seldom feeds on mustard or turnip. The cabbage aphid is difficult to control and should be monitored closely when it is discovered colonizing. Treatments should be made if populations spread beyond the small initial colonies.

Turnip Aphid

The turnip aphid, *Lipaphis erysimi*, resembles the cabbage aphid, but lacks a waxy covering and is pale green. The turnip aphid feeds mostly on turnip and mustard. It is difficult to control when conditions favor rapid development.

Green Peach Aphid (Figure 28)

The green peach aphid, *Myzus persicae*, is the most common aphid in Georgia and feeds on many vegetable crops and row crops. The wingless types are yellowish-green, green or pink. The winged forms are usually darker. The green peach aphid is most destructive to turnip, mustard, kale and collard but can cause problems in cabbage. Control may be difficult, but can be accomplished with thorough coverage of insecticide sprays. Insecticide controls on seedling stage greens should be avoided until parasites and diseases are given a chance to suppress the population.

Turnip Root Aphid (Figure 29)

The turnip root aphid, *Pemphigus populitransversus*, feeds on cabbage, collard, kale, mustard and turnip. Infested plants may be yellow and stunted, but under good growing conditions late infestations often result in very little yield loss. However, turnip roots will be disfigured or discolored and even unmarketable. Preplant incorporation of soil insecticides is the best means of control. Usually this aphid develops higher populations on late fall or early spring plantings. It is difficult to predict, so apply preventive controls only if a history of problems exists.

Thrips *(Figure 30)*

Several thrips species feed on cabbage and collard sparingly. Occasionally, damage may be noted. Thrips may be found aggregated in areas damaged by small worms. This behavior is suspected to favor the acquisition of moisture and other nutrients in the exudates of the worm-damaged tissue.

Because cabbage is susceptible to tomato spotted wilt virus (TSWV), thrips may become a more important pest in the future. Occasionally, thrips cause a mechanical, “buckskin-type” injury. Controls are not recommended unless heavy populations are observed.

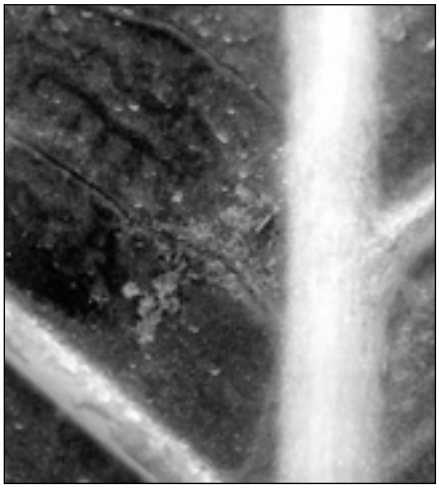

Figure 30. *Thrips*

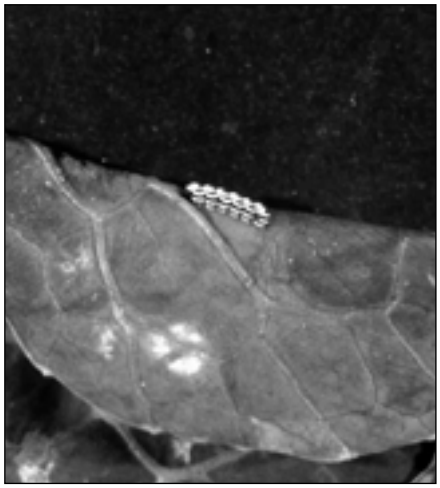

Figure 31. *Harlequin bug (eggs)*

Figure 32. *Harlequin bug (adult)*

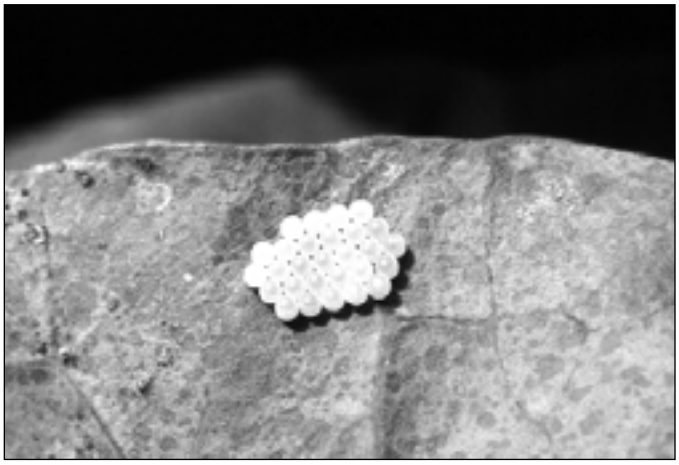

Figure 33. *Stink bug eggs*

Figure 34. *Stink bugs (nymphs and adults)*

Harlequin Bug *(figures 31, 32)*

The harlequin bug, *Murgantia histrionica*, is rarely a pest of commercial plantings of kale, mustard or turnip. It is more likely to be a problem in cabbage and collard. The harlequin bug is a brightly marked shield-shaped bug that has piercing, sucking mouthparts. It feeds on the veins of leaves, causing the leaf to wilt. Their eggs are barrel-shaped and laid in clusters on the leaves. Eggs are white with two black bands around them. Initiate controls if one bug per 10 plants is found.

Stink Bugs *(figures 33, 34)*

Several species of stink bugs attack leafy greens. One of the most common species is the Southern green stink bug, *Nezara viridula*. Stink bugs commonly infest turnip and mustard more than cabbage and other leafy greens. Stink bugs pierce the plant cell and suck out plant sap. The most common problem with stink bug infestations is that they are a contaminant in processed greens. Control stink bugs when wilting is observed from feeding or when they are found above the accepted threshold for processing.

Chinch Bug *(Figure 35)*

The chinch bug, *Blissus leucopterus*, may infest turnip and mustard crops, especially when they are planted near corn or small grains. Chinch bugs are small sucking bugs that prefer to feed on grass crops but may migrate to vegetables when these hosts become unsuitable. Even though the adults have wings, they do not fly. Chinch bugs are difficult to control, so early scouting for chinch bugs migrating from nearby sources is important. Initiate controls if a large migrating population is detected.

False Chinch Bug *(Figure 36)*

The false chinch bug, *Nysius raphanus*, is a fragile sucking bug that is primarily a pest on turnip and mustard. False chinch bugs may infest fields in large num-

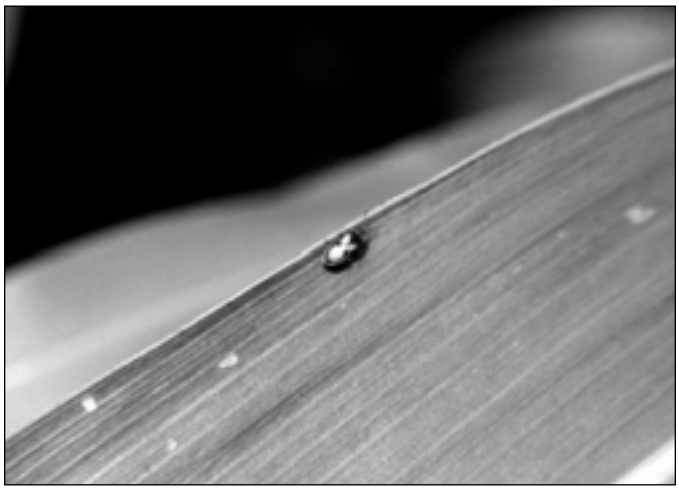

Figure 35. *Chinch bug*

Figure 36. *False chinch bug*

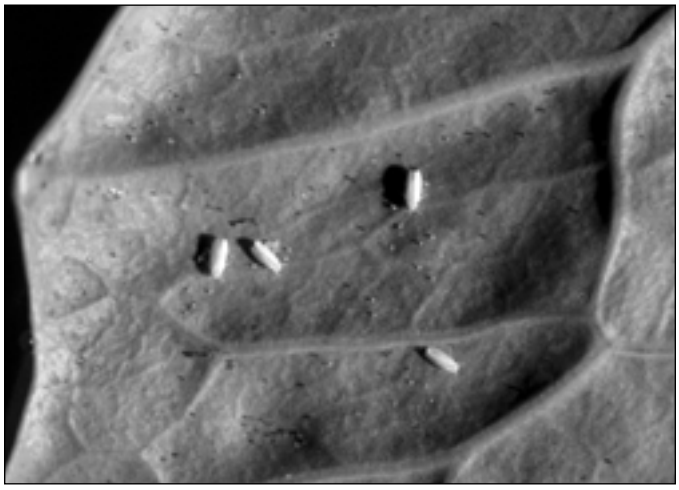

Figure 37. *Silverleaf whitefly*

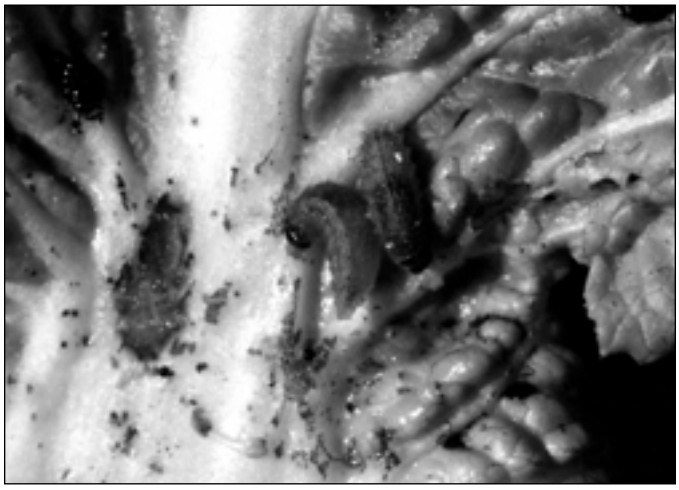

Figure 38. *Vegetable weevil (larvae)*

bers. They damage plants by feeding on the veins on the undersides of the leaves. They inject enzymes during the feeding process, causing a green wilting of the leaf margins. This condition is variable; no information is available on how many bugs cause wilting. Therefore, decisions on control are arbitrary, but heavy infestations should not be left uncontrolled.

Silverleaf Whitefly *(Figure 37)*

The silverleaf whitefly, *Bemisia argentifolii*, is a sporadic pest of cabbage and leafy greens. The silverleaf whitefly may become a problem in late plantings, but is rarely a problem in spring greens. The adult is smaller than a gnat and is bright white with a yellow head and thoracic region. It is mothlike in appearance and feeds on the undersides of leaves, where it also lays eggs. The larvae hatch and become sessile on the underside of the leaf. The adults fly rapidly from the plant when disturbed.

Heavy feeding can result in small yellow spots on the foliage of the tender leafy greens. When on cabbage or collard, the whitefly is more a contaminant than an injurious pest. Control for whiteflies is not recommended unless populations in the area are becoming excessively large or honeydew and/or sooty mold is developing on the foliage. Whitefly control is strictly a judgment decision without threshold guidelines.

Vegetable Weevil *(Figure 38)*

The vegetable weevil, *Listroderes costirostris*, may be a pest of seedling cabbage and leafy greens, especially under the cool growing conditions of the early fall and spring plantings. Adults are about ¼- to 3/8-inch long with a stout snout. They are brownish-gray with two nondescript whitish marks on the wing covers. The larvae are white legless grubs. The adult weevil and grub feed directly on the foliage and stems of greens. They can cause significant stand reductions on young plantings. If weevils or grubs are found feeding, apply treatments if more than 5 percent of the stand is being damaged.

Yellow-margined Leaf Beetle *(figures 39, 40)*

The yellow-margined leaf beetle, *Microtheca ochroloma*, is a small beetle that infests turnip and mustard, especially at field margins. The beetle is black with dirty, yellow-margined wing covers. The larvae are black and alligator-shaped with three pairs of stocky legs. The larvae and adults feed all over the leaves, leaving them with a laced appearance. The pupae may be found in white, round and loosely woven cocoons near the crown of the plants.

Initiate controls when larvae and adults are causing noticeable damage and are still present in the field.

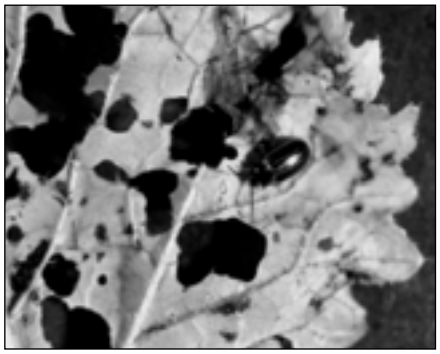

Figure 39. *Yellow-margined leaf beetle (adult)*

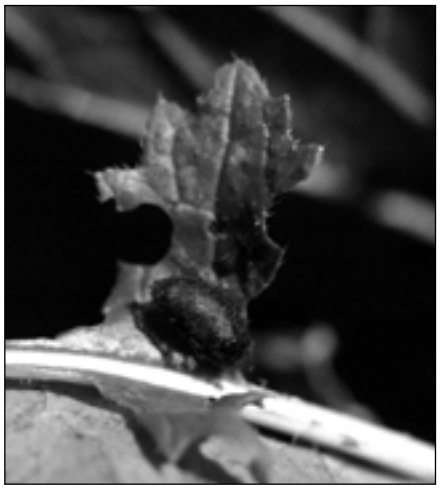

Figure 40. *Yellow-margined leaf beetle (pupa)*

Weed Management

Greg MacDonald, Extension Weed Scientist

Managing weeds in leafy greens and cabbage is an important component of overall crop production. With the increased emphasis on integrated pest management and reduced pesticide inputs, weed management efforts will continue to intensify.

Weeds compete with the crop for light, water, nutrients and physical space. In addition, weeds can harbor harmful insects and diseases that can severely damage the present or proceeding crop. This is especially important with crucifer crops such as greens and cole crops, because many common weeds can harbor blackrot (*Xanthomonas campestris*). This disease is a serious problem for many cole crops. Wild radish can also harbor and increase problems with diamondback moth caterpillars (*Plutella xylostella*). Weeds also interfere with the harvesting process, either through decreased efficiency with the hand-harvested crops or contamination of machine-harvested commodities. In the case of leafy greens for processing, weed contamination may make the product unmarketable.

As alluded to previously, several weedy species commonly infest cabbage and leafy greens. Weed spectrum is highly influenced by the growing season — whether fall, winter or spring. In the fall, the weed spectrum will consist of summer annual weeds such as crabgrass, pigweed, Florida pusley, Texas panicum, sicklepod and nutsedge. In areas heavily infested with nutsedge, crop production should be avoided. During winter production, weeds such as cutleaf evening primrose, swinecress, Virginia pepperweed, shepherd's purse, henbit, chickweed and wild radish will begin to germinate and grow. These weeds are nearly impossible to control post-emergence in leafy greens and heavy infestations should be avoided, especially areas with wild radish. Spring production generally occurs with decreasing winter weed populations followed by emergence of summer annuals as the temperature increases.

Cultural weed management practices are the most effective methods of weed control because of the lack of chemical weed control alternatives. Such practices include rotation and the stale seedbed technique. The first step in cultural weed management is growing a good crop. Proper fertilization as well as good disease, insect and nematode management are critical. Most leafy greens and cabbage are not highly competitive and early season weed control is necessary for these crops to gain a competitive advantage.

Rotation will continue to be one of the vital components to a successful weed management program in cabbage and leafy greens. Rotation also benefits crop production by lowering the levels of insects and soilborne pathogens and maintains better soil tilth. From a rotational standpoint, controlling weeds in one crop is easier than in another because of: 1) the ability to cultivate, 2) the ability to use different herbicides and 3) the economics of hand weeding. One problem with leafy greens production is the inability to cultivate; thereby, rotational crops that can employ cultivation will help to reduce weed levels.

The stale seedbed technique employs the use of a nonselective herbicide such as paraquat or glyphosate to kill emerged weeds before planting the crop. In the stale seedbed method, the seedbed is prepared as usual but the crop is not planted. The weeds are allowed to emerge and are then killed by the nonselective herbicide. The crop is planted with minimal soil disturbance to prevent stimulation of weed germination. This method can also be used to kill weeds that emerge before the crop. However, great care must be taken to properly identify seedling weeds vs. the crop. This generally works well with weeds such as nutsedge, which commonly emerges three to four days before most crops. Another, nonchemical, method involves reworking the desired area several times before planting, destroying weed seedlings as they emerge. This method seeks to reduce the levels of infestation. Coupled with chemical control just prior to planting, it is an effective means of reducing weed problems.

Mechanical weed control has been, and will continue to be, one of the primary methods of weed control for cole crops such as cabbage, cauliflower, broccoli or collard. Cultivation works extremely well for transplanted crops where small weeds can be eliminated without damaging the crop. Care must be taken to

avoid root pruning and excessive leaf damage. If the crop is direct seeded, care must be taken to avoid covering the crop with soil.

Carryover from herbicides is a critical issue with many vegetable crops, especially leafy greens. Leafy greens such as turnip and mustard are very sensitive to many soil active herbicides and great care must be taken to avoid such possibilities. Be sure to know the cropping history of the area, including herbicide use. Rotational restrictions are listed on all herbicide labels and must be followed to avoid severe injury or crop death.

Herbicides approved for use in leafy greens and cabbage are listed in the *Georgia Pest Control Handbook*. The use of unregistered herbicides is illegal and could result in crop injury and undesirable residues.

Sprayers

Paul E. Sumner, Extension Engineer

Two types of sprayers, boom and air-assisted, are used for applying insecticides, fungicides, herbicides and foliar fertilizers. Air-assisted sprayers (Figure 41) utilize a conventional hydraulic nozzle. Air forces the spray into the plant foliage. Boom sprayers (Figure 42) get their name from the arrangement of the conduit that carries the spray liquid to the nozzles. Booms or long arms on the sprayer extend across a given width to cover a swath as the sprayer passes over the field.

Pumps

Three factors to consider in selecting the proper pump for a sprayer are:

1. ***Capacity***. The pump should have sufficient capacity to supply the boom output and to provide for agitation (5 to 7 gallons per minute (gpm) per 100-gallon tank capacity). Boom output will vary depending upon the number and size of nozzles. Also, 20 percent to 30 percent should be allowed for pump wear when determining pump capacity. Pump capacities are given in gallons per minute.
2. ***Pressure***. The pump must produce the desired operating pressure for the spraying job. Pressures are indicated as pounds per square inch (psi).
3. ***Resistance to corrosion and wear.*** The pump must be able to withstand the chemical spray materials without excessive corrosion or wear. Use care in selecting a pump if wettable powders are to be used because these materials will cause pump wear.

Before selecting a pump, consider factors such as cost, service, operating speeds, flow rate, pressure and wear. For spraying vegetable crops, a diaphragm pump is preferred because of serviceability and pressures required.

Nozzles

Nozzle tips are the most neglected and abused part of the sprayer. Because clogging can occur when spraying, clean and test nozzle tips and strainers before each application. When applying chemicals, maintain proper ground speed, boom height and operating pressure. This will ensure proper delivery of the recommended amount of pesticide to the plant canopy.

Herbicides

The type of nozzle used for applying herbicides is one that develops a large droplet and has no drift. The nozzles used for broadcast applications include the extended range flat fan, drift reduction flat fan, turbo flat fan, flooding fan, turbo flooding fan, turbo drop flat fan and wide angle cone nozzles. Operating pressures should be 20 to 30 psi for all except drift reduction and turbo drop flat fans, flooding fans and wide angle cones. Spray pressure more than 40 psi will create significant drift with flat fans nozzles. Drift reduction and turbo drop nozzles should be operated at 40 psi. Flooding fan and wide angle cone nozzles should be operated at 15 to 18 psi. These nozzles will achieve uniform application of the chemical if they are uniformly spaced along the boom. Flat fan nozzles should overlap 50 percent to 60 percent.

Figure 41. *Air-assisted sprayer*

Figure 42. *Hydraulic boom sprayer*

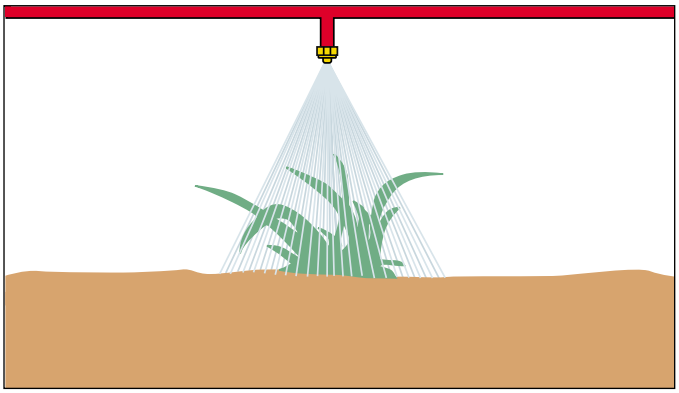

Figure 43. *One or two nozzles over the row for small plants*

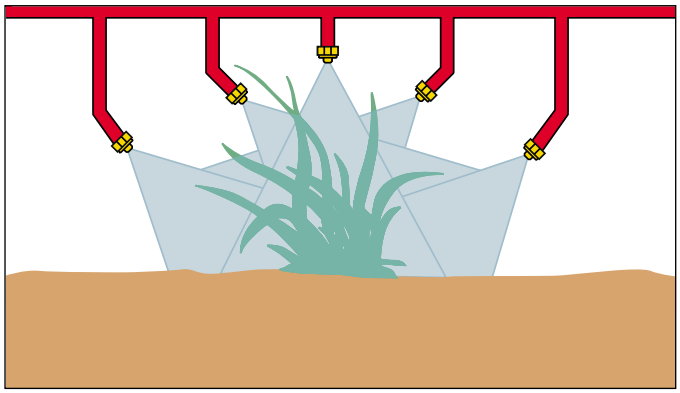

Figure 44. *Drop nozzles as plants grow*

Insecticides and Fungicides

Hollow cone nozzles are used primarily for plant foliage penetration for effective insect and disease control and when drift is not a major concern. At pressures of 60 to 200 psi, these nozzles produce small droplets that penetrate plant canopies and cover the undersides of the leaves more effectively than any other nozzle type. The hollow cone nozzles produce a cone-shaped pattern with the spray concentrated in a ring around the outer edge of the pattern. Even fan and hollow cone nozzles can be used for banding insecticide or fungicides over the row.

Nozzle Material

Various types of nozzle bodies and caps, including color-coded versions and multiple-nozzle bodies are available. Nozzle tips are interchangeable and are available in a wide variety of materials, including hardened stainless steel, stainless steel, brass, ceramic, and various types of plastic. Hardened stainless steel and ceramic are the most wear-resistant materials. Use stainless steel tips, with corrosive or abrasive materials, because they have excellent wear resistance. Plastic tips are resistant to corrosion and abrasion and are proving to be very economical for applying pesticides. Brass tips have been common but wear rapidly when used to apply abrasive materials such as wettable powders. Brass tips are economical for limited use, but other types should be considered for more extensive use.

Nozzle Arrangements

When applying insecticides and fungicides, it is advantageous to completely cover both sides of all leaves with spray. When spraying greens, use one nozzle over the top of the row (up to 12 inches wide). Then as the plants start to bush, place nozzles on 10- to 12-inch centers for broadcast spraying. For cabbage, the nozzle arrangement should be adapted for the various growth stages of plants (figures 43 and 44). When plants are small (up to 12 inches) one or two nozzles over the top are sufficient. Then as the plant starts to form a head, drop nozzles should be added in pairs.

This will guarantee that the spray is applied from all directions into the canopy. As the plant increases in height, add additional nozzles for every 8 to 10 inches of growth. In all spray configurations, the nozzle tips should be 6 to 10 inches from the foliage. Properly selected nozzles

should be able to apply 25 to 125 gallons per acre when operating at a pressure of 60 to 200 or higher psi. Usually, more than one size of nozzle will be needed to carry out a season-long spray program. Volume and pressure will vary with growth stage and type of material sprayed.

Spray Volume – Water Rates (GPA)

The grower who plans to use spray materials at the low water rates should follow all recommendations carefully. Use product label recommendations on water rates to achieve optimal performance. Plant size and condition influence the water rate applied per acre. Examination of the crop behind the sprayer before the spray dries will give a good indication of coverage.

Agitation

Most materials applied by a sprayer are in a mixture or suspension. Uniform application requires a homogeneous solution provided by proper agitation (mixing). The agitation may be produced by jet agitators, volume boosters (sometimes referred to as hydraulic agitators) and mechanical agitators. These can be purchased separately and installed on sprayers. Continuous agitation is needed when applying pesticides that tend to settle out, even when moving from field to field or when stopping for a few minutes.

The procedure below is based on spraying 1/128 of an acre per nozzle or row spacing and collecting the spray that would be released during the time it takes to spray the area. Because 1 gallon contains 128 ounces of liquid, this convenient relationship results in ounces of liquid collected being directly equal to the application rate in gallons per acre.

Calibrate with clean water when applying toxic pesticides mixed with large volumes of water. Check uniformity of nozzle output across the boom. Collect from each for a known time period. Each nozzle should be within 10 percent of the average output. Replace with new nozzles if necessary. When applying materials that are appreciably different from water in weight or flow characteristics, such as fertilizer solutions, etc., calibrate with the material to be applied. Exercise extreme care and use protective equipment when active ingredient is involved.

1. From Table 9, determine the distance to drive in the field (two or more runs suggested). For broadcast spraying, measure the distance between nozzles. For band spraying, use band width. For over-the-row or directed spraying, use row spacing.
2. Measure the time (seconds) to drive the required distance with all equipment attached and operating. Maintain this throttle setting!
3. With the sprayer sitting still and operating at the same throttle setting or engine RPM as used in Step 2, adjust the pressure to the desired setting. The machine must be operated at the same pressure used for calibration.
4. *For broadcast application*, collect spray from one nozzle or outlet for the number of seconds required to travel the calibration distance.
   For band application, collect spray from all nozzles or outlets used on one band width for the number of seconds required to travel the calibration distance.
   For row application, collect spray from all outlets (nozzles, etc.) used for one row for the number of seconds required to travel the calibration distance.
5. Measure the amount of liquid collected in fluid ounces. The number of ounces collected is the gallons per acre rate on the coverage basis indicated. For example, if you collect 18 ounces, the sprayer will apply 18 gallons per acre. Adjust applicator speed, pressure, nozzle size, etc., to obtain recommended rate. If speed is adjusted, start at Step 2 and recalibrate. If pressure or nozzles are changed, start at Step 3 and recalibrate.

Table 9. *Distance to measure to spray 1/128 acre*
One ounce discharged equals one gallon per acre.

Nozzle Spacing (inches)	Distance (feet)
6	681
8	510
10	408
12	340
14	292
16	255
18	227
20	204
22	186
24	170
30	136
36	113
38	107
40	102

To determine a calibration distance for an unlisted spacing, divide the spacing expressed in feet into 340. Example: Calibration distance for a 13" band = 340 ÷ 13/12 = 313 feet.

Sprayers should be calibrated at 2½ to 4 miles per hour. Calibration should be conducted every eight to 10 hours of operation to ensure proper pesticide application.

Irrigation

Anthony W. Tyson and Kerry A. Harrison, Extension Engineers

Even though cabbage and leafy greens are primarily cool-season crops, irrigation will significantly increase their yield and quality in most years. These crops are shallow rooted, and even though their water requirements are less than those for most crops, they can use up the available moisture in the shallow root zone very quickly. The most serious yield reductions result when moisture deficits occur during late development and, in the case of cabbage, during head formation.

Sprinkler irrigation is the only method that has proven practical for irrigation of these crops in Georgia. Common types of systems include center pivot, linear move, traveling big-gun, permanent set and portable aluminum pipe with sprinklers. Each of these systems is satisfactory if used correctly. There are, however, significant differences in initial costs, fuel costs and labor requirements.

Any sprinkler system used on cabbage or greens should be capable of delivering at least 1¼ inches of water each week. In addition, the system should apply the water slowly enough to prevent run-off. With most soils, a rate less than 2 inches per hour safely prevents runoff. Drip irrigation is often used when cabbage, collard or kale are double cropped with another vegetable on mulched beds.

Scheduling Irrigation

The water used by a crop and the water evaporated from the soil is commonly referred to as evapotranspiration (ET). ET rates for cabbage and greens rarely exceed 0.15 inch per day. Factors that affect ET are the stage of crop growth, temperature, relative humidity, solar radiation, wind velocity and plant spacing.

Plant seeded crops into moist soil and irrigate frequently with light applications until germination occurs. If possible, apply 0.25 inch every other day to ensure complete germination. The soil should not become waterlogged.

Plant transplants into moist soil and irrigate with 0.3 to 0.5 inch immediately. This helps to ensure good contact between the soil and roots.

Once a root system is established, maintain soil moisture to a depth of 12 inches. The sandier soils in South Georgia have an available water-holding capacity of about 1 inch per foot of soil depth. Clay soils will hold up to 2 inches per foot. No more than 50 percent of the available water should be depleted before irrigating. This means that net irrigation amounts should be between 0.5 and 1.0 inch per irrigation. The actual amount applied should be 10 percent to 20 percent higher to account for evaporation losses and wind drift. The irrigation frequency will depend on the daily ET rate. In general, during peak water-use periods, sandy soils need 0.6 inch twice a week, and clay soils need 1.2 inches once a week.

Irrigation can best be managed by monitoring the amount of moisture in the soil. Tensiometers or resistance blocks can be used to measure soil moisture. For best results on cabbage and greens, maintain soil tension below 30 centibars. For cabbage, maintaining uniform moisture during head formation is especially important to prevent bursting. Maintain soil moisture until harvest.

Harvest and Handling

William C. Hurst, Extension Food Scientist

Harvesting

Many leafy greens (including cabbage, collard, kale, mustard and turnip) are cut by hand and packed directly in the field for the fresh market. Necessary trimming to remove any yellowed, brownish or damaged leaves should be done as the plants are picked and before they are tied into bunches and placed into containers. In addition, cabbage may be cut by hand, loaded into a bulk container such as a field wagon and hauled to a packing shed for trimming, grading and packaging. During cabbage harvest, cut stems so that they do not extend more than ½ inch beyond the point of attachment of the outmost leaves. Heads may be damaged by excessively long, protruding stems. Bunch collards according to uniform size. Coarse, tough stems of plants should not be packed. Harvest leaves of turnip, mustard and kale when tender by feel, and avoid those showing tough stems.

Ensuring a quality pack can be a problem for hand harvesters. Field labor must be adequately trained and supervised to harvest only optimum maturity and/or sized leaves or rooted plants to meet potential buyer's quality standards.

Field sanitation is very important to reduce the spread of disease among plants. Cutting tools are a primary source of disease carryover. Knives should be routinely sanitized to keep disease inoculum from building on their surfaces and infecting sound cabbage heads or leafy greens. Worker's knives should be collected at the end of a harvest day and placed in a bucket of sanitizer (use 1 ounce of household bleach per gallon of water). For better protection, place buckets of sanitizer at the end of selected rows in the field so workers can sanitize their knives at regular intervals to reduce disease build-up over the course of the production day.

Postharvest Handling/Cooling

When harvesting cabbage or other leafy greens, field crews should exercise care to minimize bruise damage and leaf punctures. Cabbage is sometimes considered a "hardware" item, because it is thrown into bulk containers in the field or at the packing shed. Outer leaves are broken and heads burst when subjected to impact damage. Leaves of leafy greens are crushed if they are overpacked into field boxes. If not used properly, cutting tools will puncture leaves. Any cuts or breaks in the leaves or heads will cause excessive wilting and provide avenues for decay pathogens.

Cabbage and other greens wilt quickly when there is a delay in removing them from the sun. Leafy greens should be harvested during the coolest part of

Figure 45. *Damaged or diseased leaves should be removed before field packing.*

Figure 46. *Pitching cabbage into field wagons or packing line bins causes splitting of heads.*

Figure 47. *Harvested greens should be shaded from direct sunlight to preserve quality.*

the day to minimize shriveling and field heat accumulation. If delays occur during packing, shade greens from direct sunlight.

Leafy greens should be cleaned before marketing. Bunches of collards and leaves of mustard, turnip and kale tied in half-dozen bundles are laid on a flatbed trailer and hauled from the field station. A straight-line packing belt conveys bunches beneath spray washers where greens are cleaned to remove sand and dirt and refreshed to improve their appearance. Workers place bundles coming off the end of the belt onto racks and into a storage cooler. Direct field packing of boxed leaves is also done without washing at the request of the buyer.

Quality maintenance is best achieved for leafy greens if they are precooled before shipping. Field workers should trim loose leaves from cabbage during harvest because these leaves interfere with cooling. Buyers prefer three to six wrapper leaves to remain. Packing line graders will typically remove any yellowed, insect damaged or disease damaged heads before boxing. Boxes should have structural integrity (use only new boxes) to prevent product crushing during stacking, loading and distribution. Cabbage is best cooled by vacuum or forced air because rapid air movement is needed to remove heat from solid heads. However, most cabbage packed in Georgia is placed in a room cooler. Other leafy greens (collard, kale, mustard and turnip) should be rapidly cooled using one of the methods above. In addition, most buyers require icing for these greens to provide needed moisture for freshness and crispness. After the field boxing of leaves, they may be taken to the shipping location where a shovel of ice is added to greens in each box. Washed bunches of greens are removed from cooling racks and bulk loaded into trucks by being laid in rows, with top icing for each row. Icing takes 2.2 pounds of ice for every 4 pounds of greens to maintain the temperature below 40°F. All leafy greens, including cabbage, should be cooled to 32°F before marketing.

Quality Grade Standards

Cabbage

U.S. No.1 and U.S. Commercial are the two U.S. grade standards provided.

U.S. No.1 consists of heads of cabbage of one cultivar or similar varietal characteristics. The heads must be reasonably solid; not withered, puffy or burst; and free of soft rot, seedstems and damage caused by discoloration, freezing, disease, insects, mechanical or other means. Each head shall be well trimmed.

U.S. Commercial consists of heads of cabbage that meet requirements for U.S. No.1 grade, but it has an greater tolerance for defects and allows heads to be reasonably firm rather than solid. A minimum size or minimum and maximum sizes may be specified in connection with the grade, such as "U.S. No.1, one pound minimum" or "U.S. No.1, two to four pounds." To allow for variations incident to proper grading and handling, defect tolerances based on product weight are provided in Table 10.

Collard

U.S. standards for collard greens provide for one grade: U.S. No.1. This consists of greens of similar varietal characteristics that are fresh, fairly tender, fairly clean, well trimmed and of characteristic color for the variety or type. Also, greens shall be free from decay, damage caused by coarse stems and seedstems, discoloration, freezing, foreign material, disease, insects, mechanical or other means. Tolerances for grading collard greens are based on product weight in a container (see Table 10 for defect percentages).

Kale

U.S. standards for kale provide two grades: U.S. No.1 and U.S. Commercial. Buyers customarily use U.S. No.1, which requires plants to be of one type: well trimmed, not stunted, free of decay and of damage caused by yellow or discolored leaves, seedstems, wilting, bud burn, freezing, dirt, disease, insects, mechanical or other means. Tolerances for grading kale are based on product weight in a container (see Table 10).

Mustard and Turnip

U.S. standards for mustard greens and turnip greens provide for one grade: U.S. No. 1. This consists of greens of similar varietal characteristics that are fresh, fairly tender, fairly clean and free of decay and of damage caused by seedstems, discoloration, freezing, foreign material, disease, insects, mechanical or other means. To allow for variations incident to proper handling and grading, defect tolerances for each are provided based on weight (see Table 10).

Packaging

Cabbage is packed in 1.8 bushel (50 pound) waxed, corrugated cartons, 1.75 bushel crate or large meshed bags in Georgia. Proper sizing and count per box are important for marketing. Buyers demand uniformly sized heads, 18 to 22 count, in cartons. Cartons bring a premium price and help protect the heads from damage during distribution. Larger heads, 10 to 14 count, are packed in meshed bags and bring a lower price.

The most common package for Georgia greens is the 1 3/5 bushel crate, which is shipped mostly to the northeastern markets. The 1 3/5 crate generally holds 16 to 18 bunches. Shipments to Midwestern markets are usually in a standard Western carton, which holds 24 bunches. Loose greens are packed in a carton and are usually shipped to markets in the Southeast. Each container holds about 25 pounds. Specifically, greens are packaged as described below.

Collards are sold in bunches of two or three plants. Collards are bulk loaded into trucks or packed into wirebound boxes. Depending on market demand, bunches are packed 12 to 24 bunches per box or sold by the dozen. Collards are top iced for sale.

Kale is stripped from the plant and tied into bunches for marketing. Usually, 12 to 16 leaves compose a bunch and bundled leaves are sold as half-dozen bundles per box. Kale is iced before sale.

Mustard greens are marketed as bundled leaves. Freshness and lack of wilt are important marketing factors. Bundles of 12 to 16 leaves are packed into wirebound or waxed cartons (18 to 20 pounds, excluding ice) depending on market demand. Leaves are iced before sale.

Turnip greens are sold as rooted plants and leaves. If marketed as plants, they should be harvested when the roots reach 1½ to 2 inches in diameter and bunched as two or three plants, similar to collard. Depending on market demand, turnips are packed into 25- or 50-pound cartons or by the dozen as bunches in wirebound crates. Turnip leaves are tied into bundles and sold, with half-dozen bundles per box. Rooted plants and leaves are top iced during packaging.

Table 10. *U.S. grade standards based on allowable defect levels*

Commodity	Grade	Tolerances by Weight	Size Requirement	Trim Requirement
Cabbage	U.S. No.1	10% total, including 2% soft decay	For off-size: 15% total, but not more than 10% above or below size	For trimming: 10% may fail to meet required number of wrapper leaves
	U.S. Commercial	25% total, including 10% serious damage and 2% soft decay		
Kale	U.S. No.1	10% total, including 1% wet decay	Size not a requirement of grade	Kale must be well trimmed
Collard, Mustard, Turnip	U.S. No.1	10% total, including 5% serious damage and 2% decay	Size reported as small, medium or large leaves	Mustard and turnip greens have no trimming requirements. Collard must be well trimmed.

Note: Some buyers expect higher quality than these limits.

Figure 48. *Damaged or used containers allow product crushing during distribution and bring lower prices.*

Figure 49. *Approximately 2 pounds of ice is needed for every 4 pounds of leafy greens to maintain freshness and crispness.*

Storage/Shipping

Maximum storage time for cabbage is three to six weeks if it has been properly precooled and held at 32°F. A relative humidity of 90 percent to 95 percent should be maintained during storage. Cabbage is compatible for holding and shipment with fruits and vegetables that do not produce the ripening gas ethylene. Quality is damaged by exposure to trace amounts of ethylene. Yellowing and shedding of outer leaves results. Do not store or ship cabbage with ripening tomatoes, cantaloupes or ethylene-producing fruits such as peaches.

Other leafy greens (collard, kale, mustard and turnip) require the same storage conditions (temperature, 32°F; humidity, 95 percent) but have a shelf life of only two weeks. This is due to their higher respiration rate and leafy nature, which causes them to lose moisture rapidly. In addition to cold storage, greens should be top iced to retain crispness. These greens are also ethylene sensitive and should not be stored or shipped with ripening tomatoes, cantaloupes or fruits such as peaches.

Production Costs

George O. Westberry, Extension Economist-Farm Management

Cabbage and greens growers can use enterprise budgets to estimate production and break-even prices. Budgets include cost estimates for those inputs necessary to achieve the specified yields over a period of years. Production practices vary among growers, so each grower should adapt budget estimates to reflect the individual situation. Detailed printed and computerized budgets are available from your county Extension agent.

Types of Costs

The total cost of producing any crop includes variable and fixed costs. The variable (operating) costs vary with the cultural practices used. Common variable costs include seed, fertilizer, chemicals, fuel and labor. Fixed costs include items such as equipment ownership (deprecation, interest, insurance and taxes), management and general overhead costs. Most of these costs are incurred even if little production takes place.

Variable costs are further broken down into preharvest operations in the budgets. This provides an opportunity to analyze the costs at different stages of the production process.

Land cost can be a variable or a fixed cost. Even if you own the land, cost is involved. Land is fixed cost in the sample budget. If land is double-cropped, charge each enterprise half the annual cost.

A fixed cost per hour of use shows ownership costs for tractors and equipment (depreciation, interest, taxes, insurance and shelter). Overhead and management are 15 percent of all pre-harvest variable expenses. This figure pays for management and farm costs that cannot be allocated to any one specific enterprise. Overhead items include utilities, farm shop and equipment, pick-up trucks and fees.

Cost per Unit of Production

The cost categories (tables 11 and 12) are broken down by cost per unit at the bottom of the budget. The preharvest variable costs and the fixed costs decline with increases in yields.

Costs per carton of cabbage for 1998 are estimated to be:

Preharvest Cost	$1.54
Harvest and Marketing Cost	$2.39
Fixed Cost	$ .54
Total Cost	**$4.47**

Costs per carton of leafy greens for 1998 are estimated to be:

Preharvest Cost	$1.03
Harvest and Marketing Cost	$2.95
Fixed Cost	$ .46
Total Cost	**$4.44**

For current cost estimates, see the most recent Extension vegetable budgets, available from your county Extension agent.

Budget Uses

In addition to estimating the total costs and break-even prices for producing cabbage and greens, the budgets have other uses.

Estimates of the cash costs (out-of-pocket expenses) provide information on how much money must be borrowed. The cash cost estimates are helpful in preparing cash flow statements.

When growers use share leases, the cost estimates by item can be used to determine more accurately a fair share arrangement by the landlord and tenant.

Risk-rated Net Returns

Because yields and prices vary from year to year, an attempt is made to estimate the riskiness of producing cabbage and greens. The Agricultural and Applied Economics Department uses five yields and prices to calculate risk. The **median** values are those prices and yields a particular grower would anticipate exceeding half the time; half the time, he would anticipate not reaching these prices and yields. **Optimistic** values are those prices and yields a grower would expect to reach or exceed one year in six. The **pessimistic** values are poor prices and yields that would be expected one year

in six. The **best** and **worst** values are those extreme levels that would occur once in a lifetime (one in 48).

The risk-rated section for cabbage (Table 13) shows a 69 percent chance of covering all costs. Over a period of years, this hypothetical grower would anticipate an average or **expected** return of $479 per acre. One year out of six, he would expect to make more than $1,459 per acre or to lose more than $526 per acre.

The risk-rated section (Table 14) for leafy greens shows a 54 percent chance of covering all costs. Over a period of years, this hypothetical grower would anticipate an average or **expected** returns of $38 per acre. He would be expected to net $38 or more about half the time and net $38 or less half the time. One year out of six he would expect to make more than $490 per acre or to lose more than $426 per acre.

Table 11. *Estimated cabbage yields, prices and costs*

	Best	Optimistic	Median	Pessimistic	Worst
Yield (cartons)	900	700	500	300	0
Price per carton	8.50	7.00	5.50	4.00	2.50

Item	Unit	Quantity	Price	Dollar Amount per Acre
Variable Costs				
Plants	1,000	16.00	26.00	416.00
Lime, Applied	Ton	.50	26.00	13.00
Fertilizer	Cwt	12.00	8.50	102.00
Sidedressing	Acre	1.00	22.80	22.80
Insecticide	Application	7.00	4.50	31.50
Fungicide	Application	10.00	2.90	29.00
Herbicide	Acre	1.00	13.50	13.50
Machinery	Hour	6.00	5.50	33.00
Labor	Hour	10.00	6.00	60.00
Irrigation	Application	3.00	4.26	12.78
Interest on Operating Capital	Dollar	733.58	10.5%	38.51
Preharvest Variable Costs				*772.09*
Harvest and Marketing Costs				
Labor	Hours	50	5.25	262.50
Container	Carton	500	1.30	650.00
Hauling and Marketing	Carton	500	.57	285.00
Total Harvest and Marketing				*1,197.50*
Total Variable Costs				***1,969.59***
Fixed Costs				
Machinery	Hour	6.00	11.31	67.86
Irrigation	Acre	1.00	47.10	47.10
Land	Acre	1.00	40.00	40.00
Overhead and Management	Dollar	772.09	.15	115.81
Total Fixed Costs				***270.77***
Total Budgeted Cost				***2,240.36***
Costs Per Carton				
Preharvest Variable Cost per Carton		1.54		
Harvest and Marketing Cost per Carton		2.39		
Fixed Cost per Carton		.54		
Total Budgeted Cost per Carton		***4.47***		

Table 12. *Estimated leafy greens yields, prices and costs*

Best	Optimistic	Median	Pessimistic	Worst	
Yield (cartons)	600	475	350	200	0
Price per carton	7.00	5.90	4.75	3.60	2.50

Item	Unit	Quantity	Price	Dollar Amount per Acre
Variable Costs				
Seed	Pounds	3.50	5.50	19.25
Lime, Applied	Ton	.50	26.00	13.00
Nitrogen	Pounds	180.00	.28	50.40
Phosphorus	Pounds	200.00	.31	62.00
Potassium	Pounds	200.00	.14	28.00
Sulfur	Pounds	10.00	.21	2.10
Boron	Pounds	1.00	2.80	2.80
Herbicide	Acre	1.00	5.85	5.85
Fungicide	Acre	1.00	50.00	50.00
Insecticide	Acre	1.00	27.60	27.60
Machinery	Hour	2.00	6.90	13.80
Labor	Hour	4.00	6.00	24.00
Irrigation	Inch	10.00	4.26	42.60
Interest on Operating Capital	Dollar	341.40	10.5%	17.92
Preharvest Variable Costs				*359.32*
Harvest and Marketing Costs				
Labor	Carton	350	1.25	437.50
Container	Carton	350	1.30	455.00
Marketing	Carton	350	.40	140.00
Total Harvest and Marketing				*1,032.50*
Total Variable Costs				***1,391.82***
Fixed Cost				
Machinery	Hour	2.00	15.74	31.48
Irrigation	Acre	1.00	35.00	35.00
Land	Acre	1.00	40.00	40.00
Overhead and Management	Dollar	359.32	.15	53.90
Total Fixed Costs				***160.38***
Total Budgeted Cost				***1,552.20***
Costs Per Carton				
Preharvest Variable Cost per Carton		1.03		
Harvest and Marketing Cost per Carton		2.95		
Fixed Costs per Carton		.46		
Total Budgeted Cost per Carton		***4.44***		

Table 13. *Risk-rated cabbage returns over total costs*

	Optimistic			Expected			Pessimistic
Net Returns ($)	1,949	1,459	969	479	-23	-526	-1,028
Chances of Obtaining This Level or More	7%	16%	31%	50%			
Chances of Obtaining This Level or Less				50%	31%	16%	7%

Chance for Profit = 69% **Base Budgeted Net Returns[1] = $511**

1 Base budgeted net returns are the returns that would be estimated if yields and prices were estimated to be the same each year.

Table 14. *Risk-rated leafy greens returns over total costs*

	Optimistic			Expected			Pessimistic
Net Returns ($)	715	490	264	38	-194	-426	-659
Chances of Obtaining This Level or More	7%	16%	31%	50%			
Chances of Obtaining This Level or Less				50%	30%	16%	7%

Chance for Profit = 54% **Base Budgeted Net Returns = $118**

Marketing Cabbage and Leafy Greens

William O. Mizelle, Jr., Extension Economist

Marketing cabbage, greens or any vegetable is more than selling. Marketing includes production, distribution and pricing. To be successful, marketing must be responsive to consumers' demands. Consumers demand quality, freshness and "reasonable" prices.

Production

Production data for most vegetables are not available. Thus, other types of data must be used to substitute for production estimates. USDA collects market arrival[1] data for "fresh" fruits and vegetables in the major markets in the United States.

During 1996, these data show, 31 states marketed cabbage at some time during the year. The top 10 producing states accounted for about 90 percent of the annual shipments to the major U.S. markets. California was the leader and was followed by Texas, New York and Florida. Georgia ranked fifth in shipments (see Table 15).

Cabbage is available throughout the year, but volume peaks in March. Georgia's share of annual volume has grown from about 4 percent in the mid-1980s to 7.5 percent to 10 percent of the annual volume by the mid-1990s. Georgia volume peaks in May but accounts for more than 10 percent of U.S. volume during December to January and May to June. Florida and Texas are the primary competitors in May; North Carolina is the primary competition in June.

Georgia primarily markets cabbage east of the Mississippi. The South (primarily the Atlanta area) accounts for about two-thirds of Georgia's shipments. Boston, Cincinnati and Chicago are also major markets for Georgia.

Twenty-nine states market greens[2] some time during the year. However, seven states account for more than 80 percent of the annual volume shipped to the 20 major U.S. markets (see Table 16). California and Georgia are the leading greens producing states. Texas and New Jersey follow in annual volume.

Although greens are available year-round, production peaks during November through May. Georgia's volume peaks during April and May. Georgia accounts for 20 percent to 30 percent of the annual volume but has more than 30 percent of the market in December, April and May.

The top three greens markets are Los Angles, Atlanta and Boston. The top markets for Georgia's greens are Atlanta, Cincinnati and Boston. Cincinnati seems to be a larger greens market than would be expected — receiving nearly the same volume as Chicago. The Cincinnati metropolitan area is the 23rd largest; Chicago is the third. Apparently, Georgia greens growers have developed a niche in the Cincinnati market. Nationally, greens are distributed fairly evenly (24 percent to 26 percent) in the four major geographical areas of the country. However, data for greens are not separated by type of greens, so one area may be consuming a higher proportion of one type when compared with other areas. The Southern cities receive more than 40 percent of Georgia's greens.

Pricing

Supply and demand determine the general price level. The competing states' production determines the **supply**. Consumers' willingness to buy different quantities at different prices determines the **demand**.

Consumption data are reported for cabbage but not for greens (see Figure 50). Cabbage and greens prices vary greatly within a season and between years. Weather effects on production cause most of the price variation within season. Changes in acreage and weather cause price variations among years. Demand changes are slight from year-to-year and cause very little of the price variation.

Figure 51 shows the average May price for Georgia cabbage for the past 20 years. Prices have not changed much over the period. During the 1978-87 period, May prices for Georgia cabbage averaged $5.15 per carton, even with the extremely high 1982. During the 1988-97 period, the average price was $6.00. Figure 52 shows the Georgia greens prices for the April and May period. Most

1 Arrivals represent that portion of total production that is shipped to the markets that USDA reports.
2 Greens include collard , dandelion greens, kale, mustard, turnip and others.

Table 15. *Average monthly cabbage shipments (million pounds) to 20 U.S. cities, 1996*

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1996	1995
California	7.3	6.5	8.7	8.0	7.8	7.0	6.2	6.3	5.7	6.9	6.3	6.1	82.8	84.2
Texas	13.9	11.6	17.1	14.8	11.5	2.0	0.4	0.3	0.0	0.1	1.1	3.5	76.3	59.2
New York	6.8	5.0	5.2	4.7	4.2	2.0	6.0	6.2	7.6	9.5	10.0	6.5	73.7	83.3
Florida	6.2	9.1	11.6	15.1	13.2	1.5	0.0	0.0	0.0	0.0	0.3	4.4	61.4	63.3
Georgia	4.4	1.8	0.5	0.9	7.7	5.5	3.7	1.1	1.1	1.6	1.4	6.3	36.0	45.2
New Jersey	–	–	–	–	–	2.4	7.1	2.4	2.9	3.1	3.9	1.5	23.3	14.1
North Carolina	0.2	–	–	–	1.0	7.5	2.9	1.5	0.7	1.2	1.5	1.7	18.2	19.2
Wisconsin	–	–	–	–	–	–	0.7	3.3	3.4	4.2	3.4	0.5	15.5	21.0
Illinois	–	–	–	–	–	0.7	2.1	2.6	2.2	2.5	1.0	0.2	11.3	10.0
Pennsylvania	–	–	–	–	–	–	0.7	2.9	2.9	2.4	1.7	0.4	11.0	11.6
Subtotal	38.8	34.0	43.1	43.5	45.4	28.6	29.8	26.6	26.5	31.5	30.6	31.1	409.5	411.1
Total	43.9	37.9	47.2	45.2	46.6	30.6	40.1	34.8	34.4	39.7	35.7	35.7	471.8	456.9
Subtotal/Total	88.4%	89.7%	91.3%	96.2%	97.4%	93.5%	74.3%	76.4%	77.0%	79.3%	85.7%	87.1%	86.8%	90.0%
Georgia/Total	10.0%	4.7%	1.1%	2.0%	16.5%	18.0%	9.2%	3.2%	3.2%	4.0%	3.9%	17.6%	7.6%	9.9%

Table 16. *Average monthly greens shipments (million pounds) to 20 U.S. cities, 1996*

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1996	1995
California	4.2	4.8	4.6	5.4	5.4	4.2	4.1	4.1	3.2	4.5	4.7	4.7	53.9	42.5
Georgia	4.8	3.7	3.3	5.5	6.2	1.9	1.5	0.6	0.7	1.8	3.0	5.6	38.6	47.5
Texas	2.7	5.1	4.8	4.2	2.2	0.0	0.0	0.0	0.0	0.1	1.0	1.7	21.	8 11.2
New Jersey	–	–	–	0.1	1.6	2.4	3.2	1.7	1.8	1.8	1.6	0.1	14.3	12.4
Arizona	2.4	2.5	3.1	1.6	0.2	–	–	–	–	–	0.2	0.8	10.8	5.9
Maryland	–	–	–	0.1	0.1	0.7	1.0	0.9	1.0	1.0	0.9	0.1	5.8	5.9
North Carolina	0.2	0.2	0.2	0.2	1.8	0.4	0.2	0.1	0.1	0.2	0.8	0.9	5.3	7.0
Subtotal	14.3	16.3	16.0	17.1	17.5	9.6	10.0	7.4	6.8	9.4	12.2	13.9	150.5	132.4
Total	16.5	18.1	17.6	18.3	18.8	11.5	14.5	12.5	11.6	14.0	15.2	16.2	184.8	164.4
Subtotal/Total	86.7%	90.1%	90.9%	93.4%	93.1%	83.5%	69.0%	59.2%	58.6%	67.1%	80.3%	85.8%	81.4%	80.5%
Georgia/Total	29.1%	20.4%	18.7%	30.1%	33.0%	16.5%	10.3%	4.8%	6.0%	12.9%	19.7%	34.6%	20.9%	28.9%

years, the prices fluctuated around $4.00 per 25-pound carton. However, the 1996 freeze caused a spike in prices. For recent prices, see Extension agricultural economics publication *Vegetable Economics – A Planning Guide*.

Summary

Nationally, cabbage is experiencing some growth. Consumption is increasing; prices are trending up. Cabbage seems to be profitable for many growers only when a competing area experiences adverse weather. Greens are experiencing a similar favorable marketing environment. Production seems to be increasing while prices have been fairly stable.

Cabbage and greens growers will have to continue to adjust to changing market conditions. For these highly competitive commodities, the better marketers will be the ones most likely to survive.

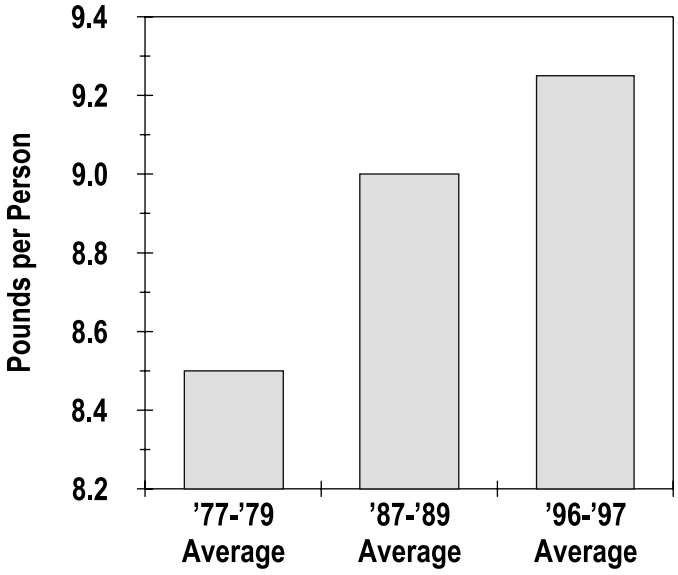

Figure 50. *Cabbage consumption*

Figure 51. *May cabbage prices*

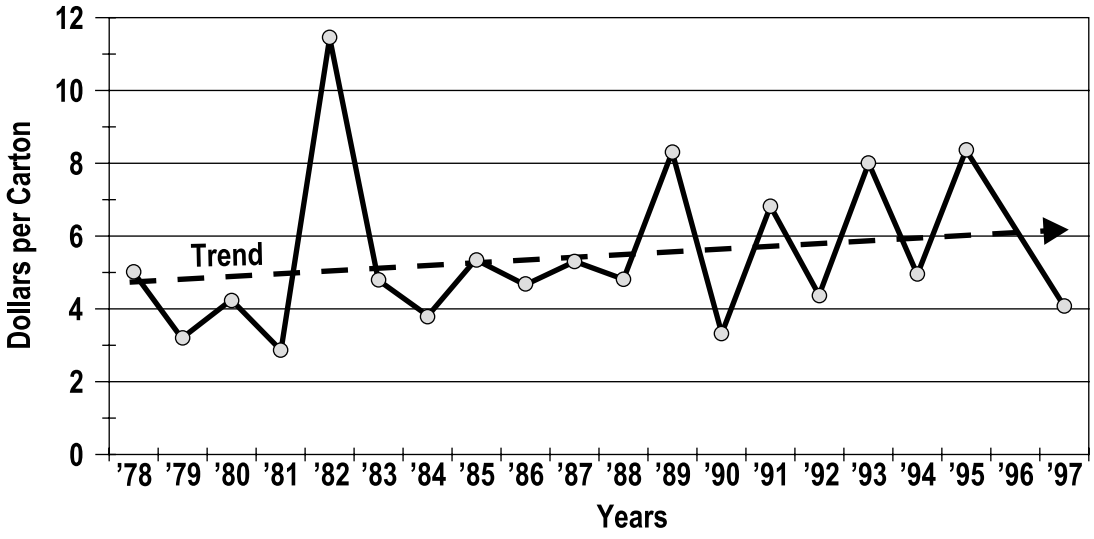

Figure 52. *April-May greens prices*

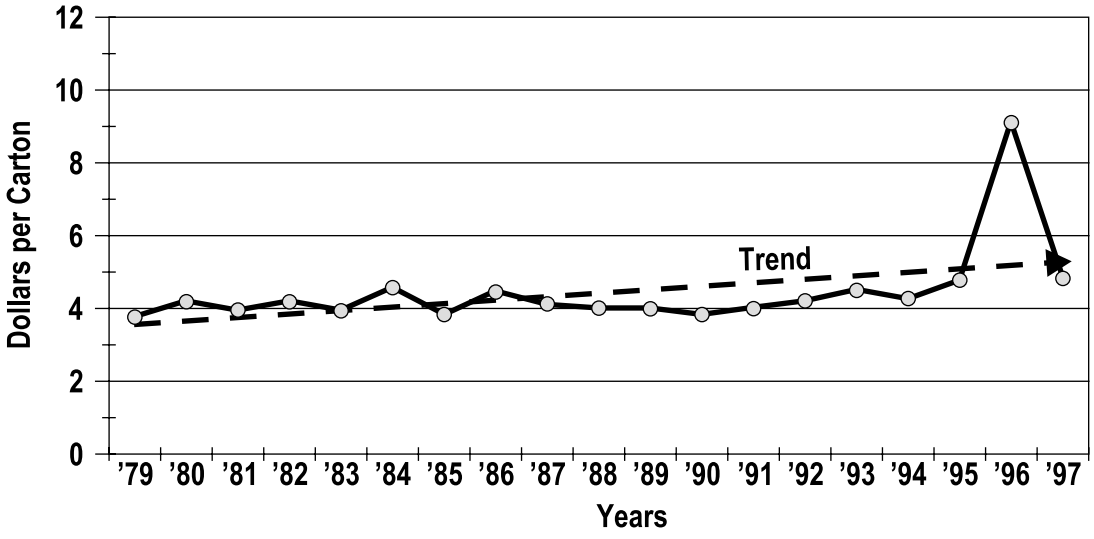

Table 17. *Average cabbage arrivals in 20 U.S. cities*

	From Georgia		From U.S.	
	Million Pounds	**Percent of Total**	**Million Pounds**	**Percent of Total**
Atlanta	12.7	53%	40.2	8%
Baltimore-Washington	1.9	8%	35.9	7%
Columbia	0.2	1%	10.5	2%
Dallas	0.1	0%	25.7	5%
Miami	0.5	2%	6.7	1%
New Orleans	0.1	0%	10.5	2%
South	*15.5*	*64%*	*129.5*	*25%*
Boston	1.7	7%	41.8	8%
Buffalo	0.2	1%	8.6	2%
New York-Newark	1.3	5%	35.3	7%
Philadelphia	1.0	4%	27.6	5%
Pittsburgh	0.6	3%	19.3	4%
Northeast	*4.8*	*20%*	*132.6*	*26%*
Cincinnati	1.5	6%	27.9	5%
Chicago	1.3	5%	43.4	8%
Denver	8.0	2%		
Detroit	0.6	3%	11.4	2%
St. Louis	0.5	2%	17.8	4%
Midwest	*3.9*	*16%*	*108.5*	*21%*
Los Angeles			87.7	17%
San Francisco			36.2	7%
Seattle-Tacoma			17.7	4%
West			*141.6*	*28%*
Total	***24.2***	***100%***	***512.2***	***100%***

Table 18. *Average greens arrivals in 20 U.S. cities*

	From Georgia		From U.S.	
	Million Pounds	**Percent of Total**	**Million Pounds**	**Percent of Total**
Atlanta	12.5	32%	17.1	11%
Baltimore-Washington	2.9	8%	9.1	6%
Columbia			2.9	2%
Dallas	0.3	1%	8.0	5%
Miami			1.1	1%
New Orleans			1.8	1%
South	*15.7*	*41%*	*40.0*	*26%*
Boston	5.1	13%	15.0	9%
Buffalo	0.1	0%	1.2	1%
New York-Newark	3.6	9%	14.8	9%
Philadelphia	2.2	6%	8.4	5%
Pittsburgh			0.4	0%
Northeast	*11.0*	*28%*	*39.8*	*24%*
Chicago	1.7	4%	14.1	9%
Cincinnati	9.9	26%	13.9	9%
Denver	1.7	1%		
Detroit	0.2	0%	9.2	6%
St. Louis	0.4	1%	3.8	2%
Midwest	*12.2*	*31%*	*42.7*	*26%*
Los Angles			25.8	16%
San Francisco			8.9	5%
Seattle			4.7	3%
West			*39.4*	*24%*
Total	***38.9***	***100%***	***161.9***	***100%***

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2016 Production Guide for Organic Lettuce

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Contents

INTRODUCTION

This guide for organic production of lettuce provides an outline of cultural and pest management practices and includes topics that have an impact on improving plant health and reducing pest problems. It is divided into sections, but the interrelated quality of organic cropping systems makes each section relevant to the others. The production of baby lettuce greens and greens in greenhouses require slightly different techniques which are generally not addressed in this guide.

This guide attempts to compile the most current information available, but acknowledges that effective means of control are not available for some pests. More research on growing crops organically is needed, especially in the area of pest management. Future revisions will incorporate new information, providing organic growers with a complete set of useful practices to help them achieve success.

Lettuce is grown for its edible leaves as a salad crop. It may be the most widely grown crop on organic farms because its value as "locally produced" is unsurpassed. There are three commonly grown types of lettuce: leaf, head (crisphead, bibb, butter) and romaine (cos). All three are popular as baby salad greens and are used in salad mixes. Cultivated lettuce is closely related to wild lettuce and both share the same insect pests and diseases.

This guide uses the term Integrated Pest Management (IPM), which like organic production, emphasizes cultural, biological, and mechanical practices to minimize pest outbreaks. With limited pest control products available for use in many organic production systems, an integrated approach to pest management is essential. IPM techniques such as identifying and assessing pest populations, keeping accurate pest history records, selecting the proper site, and preventing pest outbreaks through use of crop rotation, resistant varieties and biological controls are important to producing a high quality crop.

Key Pests of Lettuce. Perennial pests in NY

Diseases	Insects
Gray mold	Aphids
Bottom rot	Tarnished plant bug
Downy mildew	

Potentially Serious Pests. Use management strategies to prevent buildup of this potentially serious pest.

Sclerotinia drop

1. General Organic Management Practices

1.1 Organic Certification

To use a certified organic label, farming operations grossing more than $5,000 per year in organic products must be certified by a U.S. Department of Agriculture National Organic Program (NOP) accredited certifying agency. The choice of certifier may be dictated by the processor or by the target market. A list of accredited certifiers (reference 14) operating in New York can be found on the New York State Department of Agriculture and Markets Organic Farming Development/Assistance webpage (reference 15). See more certification and regulatory details under Section 4.1: *Certification Requirements* and Section 10: *Using Organic Pesticides.*

1.2 Organic System Plan

An organic system plan (OSP) is central to the certification process. The OSP describes production, handling, and record-keeping systems, and demonstrates to certifiers an understanding of organic practices for a specific crop. The process of developing the plan can be very valuable in terms of anticipating potential issues and challenges, and fosters thinking of the farm as a whole system. Soil, nutrient, pest, and weed management are all interrelated on organic farms and must be managed in concert for success. Certifying organizations may be able to provide a template for the farm plan. The following description of the organic system plan is from the USDA National Organic Program Handbook:

> "A plan of management of an organic production or handling operation that has been agreed to by the producer or handler and the certifying agent and that includes written plans concerning all aspects of agricultural production or handling described in the Organic Food Production Act of 1990 and the regulations in Subpart C, Organic Production and Handling Requirements."

The National Sustainable Agriculture Information Service, (formerly ATTRA), has produced a Guide for Organic Crop Producers that includes a chapter on writing the organic system plan. The Rodale Institute has also developed resources for transitioning to organic and developing an organic system plan.

2. Soil Health

Healthy soil is the foundation of organic farming. Regular additions of organic matter in the form of cover crops, compost, or manure create a soil that is biologically active, with good structure and capacity to hold nutrients and water (note that any raw manure applications must occur at least 120 days before harvest). Decomposing plant materials will

activate a diverse pool of microbes, including those that break down organic matter into plant-available nutrients, as well as others that compete with plant pathogens in the soil and on the root surface. However, newly incorporated organic matter can reduce germination and increase damping-off in lettuce. Allow 2 weeks between incorporation and planting.

Rotating between crop families can help prevent the buildup of diseases that overwinter in the soil. Rotation with a grain crop, or preferably a crop or crops that will be in place for one or more seasons, deprives many, but not all, disease-causing organisms of a host, and also contributes to a healthy soil structure that promotes vigorous plant growth. The same practices are effective for preventing the buildup of a number of root damaging nematodes in the soil, especially the root-knot nematode, but keep in mind that certain grain crops are also hosts for some nematode species including lesion nematodes. Rotating between crops with late and early season planting dates can reduce the buildup of weed populations. Organic growers must attend to the connection between soil, nutrients, pests, and weeds to succeed. An excellent resource for additional information on soils and soil health is Building Soils for Better Crops by Fred Magdoff and Harold Van Es, 2010 (reference 25). For additional information, refer to the Cornell Soil Health website (reference 26).

3. Cover Crops

Unlike cash crops, which are grown for immediate economic benefit, cover crops are grown for their valuable effect on soil properties and on subsequent cash crops. Cover crops help maintain soil organic matter, improve soil tilth, prevent erosion and assist in nutrient management. They can also contribute to weed management, increase water infiltration, maintain populations of beneficial fungi, and may help control insects, diseases and nematodes. To be effective, cover crops should be treated as any other valuable crop on the farm, carefully considering their cultural requirements, life span, mowing recommendations, incorporation methods, and susceptibility, tolerance, or antagonism to root pathogens and other pests. Some cover crops and cash crops share susceptibility to certain pathogens and nematodes. Careful planning and monitoring is required when choosing a cover crop sequence to avoid increasing pest problems in the subsequent cash crops. See Tables 3.1 and 3.2 for more information on specific cover crops and Section 8: *Crop and Soil Nutrient Management* for more information about how cover crops fit into a nutrient management plan.

A certified organic farmer is required to plant certified organic cover crop seed. If, after contacting at least three suppliers, organic seed is not available, then the certifier may allow untreated conventional seed to be used. Suppliers should provide a purity test for cover crop seed. Always inspect the seed for contamination from weed seeds and return if it is not clean. Cover crop seed is a common route for introduction of new weed species onto farms.

3.1 Goals and Timing for Cover Crops

Adding cover crops regularly to the crop rotation plan can result in increased yields of the subsequent cash crop. Goals should be established for choosing a cover crop; for example, the cover crop can add nitrogen, smother weeds, or break a pest cycle. The cover crop might best achieve some of these goals if it is in place for an entire growing season. If this is impractical, a compromise might be to grow the cover crop between summer cash crops. Allow two or more weeks between cover crop incorporation and cash crop seeding to permit decomposition of the cover crop, which will improve the seedbed while avoiding any unwanted allelopathic effects on the next cash crop. Another option is to overlap the cover crop and the cash crop life cycles by overseeding, interseeding or intercropping the cover crop between cash crop rows at final cultivation. An excellent resource for determining the best cover crop for your situation is Northeast Cover Crop Handbook, by Marianne Sarrantonio (reference 22) or the Cornell online decision tool to match goals, season, and cover crop (reference 24).

Leaving cover crop residue on the soil surface might make it easier to fit into a crop rotation and will help to conserve soil moisture, but some of the nitrogen contained in the residue will be lost to the atmosphere, and total organic matter added to the soil will be reduced. Turning under the cover crop will speed up the decomposition and nitrogen release from the residue. In wet years, the presence of cover crop residues may increase slug damage and infections by fungal pathogens such as *Pythium* and *Rhizoctonia,* affecting stand establishment.

3.2 Legume Cover Crops

Legumes are the best cover crop for increasing available soil nitrogen for crops with a high nitrogen requirement like lettuce (Table 4.2.1). Plant legumes in advance of the lettuce crop to build soil nitrogen, or after to replace the nitrogen used by the lettuce crop. Legumes have symbiotic bacteria in their roots called rhizobia, which convert atmospheric nitrogen gas in the soil pores to ammonium, a form of nitrogen that plant roots can use. When the cover crop is mowed, winter killed, or incorporated into the soil, the nitrogen is released and available for the next crop. Because most of this nitrogen was taken from the air, there is a net nitrogen gain to the soil (See Table 3.1). Assume approximately 50 percent of the nitrogen fixed by the cover crop will be available for the crop in the first season, but this will vary depending on factors such as the maturity of the legume, environmental conditions during decomposition, the type of legume grown, and soil type.

It is common to inoculate legume seed with rhizobia prior to planting, but the inoculant must be approved for use in

organic systems. Request written verification of organic approval from the supplier and confirm this with your organic farm certifier prior to inoculating seed.

Special considerations for lettuce

Annual field pea is an example of an appropriate legume cover crop for lettuce planted in the early spring or late summer. Under the right conditions, field peas can supply up to ~90 pounds of nitrogen per acre after incorporation. Avoid hairy vetch if lesion nematode is a problem since both hairy vetch and lettuce serve as hosts (reference 23). See more about managing these pests in Section 2: *Soil Health*.

3.3 Non-legume Cover Crops

Barley, rye grain, rye grass, Sudangrass, wheat, oats, and other grain crops left on the surface as dead plant residues, or plowed under in the spring as green manures, are beneficial because these plants take up nitrogen that otherwise might be leached from the soil, and release it back to the soil when as they decompose. If incorporated, allow two weeks or more for decomposition prior to planting.

3.4 Combining Legumes and Non-legumes.

Interseeding a legume with non-legume cover crop combines the benefits of both. An oat and field pea combination is a quick cover crop that can be grown and incorporated in the same season as a lettuce crop. They supply extensive organic matter and nitrogen when incorporated. Growing these cover crops together reduces the overall nitrogen contribution but is offset by the improvement in soil organic matter.

3.5 Biofumigant Cover Crops

Certain cover crops have been shown to inhibit weeds, pathogens, and nematodes by releasing toxic volatile chemicals when tilled into the soil as green manures and degraded by microbes or when cells are broken down by finely chopping. Degradation is quickest when soil is warm and moist. These biofumigant cover crops include Sudangrass, sorghum-sudangrasses, and many in the brassica family. Varieties of mustard and arugula developed with high glucosinolate levels that maximize biofumigant activity have been commercialized (e.g. Caliente brand 199 and Nemat).

The management of the cover crops should encourage maximum growth. Fertilizer applied to the cover crops will be taken up and then returned to the soil for use by the cash crop after the cover crop is incorporated. Biofumigant cover crops like mustard should be allowed to grow to their full size, normally several weeks after flowering starts, but incorporated before the seeds become brown and hard indicating they are mature. To minimize loss of biofumigant, finely chop the tissue early in the day when temperatures are low. Incorporate immediately by tilling, preferably with a second tractor following the chopper. Lightly seal the soil surface using a culti-packer and/or 1/2 inch of irrigation or rain water to help trap the volatiles and prolong their persistence in the soil. Wait at least two weeks before planting a subsequent crop to reduce the potential for the breakdown products to harm the crop, also known as phytotoxicity. Scratching the soil surface before planting will release the remaining biofumigant. This biofumigant effect is not predictable or consistent. The levels of the active compounds and suppressiveness can vary by season, cover crop variety, maturity at incorporation, amount of biomass, fineness of chopping, how quickly the tissue is incorporated, soil microbial diversity, soil tilth, and microbe population density.

Green-chopped Sudangrass, incorporated prior to planting, has been shown to suppress root-knot nematodes and improve lettuce yields. The effect is best when Sudangrass is grown for 1 to 2 months, then incorporated before frost (reference 23).

Reference

Crop Rotations on Organic Farms: A Planning Manual (reference 3).
Northeast Cover Crops Handbook (reference 22).
Cover Crops for Vegetable Production in the Northeast (reference 23).
Cover Crops for Vegetable Growers: Decision Tool (reference 24).

Table 3.1 Leguminous Cover Crops: Cultural Requirements, Nitrogen Contributions and Benefits.

Species	Planting Dates	Life Cycle	Cold Hardiness	Tolerances: Heat	Tolerances: Drought	Tolerances: Shade	pH Preference	Soil Type Preference	Seeding (lb/A)	Nitrogen Fixed (lb/A)[a]	Comments
CLOVERS											
Alsike	April-May	Biennial/ Perennial	4	5	5	6	6.3	Clay to silt	4-10	60-119	+Endures waterlogged soils & greater pH range than most clovers
Berseem	Early spring	Summer annual[b]/ Winter ann.	7	6-7	7-8	5	6.5-7.5	Loam to silt	9-25	50-95	+Good full-season annual cover crop
Crimson	Spring	Summer annual[b]/ Winter annual	6	5	3	7	5.0-7.0	Most if well-drained	9-40	70-130	+Quick cover +Good choice for overseeding (shade tolerant) + Sometimes hardy to zone 5.
Red	Very early spring or late summer	Short-lived perennial	4	4	4	6	6.2-7.0	Loam to clay	7-18	100-110	+Strong taproot, good heavy soil conditioner +Good choice for overseeding (shade tolerant)
White	Very early spring or late summer	Long-lived perennial	4	6	7	8	6.2-7.0	Loam to clay	6-14	≤130	+Good low maintenance living cover +Low growing +Hardy under wide range of conditions
SWEET CLOVERS											
Annual White	Very early spring	Summer annual[b]	NFT	6-7	6-7	6	6.5-7.2	Most	15-30	70-90	+Good warm weather smother & catch crop +Rapid grower +High biomass producer
Biennial White and Yellow	Early spring-late summer	Biennial	4	6	7-8	4	6.5-7.5	Most	9-20	90-170	+Deep taproot breaks up compacted soils & recycles nutrients +Good catch crop +High biomass producer
OTHER LEGUMES											
Cowpeas	Late spring-late summer	Summer annual[b]	NFT	9	8	6	5.5-6.5	Sandy loam to loam	25-120	130	+Rapid hot weather growth
Faba Beans	April-May or July- August	Summer annual[b]	8	3	4	NI	5.5-7.3	Loam to silty clay	80-170 small seed 70-300 lg seed	71-220	+Strong taproot, good conditioner for compacted soils + Excellent cover & producer in cold soils +Efficient N-fixer
Hairy Vetch	Late August-early Sept.	Summer annual/ Winter ann.	4	3	7	5	6.0-7.0	Most	20-40	80-250 (110 ave.)	+Prolific, viney growth +Most cold tolerant of available winter annual legumes
Field Peas	March-April OR late summer	Winter annual/ Sum. ann[b]	7	3	5	4	6.5-7.5	Clay loam	70-220	172-190	+Rapid growth in chilly weather

NI=No Information, NFT=No Frost Tolerance. Drought, Heat, Shade Tolerance Ratings: 1-2=low, 3-5=moderate, 6-8=high, 9-10=very high.
a Nitrogen fixed but not total available nitrogen. See Section 8 for more information. b Winter killed. Reprinted with permission from Rodale Institute ®,http://www.rodaleinstitute.org/, M. Sarrantonio. 1994. Northeast Cover Crop Handbook (reference 22).

Table 3.2 Non-Leguminous Cover Crops: Cultural Requirements and Crop Benefits

Species	Planting dates	Life Cycle	Cold Hardiness Zone	Tolerance			pH Preference	Soil Type Preference	Seeding (Lb/A)	Comments
				Heat	Drought	Shade				
Brassicas e.g. mustards, canola	April or late August-early Sept.	Annual / Biennial [b]	6-8	4	6	NI	5.3-6.8	Loam to clay	5-12	+Good dual purpose cover & forage +Establishes quickly in cool weather +Biofumigant properties
Buckwheat	Late spring-summer	Summer annual [b]	NFT	7-8	4	6	5.0-7.0	Most	35-134	+Rapid grower (warm season) +Good catch or smother crop +Good short-term soil improver for poor soils
Cereal Rye	August-early October	Winter annual	3	6	8	7	5.0-7.0	Sandy to clay loams	60-200	+Most cold-tolerant cover crop +Excellent allelopathic weed control +Good catch crop +Rapid germination & growth +Temporary N tie-up when turned under
Fine Fescues	Mid March-mid-May OR late Aug.-late Sept.	Long-lived perennial	4	3-5	7-9	7-8	5.3-7.5 (red) 5.0-6.0 (hard)	Most	16-100	+Very good low-maintenance permanent cover, especially in infertile, acid, droughty &/or shady sites
Oats	Mid Sept-early October	Summer annual[b]	8	4	4	4	5.0-6.5	Silt & clay loams	110	+Rapid growth +Ideal quick cover and nurse crop
Ryegrasses	August-early Sept.	Winter annual (AR)/ Short-lived perennial (PR)	6 (AR) 4 (PR)	4	3	7 (AR) 5 (PR)	6.0-7.0	Most	14-35	+Temporary N tie-up when turned under +Rapid growth +Good catch crop +Heavy N & moisture users
Sorghum-Sudangrass	Late spring-summer	Summer Annual [b]	NFT	9	8	NI	Near neutral	NI	10-36	+Tremendous biomass producers in hot weather +Good catch or smother crop +Biofumigant properties

NI-No Information, NFT-No Frost Tolerance. Drought, Heat, Shade Tolerance Ratings: 1-2=low, 3-5=moderate, 6-8=high, 9-10=very high. AR=Annual Rye, PR=Perennial Rye. b Winter killed. Reprinted with permission from Rodale Institute®, www.rodaleinstitute.org, M. Sarrantonio. 1994. Northeast Cover Crop Handbook (reference 22)

4. Field Selection

For organic production, give priority to fields with excellent soil tilth, high organic matter, good drainage and airflow.

4.1 Certification Requirements

Certifying agencies have requirements that affect field selection. Fields cannot be treated with prohibited products for three years prior to the harvest of a certified organic crop. Adequate buffer zones are required between certified organic and conventionally grown crops. Buffer zones must be a barrier, such as a diversion ditch or dense hedgerow, or be a distance large enough to prevent drift of prohibited materials onto certified organic fields. Determining what buffer zone is needed will vary depending on equipment used on adjacent non-certified land. For example, use of high-pressure spray equipment or aerial pesticide applications in adjacent fields will increase the buffer zone size. Pollen from genetically engineered crops can also be a contaminant. An organic crop should not be grown near a genetically engineered crop of the same species. Check with your certifier for specific buffer requirements. Buffer zones commonly range between 20 and 250 feet depending on adjacent field practices.

4.2 Crop Rotation Plan

A careful crop rotation plan is the cornerstone of organic crop production because it allows the grower to improve soil quality and proactively manage pests. Although growing a wide range of crops complicates the crop rotation planning process, it ensures diversity in crop residues in the soil, and a

greater variety of beneficial soil organisms. Individual organic farms vary widely in the crops grown and their ultimate goals, but some general rules apply to all organic farms regarding crop rotation. Rotating individual fields away from crops within the same family is critical and can help minimize crop-specific disease and non-mobile insect pests that persist in the soil or overwinter in the field or field borders. Pests that are persistent in the soil, have a wide host range, or are wind-borne, will be difficult to control through crop rotation. Conversely, the more host specific, non-mobile, and short-lived a pest is, the greater the ability to control it through crop rotation. The amount of time required for a crop rotation is based on the particular pest and its severity. Some particularly difficult pests may require a period of fallow. See specific recommendations in the disease and insect sections of this guide (sections 11, 12, 14). Partitioning the farm into management units will help to organize crop rotations and ensure that all parts of the farm have sufficient breaks from each type of crop.

A well-planned crop rotation is key to weed management. Short season crops such as lettuce and spinach are harvested before many weeds go to seed, whereas vining cucurbits, with their limited cultivation time and long growing season, allow weeds to go to seed before harvest. Including short season crops in the rotation will help to reduce weed populations provided the field is cleaned up promptly after harvest. Other weed reducing rotation strategies include growing mulched crops, competitive cash crops, short-lived cover crops, or crops that can be intensively cultivated. Individual weed species emerge and mature at different times of the year, therefore alternating between spring, summer, and fall planted crops helps to interrupt weed life cycles.

Cash and cover crop sequences should also take into account the nutrient needs of different crops and the response of weeds to high nutrient levels. High soil phosphorus and potassium levels can exacerbate problem weed species. A cropping sequence that alternates crops with high and low nutrient requirements can help keep nutrients in balance. The crop with low nutrient requirements can help use up nutrients from a previous heavy feeder. A fall planting of a non-legume cover crop will help hold nitrogen not used by the previous crop. This nitrogen is then released when the cover crop is incorporated in the spring. See Section 3: *Cover Crops* and Section 5: *Weeds* for more information.

Rotating crops that produce abundant organic matter, such as hay and grain-legume cover crops, with ones that produce less, such as vegetables, will help to sustain organic matter levels and promote good soil tilth (see Section 2: *Soil Health* and Section 8: *Crop and Soil Nutrient Management*). Lettuce generally has a high nutrient requirement (Table 4.2.1).

Growing a cover crop, preferably one that includes a legume, prior to or after a lettuce crop will help to renew soil nitrogen, improve soil structure, and diversify soil organisms. Include deep rooted crops in the rotation to help break up compacted soil layers.

Table 4.2.1 Crop Nutrient Requirements

	Nutrient Needs		
	Lower	**Medium**	**Higher**
Crop	Bean Beet Carrot Herbs Pea Radish	Cucumber Eggplant Brassica greens Pepper Pumpkin Spinach Chard Squash Winter squash	Broccoli Cabbage Cauliflower Corn Lettuce Potato Tomato

From NRAES publication *Crop Rotation on Organic Farms: A Planning Manual*, Charles L. Mohler and Sue Ellen Johnson, editors (reference 3).

Crop rotation information specific to lettuce

Growers are encouraged to rotate lettuce with another crop whenever possible. This aids in the management of many pests that affect lettuce. Double-cropping lettuce on the same field may greatly increase problems such as *Sclerotinia* drop, corky root rot, root-knot nematode, and virus diseases in the second planting. For most diseases, maintaining at least 3 years between lettuce crops is recommended, although heavy infestations of pathogens causing diseases like drop may require longer rotations.

Sclerotinia sclerotiorum (lettuce drop)*:* Broccoli grown prior to lettuce helps to reduce lettuce drop. Rotate away from bean, potato, and pea which are all especially susceptible to *Sclerotinia.*

Rhizoctonia*:* Highly susceptible crops include beans, lettuce, cabbage, and potato. Rotate away from these crops for at least 3 years. Other host crops include broccoli, kale, radish, turnip, carrot, cress, cucumber, eggplant, pepper, and tomato. Cereal crops are not susceptible and are useful for reducing *Rhizoctonia.*

Colletotrichum coccodes: Lettuce can be a symptomless carrier of the pathogen causing anthracnose in tomato and black dot in potato.

Root-knot Nematode*:* This nematode feeds on many plants including weeds and cover crops. Nutsedge is a weed particularly prone to root-knot nematode and hairy vetch is a highly susceptible cover crop. Many vegetables also are hosts, therefore rotating with sorghum, small grains, or grasses is recommended. Green-chopped Sudangrass, incorporated prior to planting, has been shown to suppress root-knot nematodes and improve lettuce yields. The effect is best

when Sudangrass is grown for 1 to 2 months, then incorporated before frost (reference 23). See Section 3.5: *Biofumigant Cover Crops* for more information.

Multiple plantings: The short growing season for lettuce makes it a good choice for double cropping with longer season crops such as cucurbits, tomato, eggplant, pepper, beet, carrot, or onion. Residues from the lettuce crop act as a green manure for subsequent crops. Growing root crops, such as beets, in rotation with lettuce is common. Fall lettuce can be planted in the same field as spring peas within the same growing season. The lettuce benefits from the elevated nitrogen provided by the pea crop. While multiple plantings of vegetable crops may fit well into the rotation, this practice can increase pest pressures on crops that share susceptibility to the same pathogens and nematodes. Careful planning and monitoring is required when double cropping vegetables in the same season.

Weeds: Growing a short season crop, like lettuce, helps reduce the weed population within a field prior to planting longer season crops which are more prone to weed infestations on organic farms.

Cover crops: Red clover, field peas, bell beans and fava beans host a related *Sclerotinia* disease that can infect lettuce, pea and possibly other plants.

For more details, see Crop Rotation on Organic Farms: A Planning Manual(reference 3)

Table 4.2.2 Potential Interactions of Crops Grown in Rotation with Lettuce

Crops	Potential Rotation Consequences	Comments
Onion, leek, carrot, tomato, eggplant, pepper, cucurbits	Reduced weeds	Alternate growing a short season crop such as lettuce with a long-season crop to break weed cycles and make efficient use of fields. An early season lettuce crop can act as a cover crop for crops planted later in the same season.
Bean, carrot, cabbage, tomato, celery, pea	Increased *Sclerotinia*	*Sclerotinia* has a wide host range including lettuce, bean, carrot, cabbage, tomato, celery, and pea. Rotate away from these crops for 3 years. Instead plant sweet corn or grain crops such as barley, oat, wheat, field corn, or grain cover crops.
Pea, fava bean, bell bean, red clover	Increase *Sclerotinia* of broadbean	*Sclerotinia trifoliorum* can attack a wide range of hosts including lettuce.
Tomato	Increase *Colletotrichum coccodes*	Lettuce, cabbage and cress can be silent carriers of this pathogen that causes tomato anthracnose and black dot in potato.

Excerpt from Appendix 2 of Crop Rotation on Organic Farms: A Planning Manual (reference 3).

4.3 Pest History

Knowledge about the pest history of each field is important for planning a successful cropping strategy. For example, germination may be reduced in fields with a history of *Pythium* or *Rhizoctonia.* Avoid fields that contain heavy infestations of perennial weeds such as nutsedge, bindweed, and quackgrass as these weeds are particularly difficult to control. One or more years focusing on weed population reduction using cultivated fallow and cover cropping may be needed before organic crops can be successfully grown in those fields. Susceptible crops should not be grown in fields with a history of *Sclerotinia* without a rotation of several years with sweet corn or grain crops. Treat with Contans™ to reduce fungal sclerotia in the soil immediately after an infected crop is harvested and/or before planting lettuce.

Lettuce is a favored host for root-knot nematode, *Meloidogyne hapla*, and can also host the root lesion nematode, *Pratylenchus penetrans*, but the degree of damage is not known. Knowing whether or not these nematodes are present aids development of cropping sequences that either reduce the populations in heavily infested fields or minimize their increase in fields that have little to no infestation. Refer to Section 12 for more information on nematodes.

4.4 Soil and Air Drainage

Most fungal and bacterial pathogens need free water on the plant tissue or high humidity for several hours in order to infect. Any practice that promotes leaf drying or drainage of excess water from the root zone will minimize favorable conditions for infection and disease development. Fields with poor air movement, such as those surrounded by hedgerows or woods, creates an environment that favors prolonged leaf wetness. Plant rows parallel to the prevailing winds, which is typically in an east-west direction, and avoid overcrowding to promote drying of the soil and reduce moisture in the plant canopy.

5. WEED MANAGEMENT

Weed management can be one of the biggest challenges on organic farms, especially during the transition and the first several years of organic production. To be successful, use an

integrated approach to weed management that includes crop rotation, cover cropping, cultivation, and planting design, based on an understanding of the biology and ecology of dominant weed species. A multi-year approach that includes strategies for controlling problem weed species in a sequence of crops will generally be more successful than attempting to manage each year's weeds as they appear. Relying on cultivation alone to manage weeds in an organic system is a recipe for disaster.

Management plans should focus on the most challenging and potentially yield-limiting weed species in each field. Be sure, however, to emphasize options that do not increase other species that are present. Alternating between early and late-planted crops, and short and long season crops in the rotation can help minimize buildup of a particular weed or group of weeds with similar life cycles or growth habits, and will also provide windows for a variety of cover crops.

5.1 Record Keeping

Scout and develop a written inventory of weed species and their severity for each field. Accurate identification of weeds is essential. Weed fact sheets provide a good color reference for common weed identification. See Cornell weed ecology and Rutgers weed gallery websites (references 37-38).

5.2 Weed Management Methods

Planting and cultivation equipment should be set up on the same number of rows to minimize crop damage during cultivation. Specialized equipment may be needed to successfully control weeds in some crops. See the resources at the end of this section to help fine-tune your weed management system. Reduce disease pressure by planting lettuce in fields that have been free from weeds that serve as alternate hosts to many lettuce diseases such as dandelion, prickly lettuce, sowthistles, wild sunflower and common groundsel for two to three years.

Heading types of lettuce grown on organic farms should be transplanted to provide them with an advantage over the weeds and to allow for earlier cultivation. See more in Section 7: *Planting*. Information on weed control for baby greens is generally not addressed in this guide.

If weed pressure is high, precede plantings for late summer or fall harvest with a one month cultivated fallow to reduce the weed seed bank. Till early enough to prevent winter annual weeds like chickweed and shepherd's purse from going to seed. Prepare a seed bed by harrowing thoroughly but shallowly at two week intervals until planting time. Use shallow tillage to prepare the final seedbed to avoid bringing new weed seeds to the soil surface. A cultivated fallow will greatly reduce species like pigweed and galinsoga that often plague summer plantings. To minimize damage to the soil caused by leaving the soil surface bare, plan to mow and incorporate a heavy cover crop, for example, rye with hairy vetch, before beginning the fallow. This will leave some small pieces of cover crop residue on the surface to intercept rain drops and create a spongy soil consistency that will absorb rain and avoid crusting. Avoid hairy vetch in fields with a history of lesion nematodes. If planting will be as late as August, include a short term cover crop of buckwheat in the fallow to maintain soil organic matter.

For early cultivations after planting, use vegetable knives on a belly mounted cultivator. Set the knives shallow, 1 to 1.5 inches below the soil surface, with the blades pointed away from the row. Cultivate as closely as possible. Use sweeps or duck foot shovels with at least 25% overlap to clean weeds out of the inter-row areas and loosen soil behind the tractor tires. Cultivate at about 10-day intervals to avoid letting weeds grow larger than 2 inches. To minimize root pruning, set knives to run as shallowly as possible without creating skips. If field preparation has created a highly uniform surface, a cultivation depth of 3/4 to 1 inch is sufficient. Continue cultivating until the crop canopy is too closed to allow tractor traffic or harvest is imminent. Usually two to three cultivations are sufficient, but note that with lettuce, the objective of weed management is not just reduction in competition. Untangling grass leaves and chickweed from lettuce during harvest can add to the cost of labor.

To control weeds between plants in the row, hand hoe once, typically just after the second machine cultivation, but before the biggest weeds are 2 inches tall. The goal is to kill weeds while they are still small. Hoe soon after cultivation since breaking the soil between the rows will ease penetration of the hoe. Use a stirrup hoe (shuffle hoe) pulling toward the plant stalk. Try to throw about 1 inch of soil in around base of the plant to cover small weeds that are too close to the crop plants to cut with the hoe. For maximum effectiveness, keep both the edges and curved shoulders of the stirrup blade sharp. Following the above practices, only one hand hoeing should be required.

Straw or hay mulch is not recommended for lettuce since the sharp ends can damage lettuce leaves and it promotes the buildup of slugs and snails. If using plastic mulch, cultivate along the edges of the mulch with hilling discs or rolling gangs and between the plastic beds with overlapping sweeps. Hand pull larger weeds growing next to the lettuce plants when the crop is 2/3 through its development.

Clean up the field soon after harvest. Lettuce can be an effective component in the overall weed control program on a vegetable farm since it is generally harvested before weeds have time to set seed. It can act as a "cleaning" crop,

reducing the seed bank following weed control failures and preceding crops in which weed management is difficult. But to receive these benefits from the lettuce, weeds must be destroyed soon after harvest before they can go to seed.

High soil phosphorus and potassium levels can exacerbate problem weed species. For example, high phosphorus promotes common purslane and high potassium promotes dandelion. See Section 8 for more information on balancing nutrients on organic farms.

Resources

Crop Rotation on Organic Farms: A Planning Manual (reference 3)
Steel in the Field (reference 35)
New Cultivation Tools for Mechanical Weed Control in Vegetables (reference 36)
Cornell Weed Ecology website (reference 37)
New Jersey Weed Gallery (reference 38)
Principles of Sustainable Weed Management for Croplands (reference 39)
Weed "Em and Reap Videos (reference 40)
Flame Weeding for Vegetable Crops (reference 41)
Vegetable Farmers and their Weed-Control Machines (reference 42)
Twelve Steps toward Ecological Weed Management in Organic Vegetables (reference 43)

6. Recommended Varieties

Variety selection is important, both for the horticultural characteristics specified by the market, and the pest resistance profile that will be the foundation of a pest management program. If a field has a known disease history, Table 6.1 can help to determine which varieties will be more successful in reducing disease problems. Consider the market when choosing varieties, selecting those with some level of disease resistance if possible.

A certified organic farmer is required to plant certified organic seed. If, after contacting at least three suppliers, organic seed is not available for a particular variety, then the certifier may allow untreated conventional seed to be used.

Table 6.1 Disease Resistance in Lettuce Varieties.

Variety Name (days to harvest)	**Type**	**Bottom Rot**	**Corky Root Rot**	**Downy Mildew**	**Bacterial Spot**	**Lettuce Mosaic Virus**	**Drop**		**Bolting**	**Heat**	**Brown Rib**	**Tip Burn**	**Comments**
BUTTERHEAD and BIBB													
Adriana (48)	Butter			X		X			X	X		X	
Escale	Bibb			X		X			X				
Barracuda	Bibb								X				
Bennett MI (64)	Butter											X	
Buttercrunch (60) [1, 2]	Butter								X				Open pollinated
Ermosa (48) [1, 2]	Butter			X		X			X	X		X	
Esmeralda (68) [1, 2]	Butter			X		X			X			X	
Fireball (51)	Butter									X			
Focea (45)	Butter			X		X							
Harmony (68)	Butter			X					X	X		X	
Kagraner Sommer [2]	Butter								X				
Kweik (55)	Butter			X			X					X	
Lucan				X					X			X	
Margarita (68)	Boston			X		X			X			X	Open pollinated
Nancy (62) [1]	Boston			X		X							Open pollinated
Odyssey MI (62)	Butter								X			X	Open pollinated
Optima (68-70)	Butter	X		X		X			X			X	Open pollinated
Pirat (55) [2]	Butter			X	X		X					X	Heirloom; red tinged.
Rex (50)	Butter			X					X			X	Better for greenhouses.
Speckled [2]	Butter												German heirloom

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Summer Bibb (65) [1]	Bibb							X	X		X	For hotbed and greenhouse growing
Summer Long Salad	Mix								X			Looseleaf, romaine, butter combination
Sylvesta (52)	Bibb			X		X						
Tom Thumb (46)	Butter							X	X			Open pollinated
Victoria (45)	Butter							X	X			Open pollinated
Winter Density (60) [2]	Butter/cos							X				Open pollinated
BUTTERHEAD - RED												
Australe (49)	Butter - red			X				X				
Lucan	Butter - red			X				X			X	
Red Cross (48) [2]	Butter - red			X					X			
Roxy (50)	Butter - red			X							X	
CRISPHEAD												
Fallgreen (70)	Crisphead			X		X		X			x	
Great Lakes (70+) [1]	"							X			X	Heirloom
Igloo (70)	"								X			
Ithaca (72-85) [1]	"					X			X	X	X	
Salinas 88 Supreme (50)	"					X						
Santa Fe (55)	"								X			
Summer Time (75)	"							X	X	X	X	Open Pollinated
Sun Devil (60)	"							X	X		X	
LOOSE LEAF - GREEN												
Baby Oakleaf (50)	Oakleaf							X				
Berenice (50)	Oakleaf					X		X	X			
Bergam's Green (57)	Loose		X					X	X		X	
Black Seeded Simpson (44) [2]	Loose			X			X	X	X		X	
Deer Tongue (48)	Loose							X				Heirloom
Emerald (50-54)	Oakleaf										X	
Galisse (48) [2]	Loose			X		X						Sensitive to short daylength
Grand Rapids (45) [1]	Loose								X		X	Open pollinated
Green Bay (48)	Loose										X	
Green Deer Tongue (48)	Loose							X	X			Open pollinated
Green Ice (45)	Loose							X				For early plantings. Bolts rapidly
Green Star (52)	Loose			X				X	X		X	
Green Vision (54)	Loose										X	
Heatwave (50-60)	Loose							X	X			
Lasting Green MI (65)	Loose							X			X	Open pollinated
Lettony (29-51)	Loose			X								Baby or mature
Loma (46)	Loose								X		X	Open pollinated
Nevada (28-48)	Loose	X		X		X		X			X	Open pollinated, baby or mature head.

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North Star	Loose		X								X	
Prizeleaf (48)	Loose							X	X			
Reine Des Glaces (57)	Batavia							X				Open pollinated
Royal Oak Leaf (47) [2]	Oakleaf							X	X			
Salad Bowl (49)	Loose							X	X			
Simpson Elite (41-53) [2]	Loose							X				Open pollinated
Slobolt (50) [1, 2]	Loose							X	X		X	
Seacrest	Oakleaf			X								
Star Fighter (58)	Loose		X					X			X	
Sulu (28)	Oakleaf			X								Baby greens
Tango (28-45)	Loose							X				Baby or mature heads
Tehama (53)	Loose		X					X			X	
Tiara (46) [1]	Loose											
Tropicana (52) [2]	Loose		X					X	X		X	
Two Star (51) [2]	Loose							X				Open pollinated
Waldmann's Dark Green (60) [1]	Loose							X	X		X	
Blade (30)	Oakleaf			X		X						Baby greens
Bronze Arrowhead [2]	Oakleaf											
Brunia [2]	Oakleaf											
Cherokee (48) [2]	Loose	X		X				X	X			
Cocarde (49) [2]	Oakleaf							X				
Continuity (56)	Loose								X			
Antago (30-53)	Lollo rossa			X								
Fides	Lollo rossa			X								
Dark Lolla Rossa (53)	Lollo rossa			X								
De Morges Braun (64)	Loose							X				Open pollinated
Ferrari (44)	Oakleaf			X								
Firecracker (28)	Loose		X	X								For baby greens
Flashy [2]												
Forte red	Oakleaf			X								
Galactic (58)	Loose			X			X					
Garrison (28)	Oakleaf			X								For baby greens
Jamai (45)	Oakleaf			X								
Magenta red	Loose	X		X		X		X			X	
Malawi (28/51)	Oakleaf							X				
Mascara (65)	Loose							X				Open pollinate
Mercury (55)	Loose			X								
Mottistone (55)	Loose			X								
Nestorix (21-28)	Loose			X								For baby greens
New Red Fire MI (48) [1]	Loose	X		X				X	X		X	Open pollinated

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Oscarde (28-55)	Oakleaf			X									
Prizehead (45) [2]	Loose				X								
Ravessa	Batavia			X		X							
Red Oakleaf (50)	Oakleaf			X			X			X		X	
Red Sails (45) [1, 2]	Loose								X	X		X	Open pollinated
Red Salad Bowl (51) [2]	Oakleaf								X				
Red Tide (28/48)	Loose	X										X	
Red Velvet (55)	Loose												Open pollinated
Revolution (48)	Lollo rossa			X					X				
Rustica (28/60)	Batavia			X	X								
Sierra (50) [1]	Batavia												
Sunfire (28)	Oakleaf			X									For baby greens
Teide (48)	Batavia			X									
Vulcan (52) [2]	Loose									X		X	
High Mowing Salad Blend				X									Open pollinated
ROMAINE/COS													
Brune d'Hiver [2]													
Claremont (28-46)	Cos			X									Baby or mature
Coastal Star (65)	"		X							X			
Dark Green Cos (70) [1]	"												
Defender (28)	"			X									For baby greens
Freckles Forellenschluss (55)	"								X	X			
Green Forest (70)	"								X			X	
Green Towers (70) [1]	"		X										
Ideal Cos (75) [1]	"								X			X	
Jericho (57) [2]	"									X		X	hybrid
King Henry	"									X			
Little Caesar (70)	"											X	
Noga	"								X				
Paramount (67)	"		X										
Parris Island (76) [1]	"					X						X	
PIC 714 (28-57)	"		X									X	
Pinecrest	"			X		X							
Plato II (53)	"					X						X	
Raptor MI (75)	"		X										
Rome 37	"					X							
Rouge d' Hiver (60) [2]	"						X					X	
Rubicon	"		X			X			X	X		X	
Tall Guzmaine (65)	"		X			X				X			
Tigress (65)	"								X	X		X	

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Triton (75)	"									X			
Valmaine (70)	"									X			Open pollinated
Vivian (28/70) [2]	"								X				
COS RED													
Annapolis (28)	Red cos			X									
Breen (45)	"			X									
Eruption (28/50)	"			X		X							
Red Rosie (28/56)	"			X									
Red Zin	"			X	X								For baby greens
Rubane (28/56)	"			X									
Spock (28)	"			X									For baby greens

1- Recommended for New York growers in the Cornell Crop and Pest Management Guidelines, 2- Recommended from organic grower experience, X= tolerant or resistant to the disease or disorder.

7. PLANTING

On average, a lettuce crop reaches maturity in 60 days. On organic farms in New York, lettuce types with a long growing season should be transplanted, not direct seeded. The small lettuce seed establishes more slowly than many weeds. Transplanting the crop makes it more competitive relative to weeds and allows earlier cultivation. For lettuce crops with a shorter cropping interval, such as baby greens, direct seeding into a well prepared seedbed is preferable. Planting information for baby greens is not addressed in this guide.

Spacing both between and within rows should allow adequate air movement to minimize grey mold, bottom rot, and drop. Rows generally are spaced about 15 inches apart and in-row spacing is determined by variety and desired size of the marketed lettuce (see Table 7.0.1). Uniform spacing is important for achieving uniform maturity. Growing on 4' wide and 4" high raised beds enhances air movement and soil drying for improved disease control.

Table 7.0.1 Recommended Spacing

Type	Between Row (inches)	In-row (inches)
Crisphead	12-24	12-18
Other lettuce	10-18	10-16

Lettuce is a cool-season crop, and high temperatures, particularly at night, are detrimental, leading to disorders such as premature bolting, tipburn, and brown rib. Crisphead (iceberg) lettuce is especially sensitive to heat, although some new varieties are more tolerant.

7.1 Direct Seeding

Lettuce will germinate at soil temperatures as low as 32^{0}F, but the optimum and maximum soil temperature is 75^{0}F. Above 80^{0}F, seed will remain dormant until temperatures cool. Because lettuce withstands cold temperatures, the season can be extended through use of high tunnels or unheated greenhouses. Early spring plantings, and fall plantings held through the winter, target the lucrative early markets.

Once-over harvesting is done on most large commercial acreage, so every effort should be made to promote uniform maturity. Purchase the best quality seed available to help ensure uniformity of the crop. Using precision seeding and coated seed can enhance uniformity. Irrigation immediately following seeding promotes consistent emergence. Where irrigation is not possible, deep plowing followed immediately by fitting and seeding is helpful. Washington State University has information on organic seed treatments (reference 52).

7.2 Transplant Production

Transplants can be started in the greenhouse in February or March, and set out in April. Germination rates are generally better in seed planted the greenhouse than seed planted directly into the field. Floating row covers over the bed, used in combination with early transplanting, can produce lettuce for the early market. A good transplant is healthy, stocky, and relatively young. Planting transplants that are at the same stage of growth will help reduce variability at harvest time. Producing such plants requires good light, proper

temperature, adequate moisture and a uniform, fertile planting mix. Maintaining optimum soil temperature and moisture will also help to prevent damping-off losses in seedlings. Harden transplants near the end of their growing period by reducing water and moving them outside to a sheltered area. See Section 7.5: *Transplanting.*

Using cell or plug flats will improve transplant uniformity and reduce plant shock at field setting. Plug flats are sold based upon the number of cells per flat (24 to 800 cell plug trays are available). Generally, the more cells per flat, the smaller the volume per cell. Selection of cell number depends on several factors including desired final plant size, fertility options and the estimated time between seeding and transplanting. Plants grown in smaller cells will require more careful monitoring of nutrients and water, but will be ready to transplant sooner. Larger cells provide more soil media, and thus more moisture and nutrients to developing seedlings, but make less efficient use of greenhouse bench space. If using smaller cells, time planting to avoid plants from becoming root bound. Lettuce is commonly grown in flats with 96-200 cells. Seeds are placed singly in individual cells, either by hand or via seeders.

Table 7.2.1 Optimal Temperatures for Growing Transplants

Optimal soil germination temperature	75^0F
Minimum soil germination temperature	32^0F
Optimal day temperature for transplant growth	60-65^0F
Optimal night temperature for transplant growth	50^0F
Weeks from seeding to planting	3-5

7.3 Greenhouse Sanitation and Disease Management

The greenhouse environment is favorable for plant pathogens, and these pathogens are difficult to control. Plants can become infected as seedlings without showing symptoms until they are maturing in the field. No single strategy will prevent greenhouse diseases, however by utilizing multiple management strategies, damage and losses can be minimized.

Preseason Sanitation: Clean and disinfect all greenhouse tables, benches, floors, hoses, flats, containers or anything that comes in contact with plants. It is important to thoroughly clean, **even if there was had no disease last year**. Persistent pathogens could still be present and spread to healthy transplants under optimal environmental conditions. Clean all seedling flats prior to reuse to remove any clinging soil or plant material that may be contaminated with fungi capable of causing damping-off in seedlings. At a minimum, use soap and water with a stiff brush to wash flats and then dry thoroughly in a hot greenhouse prior to storage. Alternatively, flats could be steamed or sanitized prior to use. Chlorine solutions are probably the most effective sanitizers, but the NOP limits the chlorine concentration in discharge water. If you plan to use chlorine, **check with your certifier** to determine its proper use. Thoroughly rinse flats after using sanitizers. Table 7.3.1 lists sanitizers**.** Use new flats to help avoid carry-over of pathogens if disease was severe the previous season.

IPM Strategies in the Greenhouse: Keep the greenhouse weed-free. Some pathogens survive on weed hosts and then move to transplants in the greenhouse. Scout greenhouses weekly for any sign of disease and remove diseased plants immediately. If a diseased plant is identified in a flat, remove the whole flat. Control insects that may spread viruses. Keep foliage as dry as possible to prevent infection. Water in the morning since foliage is likely to dry quickly during the day. Do not brush against or trim when plants are wet to reduce the spread of pathogens.

Table 7.3.1 Disinfectants

Compound **Trade Name** ***Active Ingredient***	**Rate**
CDG Solution 3000 *(chlorine dioxide)*	*For surfaces, equipment and structures:* use 1:12 dilution. *For pots, flats, trays and tools:* use 1:6 dilution.
***GreenClean PRO** (*sodium carbonate peroxyhydrate*)	0.5-2 lbs granular/1000 ft^2
* Restricted-use pesticide in New York State; may be purchased and used only by certified applicators	

Use power sprayer to wash all surfaces and remove plant debris and other organic material before treating. Use to disinfect pots, flats and trays, surfaces, equipment and structures.

7.4 Transplant Growing Mix

A good transplant mix is well drained, has good aeration, supplies a reserve of nutrients, and provides adequate support to developing seedlings. Most organic transplant mixes are based upon a combination of peat moss, vermiculite or perlite and a proportion of stable, cured compost. Soil may be included in an organic mix, but could harbor damping-off pathogens. Organic transplant mixes must not contain any materials prohibited by the NOP, including synthetic fertilizers and most wetting agents. Commercial organic potting media is available. See the OMRI Products list for approved media, wetting agents, and soil amendments (reference 13).

7.5 Transplanting

Prior to field setting, reduce temperature, water, and nutrients for 3-5 days to harden transplants. Gradually expose them to direct sunlight in a protected location, while watching to make sure plants are not stressed. This 'hardening' process helps greenhouse-grown transplants develop a thicker leaf cuticle that resists water stress. Hardening also helps plants accumulate the food reserves needed to expand the root system after field setting. Over mature or stressed transplants usually resume growth slowly and rarely achieve full yields.

To transplant, set plants deep enough to completely cover the media of the plug and firm the soil around the plants to minimize water loss from the plug. Apply water using the transplanter or irrigate immediately after transplanting, especially if the soil is somewhat dry. High temperatures or strong drying winds at the time of transplanting contribute to delayed recovery and increased plant mortality. If possible, avoid planting under such conditions or be prepared to irrigate immediately.

7.6 Planting Dates

Since lettuce is a short-season crop, it can be grown from early spring into late fall, especially when expanding the season through use of high tunnels, floating row covers, or other season extension systems. Cold tolerant lettuce varieties can be planted as soon as the soil is workable in the spring. Lettuce varieties vary in their tolerance to heat and cold. See Table 6.1 or review seed company information to match varieties to the climate conditions.

8. Crop and Soil Nutrient Management

To produce a healthy crop, sufficient soluble nutrients must be available from the soil to meet the minimum requirements for the whole plant. The total nutrient needs of a crop are much higher than just the nutrients that are removed from the field when that crop is harvested. All of the roots, stems, leaves and other plant parts require nutrients at specific times during plant growth and development. Restrictions in the supply of required plant nutrients will limit growth and reduce crop quality and yields.

The challenge in organic systems is balancing soil fertility to supply these required plant nutrients at a time and at sufficient levels to support healthy plant growth. Soil microbes decompose organic matter to release nutrients and convert organic matter to more stable forms such as humus. This breakdown of soil organic matter occurs throughout the growing season, depending on soil temperatures, water availability and soil quality. The released nutrients are then held on soil particles or humus making them available to crops or cover crops for plant growth. Amending soils with compost, cover crops, or crop residues also provides a food source for soil microorganisms and when turned into the soil, starts the nutrient cycle again.

During the transition years and the early years of organic production, soil amendment with composts or animal manure can be a productive strategy for building organic matter, biological activity and soil nutrient levels. This practice of heavy compost or manure use is not, however, sustainable in the long-term. If composts and manures are applied in the amounts required to meet the nitrogen needs of the crop, phosphorous may be added at higher levels than required by most vegetable crops. This excess phosphorous will gradually build up to excessive levels, increasing risks of water pollution or invigorating weeds like purslane and pigweed. A more sustainable, long-term approach is to rely more on legume cover crops to supply most of the nitrogen needed by the crop and use grain or grass cover crops to capture excess nitrogen released from organic matter at the end of the season to minimize nitrogen losses to leaching. See Section 3: *Cover Crops*. When these cover crops are incorporated into the soil, their nitrogen, as well as carbon, feeds soil microorganisms, supporting the nutrient cycle. Harvesting alfalfa hay from the field for several years can reduce high phosphorus and potassium levels.

Some soils are naturally high in P and K, or have a history of manure applications that have resulted in elevated levels. Regular soil testing helps monitor nutrient levels, in particular phosphorus (P) and potassium (K). Choose a reputable soil-testing lab (Table 8.0.1) and use it consistently to avoid discrepancies caused by different soil extraction methods. Maintaining a soil pH between 6.3 and 6.8 will maximize the availability of all nutrients to plants.

To assess overall impact of organic matter additions on soil health, consider selecting a few target or problem fields for soil health monitoring over time via the Cornell Standard Soil Health Analysis Package. This suite of eight tests complements a standard soil chemical nutrient analysis by focusing on biological and physical soil health indicators. While the test results will provide feedback on how the soil sample compares to other New York soils, the real power is in the baseline readings for comparison in the future after implementing new soil health and nutrient management strategies.

Table 8.0.1 Nutrient Testing Laboratories.

Testing Laboratory	Soil	Compost/ Manure	References
The Agro One Lab (Cornell Recommendations)	x	x	32
Agri Analysis, Inc.		x	29
A&L Eastern Ag Laboratories, Inc.	x	x	30
Cornell Soil Nutrient Analysis Lab	x		34c
Penn State Ag Analytical Services Lab.	x	x	31
University of Massachusetts	x	x	33
University of Maine	x	x	34

8.1 Fertility

Recommendations from the Cornell Crop and Pest Management Guidelines (reference 1) indicate that a lettuce crop requires 80-100 lbs. of available nitrogen (N), 120 lbs. of phosphorus (P), and 150 lbs. of potassium (K) per acre to support a good yield. These levels are based on the total nutrient needs of the whole plant and assume the use of synthetic fertilizers. Research and grower experience suggests that somewhat lower levels may be adequate in organic systems. See Table 8.2.2 for the recommended rates of N, P, and K based on soil test results. Nitrogen is not included because levels of available N change in response to soil temperature, moisture, N mineralization potential, and leaching. As much of the nutrients as possible should come from cover crop, manure, and compost additions in previous seasons.

Develop a plan for estimating the amount of nutrients that will be released from soil organic matter, cover crops, compost, and manure. A strategy for doing this is outlined in Section 8.2: *Preparing an Organic Nutrient Budget*. It is important to remember that in cool soils, microorganisms are less active, and nutrient release may be too slow to meet the crop needs. Once the soil warms, nutrient release may exceed crop needs. In a long-term organic nutrient management approach, most of the required crop nutrients would be in place as organic matter before the growing season starts. Nutrients required by the crop in the early season can be supplemented by highly soluble organic amendments such as poultry manure composts or organically approved bagged fertilizer products (see Tables 8.2.4 to 8.2.6). These products can be expensive so are most efficiently used if banded at planting. The National Organic Standards Board states that no more than 20% of total N can be applied as Chilean nitrate. Be sure to confirm that the products you select are approved for use in organic by your certifier prior to field application.

8.2 Preparing an Organic Nutrient Budget

To create a robust organic fertility management plan, develop a plan for estimating the amount of nutrients that will be released from soil organic matter, cover crops, compost, and manure. As these practices are integrated into field and farm management, the goal is to support diverse microbial communities that will help release nutrients from the organic matter additions.

Remember that with a long-term approach to organic soil fertility, the N mineralization rates of the soil will increase. This means that more N will be available from organic amendments because of increased soil microbial activity and diversity. Feeding these organisms different types of organic matter is essential to building this type of diverse biological community and ensuring long-term organic soil and crop productivity. Included in the Soil Health Test is an analysis of soil protein content. As with the other soil health tests, this serves as an indicator of soil management and amendment history. The test measures organic soil N that is in the form of proteins- an important food source for soil microbes. Use this test to help monitor impact and target future investments of legume cover crops and compost / manure applications.

Estimating total nutrient release from the soil and comparing it with soil test results and recommendations requires record-keeping and some simple calculations. Table 8.2.1 below can be used as a worksheet for calculating nutrients supplied by the soil compared to the total crop needs. Table 8.2.3 estimates common nutrient content in animal manures; however actual compost and manure nutrient content should be tested just prior to application. Analysis of other amendments, as well as cover crops, can be estimated using published values (see Tables 8.2.4 to 8.2.6 and 3.1 for examples). Keeping records of these nutrient inputs and subsequent crop performance will help evaluate if the plan is providing adequate fertility during the season to meet production goals.

Table 8.2.1 Calculating Nutrient Credits and Needs

	Nitrogen (N) lbs/A	Phosphate (P_2O_5) lbs/A	Potash (K_2O) lbs/A
1. Total crop nutrient needs			
2. Recommendations based on soil test	Not provided		
3. Credits			
a. Soil organic matter		---	---
b. Manure			
c. Compost			
d. Prior cover crop			
4. Total credits:			
5. Additional needs (2-4=)			

Line 1. Total Crop Nutrient Needs: Agricultural research indicates that an average lettuce crop requires 80-100 lbs. nitrogen (N), 120 lbs. phosphorus (P), and 150 lbs. potassium (K) per acre to support a medium to high yield (see section 8.1:*Fertility* above).

Line 2. Recommendations Based on Soil Test: Use Table 8.2.2 to determine the amount of P and K needed based on soil test results.

Table 8.2.2 Recommended Amounts of Phosphorus and Potassium for Lettuce Based on Soil Tests

	Nitrogen Level	**Soil Phosphorus Level**			**Soil Potassium Level**		
Level shown in soil test	Not provided	low	med	high	low	med	high
	N lbs/A	**Pounds/A P_2O_5**			**Pounds/A K_2O**		
Total nutrient recommendation	80-100	120	80	40	150	100	50

Line 3a. Soil Organic Matter: Using the values from your soil test, estimate that 20 lbs. of nitrogen will be released from each percent organic matter in the soil. For example, a soil that has 2% organic matter could be expected to provide 40 lbs N per acre.

Line 3b. Manure: Because lettuce is eaten fresh, the use of manure as a nutrient supplement is generally not recommended unless it has been composted with an organically certified process. The NOP rules allow manure applications 120 days or more before harvest, but your farm certifier may have a more restrictive policy.

Line 3c. Compost: Estimate that between 10 to 25% of N, 80% of the phosphorous and 90% of the potassium contained in most compost is available to the crop the first year. It is important to test each new mix of compost for actual amounts of the different nutrients available. Compost maturity will influence how much N is available. If the material is immature, more N tends to be available to the crop in the first year. A word of caution: using compost to provide for a crop's nutrient needs is not generally a financially viable strategy. The high total volume needed can be very expensive for the units of N available to the crop, especially if trucking is required. Most stable composts should be considered as soil conditioners, improving soil health, microbial diversity, tilth, and nutrient retention capacity. . Also keep in mind that manure-based composts are potentially high in salts that could become a problem if used yearly. Most compost analyses include a measure of electrical conductivity which indicates level of salts present in the finished product. Any compost applied on organic farms must be approved for use by the farm certifier. Compost generated on the farm must follow an approved process outlined by the certifier.

Line 3d. Cover Crops: Estimate that 50 percent of the fixed N is released for plant uptake during the season it is incorporated. Consult Table 3.1 to estimate the amount of N fixed by legume cover crops.

Line 4. Total Credits: Add together the various nutrient values from soil organic matter, compost, and cover crops to estimate the total nutrient supplying potential of the soil (see example below). There is no guarantee that these amounts will actually be available in the season, since soil temperatures, water, and crop physiology all impact the release and uptake of these soil nutrients. If the available N does not equal the minimum requirement for this crop (80-100 lbs/acre), a side-dress application of organic N may be needed. There are several sources of N for organic side-dressing (see Table 8.2.4) as well as pelleted composts. Early in the organic transition, a grower may consider increasing the N budget supply by 25%, to help reduce some of the risk of N being limiting to the crop.

Table 8.2.3 includes general estimates of nutrient availability for manures and composts but these can vary widely depending on animal feed, management of grazing, the age of the manure, amount and type of bedding, and many other factors. See Table 3.1 for estimates of the nitrogen content of various cover crops. Because lettuce is eaten fresh, **manure applications may not be allowed by your certifier or marketer. Check with both these sources prior to making manure applications.**

Table 8.2.3 Estimated Nutrient Content of Common Animal Manures and Manure Composts

	Total N	P_2O_5	K_2O	N1 [1]	N2 [2]	P_2O_5	K_2O
	Nutrient content lb/ton			*Available nutrients lb/ton in first season*			
Dairy (with bedding)	9	4	10	6	2	3	9
Horse (with bedding)	14	4	14	6	3	3	13
Poultry (with litter)	56	45	34	45	16	36	31
Composted dairy manure	12	12	26	3	2	10	23
Composted poultry manure	17	39	23	6	5	31	21
Pelleted poultry manure [3]	80	104	48	40	40	83	43
Swine (no bedding)	10	9	8	8	3	7	7
	Nutrient content lb/1000 gal.			*Available nutrients lb/1000 gal first season*			
Swine finishing (liquid)	50	55	25	25[a]	20[b]	44	23
	Nutrient content lb/1000 gal.			*Available nutrients lb/1000 gal first season*			
Dairy (liquid)	28	13	25	14[a]	11[b]	10	23

1-N1 is an estimate of the total N available for plant uptake when compost is incorporated within 12 hours of application, 2-N2 is an estimate of the total N available for plant uptake when manure is incorporated after 7 days. 3 –Pelletized poultry manure compost (available in New York from Kreher's). a injected, b incorporated. Table adapted from Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops by Carl Rosen and Peter Bierman (reference 27) and Penn State Agronomy Guide 2015-16 (reference 28)

Tables 8.2.4-8.2.6 lists some commonly available fertilizers, their nutrient content.

Table 8.2.4 Available Nitrogen in Organic Fertilizer

	Pounds of Fertilizer/Acre to Provide X Pounds of N per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Blood meal, 13% N	150	310	460	620	770
Soy meal 6% N (x 1.5) [a] also contains 2% P and 3% K_2O	500	1000	1500	2000	2500
Fish meal 9% N, also contains 6% P_2O_5	220	440	670	890	1100
Alfalfa meal 2.5% N also contains 2% P and 2% K_2O	800	1600	2400	3200	4000
Feather meal, 15% N (x 1.5) [a]	200	400	600	800	1000
Chilean nitrate 16% N cannot exceed 20% of crop's need.	125	250	375	500	625

a Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil testing lab (reference 34).

Table 8.2.5 Available Phosphorous in Organic Fertilizers.

	Pounds of Fertilizer/Acre to Provide X Pounds of P_2O_5 per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Bonemeal 15% P_2O_5	130	270	400	530	670
Rock Phosphate 30% total P_2O_5 (x4) [a]	270	530	800	1100	1300
Fish meal, 6% P_2O_5 (also contains 9% N)	330	670	1000	1330	1670

a Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil testing lab (reference 34).

Table 8.2.6 Available Potassium in Organic Fertilizers.

	Pounds of Fertilizer/Acre to Provide X Pounds of K_2O per Acre:				
Sources	**20**	**40**	**60**	**80**	**100**
Sul-Po-Mag 22% K_2O also contains 11% Mg	90	180	270	360	450
Wood ash (dry, fine, grey) 5% K_2O, also raises pH	400	800	1200	1600	2000
Alfalfa meal 2% K_2O also contains 2.5% N	1000	2000	3000	4000	5000
Greensand or Granite dust 1% K_2O (x 4) [a]	8000	16000	24000	32000	40000
Potassium sulfate 50% K_2O	40	80	120	160	200

a Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil testing lab (reference 34).

An example of how to determine nutrient needs for lettuce. You will be growing an acre of leaf lettuce. The Cornell Crop and Pest Management Guidelines suggests a total need of 80-100 lb. N, 120 lb. P, and 150 lb. K per acre to grow a high yielding crop. Soil tests show a pH of 6.0, with high P. Looking at table 8.2.2, this means 40 lbs $P_2 0_5$/A is recommended. Potassium levels are medium according to the soil test, therefore 100 lbs $K_2 0$/A are recommended. The field has 2% organic matter. Last fall 3 tons/acre of composted dairy manure were spread and immediately incorporated prior to planting a cover crop of oats. Nutrient credits for soil organic matter, composted dairy manure, and cover crops appear in Table 8.2.7.

Table 8.2.7 Lettuce Example: Calculating Nutrient Credits and Needs Based on Soil Test Recommendations.

	Nitrogen (N) lbs/acre	Phosphate (P_2O_5) lbs/acre	Potash (K_2O) lbs/acre
1. Total crop nutrient needs:	80-100	120	150
2. Recommendations based on soil test	# not provided	40	100
3. Credits			
a. Soil organic matter 2%	40	---	---
b. Manure			
c. Compost –dairy manure 3T/A	9	30	69
d. Cover crop – oat	-	-	-
4. Total credits:	49	30	69
5. Additional needed (2-4) =	40	10	31

Estimate nitrogen first. Each percent organic matter will release about 20 lbs of N, so the 2% organic matter will supply 40 lbs/A (line 3a). Line 3c is calculated using Table 8.2.3 which indicates about 9 lbs N will be released in the first season from the 3 tons/A of composted dairy manure (N1). The total estimated N released and available for plant uptake is 49 lbs per acre (line 4). Line 5 suggests that 40 lbs/A of N is still needed, which can be added by side-dressing with 1,000 lbs/A of soy meal.

Phosphorus and potassium will also need to be supplemented. Looking at P, the compost supplies 30 of the 40 lbs/A recommended based on the soil test. Apply 65 lbs/A of bonemeal to meet the 10 lb/A phosphorus deficit (Table 8.2.5). About 70 lbs/A of the potassium needs are supplied by the composted dairy manure out of the 100 lbs/A recommended. The remaining 30 lbs K_2O/A can be added by applying 135 lbs./A of Sul-Po-Mag, broadcast and then incorporated (Table 8.2.6).

Additional Resources
Using Organic Nutrient Sources (reference 34a)
Determining Nutrient Applications for Organic Vegetables (reference 34b)

9. HARVESTING

Care in harvesting and handling is important for lettuce crops since they are easily damaged.

Table 9.0 Average Days to Harvest for Lettuce Types

Lettuce Type	Average days to harvest after seeding
Crisphead	70-80
Butter and Bibb	50-60
Romaine	60-70
Leaf	50-60

Reference 12a

9.1 Harvest Methods

Crisphead: Harvest when the full-sized head can be slightly compressed with moderate hand pressure. Loose heads are immature, and overly hard heads are past maturity. Over mature heads tend to lack flavor and have increased postharvest problems. Leave 3 to 4 wrapper leaves to protect the heads. Properly harvested and trimmed heads should have a bright green color and be crisp.

Romaine: Harvest romaine when mature heads have about 35 leaves per head after trimming, and are not too loose or tight. Romaine loses its flavor when over mature, and has more postharvest problems. The marketable head should have brightly colored outer leaves. Romaine "hearts" are the tender inner leaves trimmed from plants that are slightly immature. Leaves of all harvested lettuce should be crisp and free from insect, decay, or mechanical damage. Varieties differ in flavor at maturity, so consider the desires of the target market when choosing varieties to plant (reference 12b).

Freeze damage to leaves can cause subsequent decay in many lettuce types. Damage can occur in storage if temperatures drop below 31.7°F. Damaged tissue looks water-soaked and will deteriorate after thawing (reference 12b).

See US Department of Agriculture standards for
Lettuce grades (reference 12c).
Field grown leaf lettuce (reference 12d).

9.2 Storage

Non-crisphead varieties are more susceptible to damage during harvest and transit and therefore have a shorter shelf life than crisphead varieties. Optimum storage conditions are

32°F with at least 95 percent relative humidity. Air flow through and around boxes is essential. Vacuum cooling is effective at quickly reducing the field temperature of the produce, but forced-air cooling can also be successful (reference 1 and 12b). Rapid cooling will improve market quality and shelf life. Use top ice during packaging to supply moisture and remove heat. Always use ice made from potable water.

Lettuce Type	Average Shelf-life at 32°F	Average Shelf-life at 41°F
Crisphead	21-28	14
Romaine	21 days	14
Leaf and butterhead	7-14	na

References 12a and 12b

9.3 Microbial Food Safety

Attention to microbial food safety is important for crops that are eaten raw. Continuing produce-associated foodborne illness outbreaks have resulted in many buyers requiring the implementation of food safety practices on the farm and the development of the first ever produce safety regulations as part of the Food Safety Modernization Act (FSMA). Pathogens can contaminate food during all phases of production, harvesting, and packing. Wild and domesticated animals, manure, irrigation water, inadequate worker hygiene, unclean picking containers, unsanitized post-harvest water, and unclean packaging materials are all potential vectors of microbiological contaminants. Growers should conduct a risk assessment to identify microbial hazards and then implement appropriate practices to reduce risks. There are many resources available to help including those at the National GAPs Program (reference 10) or the Produce Safety Alliance (reference 10a). Regardless of farm size, commodities or cultural practices, Good Agricultural Practices can be used to identify and possibly reduce microbial risks.

Implementing just a few simple practices can reduce risks significantly. One of these is to wash hands prior to any contact with the crop using potable water and sanitizer, particularly after using the restroom or eating. Do not allow workers who are ill to handle produce. If they are able to work, assign jobs that do not involve contact with produce or customers. Prevent animals or animal manure from contacting produce, by discouraging animals (including pets) from entering production fields and by not using irrigation water that may have been contaminated with manure. Manure must be properly composted or applied well in advance of harvesting a fresh market crop such as lettuce, but check with your certifier or marketer for separate restrictions for manure use on lettuce. Ensure that picking containers are clean and free from animal droppings. Following these steps can dramatically reduce risks of pathogen contamination. Conduct a full assessment of your farm to identify other high risk practices.

The Food Safety Modernization Act (FSMA) will apply to farms that grow, harvest, pack or hold most fruits and vegetables when those fruits and vegetables are in an unprocessed state, and will govern practices affecting: water, worker hygiene, manure and other soil additions, animals in the growing area, and equipment, tools and buildings When the FSMA is finalized, the Food and Drug Administration (FDA) will be mandated to enforce preventive control measures, and to conduct inspections across the food supply system. Updates and information on this proposed rule are available at the United States Food and Drug Administration's Food Safety Modernization Act webpage.

At the time this guide was produced, the following materials were available in New York State as sanitizers allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 9.3.1 Rates for Sanitizers for Postharvest Carrots and/or Postharvest Facilities

Active ingredient **Product name**	***Uses***			
	Food contact surfaces[1]	**Hard surface, non-food contact[1]**	**Vegetable surface (spray or drench)**	**Vegetable rinse water**
chlorine dioxide				
CDG Solution 3000	50 ppm solution	500 ppm dilution	-	5 ppm solution
Oxine[2]	100 ppm solution	500 ppm solution	-	In tanks, use a 5 ppm solution; for process waters use a chemical feed pump or other injector system at 3 ¼ fl oz per 10 gal water.[3]
Pro Oxine[2]	50-200 ppm solution	500 ppm solution	-	-
hydrogen peroxide/peroxyacetic acid				
Enviroguard Sanitizer	-	2.5-20 fl oz/5 gal water	1 fl oz/20 gal water	1 fl oz/20 gal water
Oxonia Active	1-1.4 oz/4 gal water	1 oz/8 gal water.	-	-
Peraclean 5	1-1.5 fl oz/5 gal water	-	-	-
Peraclean 15	0.33 fl oz/5 gal water	-	-	-
Perasan A	1-6.1 oz/6 gal	-	4 oz/20 gal water	-
Per-Ox	1-2.25 fl oz/5 gal water	1-10 fl oz/15 gal water	1 fl oz/5 gal water	1 fl oz/5 gal water
SaniDate 5.0	1.6 fl oz/ 5 gal water	1.6 fl oz/ 5 gal water	59.1 to 209.5 fl oz/ 1,000 gallons water	59.1 to 209.5 fl oz/ 1,000 gallons water
SaniDate 12.0	-	-	25.6 to 89.6 fl oz / 1,000 gallons water	25.6 to 89.6 fl oz / 1,000 gallons water
Shield-Brite PAA 5.0	1.6fl oz/5 gal water	1.6fl oz/5 gal water	59.1 to 209.5 fl. oz./1,000 gal water	59.1 to 209.5 fl. oz./1,000 gal water
Shield-Brite PAA 12.0			25.6 to 107 fl.oz/1,000 gal water	25.6 to 107 fl.oz/1,000 gal water
StorOx 2.0	0.5 fl oz/1 gal water	0.5 fl oz/1 gal water	1:220 – 1:1,000 dilution (on process/packing line); .035-0.58 fl. oz./gal water (post-harvest spray treatment)	
Tsunami 100	-	-	2.5-6.7 fl oz/100 gal water	2.5-6.7 fl oz/100 gal water
Victory	-	-	1 fl oz/16.4 gal water	1 fl oz/16.4 gal water
VigorOx 15 F & V	0.31-0.45 fl oz/5 gal water-	1.1-9.5 fl oz/5 gal water -	1 fl oz/ 16 gal water as spray or dip	0.54 fl oz/ 16 gal water (processing water)
VigorOx LS-15	0.31-0.45 fl oz/5 gal water	1.1-9.5 fl oz/5 gal water	-	-
sodium hypochlorite				
San-I-King No. 451	100 ppm chlorine in solution	-	-	-

1. Thoroughly clean all surfaces and rinse with potable water prior to treatment. 2. Requires acid activator. 3. After treatment, rinse with potable water.

10. USING ORGANIC PESTICIDES

Given the high cost of many pesticides and the limited amount of efficacy data from replicated trials with organic products, the importance of developing an effective system of cultural practices for insect and disease management cannot be emphasized strongly enough. **Pesticides should not be relied on as a primary method of pest control**. Scouting and forecasting are important for detecting symptoms of pests at an early stage. When conditions do warrant an application, proper choice of materials, proper timing, and excellent spray coverage are essential.

10.1 Sprayer Calibration and Application

Calibrating sprayers is especially critical when using organic pesticides since their effectiveness is sometimes limited. For this reason, they tend to require the best spraying conditions to be effective. Read the label carefully to be familiar with the unique requirements of some products, especially those with live biocontrol organisms as their active ingredient (e.g. Contans). The active ingredients of some biological pesticides (e.g. Serenade) are actually a metabolic by product of the organism. Calculating nozzle discharge and travel speed are two key components required for applying an accurate pesticide dose per acre. Applying too much pesticide is illegal, can be unsafe and is costly, while applying too little can fail to control pests or lead to pesticide resistance.

Resources

Calibrating Backpack Sprayers (reference 45)
Cornell Crop and Pest Management Guidelines: Pesticide Information and Safety (reference 46)
Pesticide Environmental Stewardship: Calibration (reference 47)
Knapsack Sprayers – General Guidelines for Use (reference 48)
Herbicide Application Using a Knapsack Sprayer (reference 49) This publication is also relevant for non-herbicide applications.
Pesticide Environmental Stewardship, Coop Extension (reference 49a)
Pesticide Environmental Stewardship, CIPM (reference 49b)
Vegetable Spraying (reference 49c)

10.2 Regulatory Considerations

Organic production focuses on cultural, biological, and mechanical techniques to manage pests on the farm, but in some cases pesticides, which include repellents, allowed for organic production are needed. Pesticides mentioned in this organic production guide are registered by the United States Environmental Protection Agency (EPA) or meet the EPA requirements for a "minimum risk" pesticide. At the time of publication, the pesticides mentioned in this guide meet New York State Department of Environmental Conservation (NYS DEC) requirements for use in New York State. See Cornell's Product, Ingredient, and Manufacturer System website (reference 11) for pesticides currently registered for use in NYS. Additional products may be available for use in other states.

To maintain organic certification, products applied must also comply with the National Organic Program (NOP) regulations as set forth in 7 CFR Part 205, sections 600-606 (reference 18). The Organic Materials Review Institute (OMRI) (reference 13) is one organization that reviews products for compliance with the NOP regulations and publishes lists of compliant products, but other entities also make product assessments. Organic growers are not required to use only OMRI listed materials, but the list is a good starting point when searching for allowed pesticides.

Finally, farms grossing more than $5,000 per year and labeling products as organic must be certified by a NOP accredited certifier who must approve any material applied for pest management. ALWAYS check with the certifier before applying any pest control products. Some certifiers will review products for NOP compliance.

Note that "home remedies" may not be used. Home remedies are products that may have properties that reduce the impact of pests. Examples of home remedies include the use of beer as bait to reduce slug damage in strawberries or dish detergent to reduce aphids on plants. These materials are not regulated as pesticides, are not exempt from registration, and are therefore not legal to use.

Do you need to be a certified pesticide applicator? The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines two categories of pesticides: general-use and-restricted use. NYS DEC also defines additional restricted-use pesticides. Pesticide applicator certification is required to purchase and use restricted-use pesticides. Restricted-use pesticides mentioned in this guide are marked with an asterisk (*). Farmers who purchase and use only general-use pesticides on property they own or rent do not need to be certified pesticide applicators. However, we do encourage anyone who applies pesticides to become certified.

Worker Protection Standard training. If the farm has employees who will be working in fields treated with a pesticide, they must be trained as workers or handlers as required by the federal Worker Protection

Standard (WPS). Having a pesticide applicator certification is one of the qualifications needed to be a WPS trainer. Certified pesticide applicators meet the WPS training requirements. For more information on the Worker Protection Standard see: How To Comply with the Worker Protection Standard (reference 21b). See Revisions To the Worker Protection Standard for a summary of new worker protection standards that will take effect January 2017. Find more information on pesticide applicator certification from the list of State Pesticide Regulatory Agencies (reference 21c) or, in New York State, see the Cornell Pesticide Management Education Program website at http://psep.cce.cornell.edu (reference 21d).

10.3 Pollinator Protection

Honey bees, wild bees, and other insects are important for proper pollination of many crops. Poor pollination results in small or odd-shaped fruit as well as low yields.

To avoid harming bees with insecticides, remember these general points:

- Always read the label before use.
- Do not spray blooming crops;
- Mow blooming weeds before treatment or spray when the blossoms are closed;
- Avoid application during the time of day when bees are most numerous; and
- Make application in the early morning or evening.

If pesticides that are highly toxic to bees are used in strict accordance with label directions, little or no harm should be done to bees. Label statements on pesticides that are highly toxic to honey bees may carry a caution statement such as: "This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area."

In early 2015 the EPA proposed new pollinator protection label language to protect managed bees under contract pollination services. The intent of this new language is to protect bees from contact exposure to pesticides that are acutely toxic to bees. Once the new language is finalized, pesticide labels will include the new wording and requirements. As part of this proposal, EPA identified certain active ingredients that are acutely toxic to bees. Active ingredients mentioned in this publication meeting this criteria are noted with a bee symbol ( ).

For more information on pollinator protection, visit www.epa.gov/opp00001/ecosystem/pollinator/index.html and pesticidestewardship.org/PollinatorProtection/Pages/default.aspx

10.4 Optimizing Pesticide Effectiveness

Information on the effectiveness of a particular pesticide against a given pest can sometimes be difficult to find. Some university researchers include pesticides approved for organic production in their trials; some manufacturers provide trial results on their web sites; some farmers have conducted trials on their own. Efficacy ratings for pesticides listed in this guide were summarized from university trials and are only provided for some products. The Resource Guide for Organic Insect and Disease Management (reference 2) provides efficacy information for many approved materials.

In general, pesticides allowed for organic production may kill a smaller percentage of the pest population, could have a shorter residual, and may be quickly broken down in the environment. Microbial-based products often have a shorter shelf life than other products, so be sure to use them by the expiration date. Read the pesticide label carefully to determine if water pH or hardness will negatively impact the pesticide's effectiveness. Use of a surfactant may improve organic pesticide performance. Check the OMRI Products List for adjuvants, under *Crop Management Tools and Production Aids* (reference 13). Regular scouting and accurate pest identification are essential for effective pest management. Thresholds used for conventional production may not be useful for organic systems because of the typically lower percent mortality and shorter residual of pesticides allowed for organic production. When pesticides are needed, it is important to target the most vulnerable stages of the pest. The use of pheromone traps or other monitoring or prediction techniques can provide an early warning for pest problems, and help effectively focus scouting efforts. When using pesticides, be sure you have sufficient coverage to provide adequate control. Consult the pesticide label for guidance.

11. Disease Management

In organic systems, cultural practices form the basis of a disease management program. Promote plant health by maintaining a biologically active, well-structured, adequately drained and aerated soil that supplies the requisite amount and balance of nutrients. Choose varieties resistant to important diseases whenever

possible (see Section 6: *Varieties*). Plant only clean, vigorous and pathogen-free seed or transplants and maintain the best growing conditions possible.

Rotation is an important management practice for pathogens that overwinter in soil or crop debris. Rotating between crop families is useful for many diseases, but may not be effective for pathogens with a wide host range, such as *Pythium*, *Rhizoctonia*, and *Sclerotinia*. Rotation with a grain crop, preferably a crop or crops that will be in place for one or more seasons, deprives many disease-causing organisms of a host, and also contributes to a healthy soil structure that promotes vigorous plant growth. The same practices are effective for preventing the buildup of root damaging nematodes in the soil, but keep in mind that certain grain crops are also hosts for some nematode species. See more on crop rotation in Section 4.2: *Crop Rotation Plan*.

Other important cultural practices can be found under each individual disease listed below. Maximizing air movement and leaf drying is a common theme. Many plant diseases are favored by long periods of leaf wetness. Any practice that promotes faster leaf drying, such as orienting rows parallel to the prevailing wind, using a wider row spacing, or controlling weeds can slow disease development. Fields surrounded by trees or brush that tend to hold moisture after rain, fog or dew should be avoided.

Scouting fields weekly is key to early detection and evaluation of control measures. The earlier a disease is detected, the more likely it can be suppressed with organic fungicides. When available, scouting protocols can be found in the sections listed below for each individual disease. While following a systematic scouting plan, keep watch for other disease problems. Removing infected plants during scouting is possible on a small farm operation. Accurate identification of disease problems, especially recognizing whether they are caused by a bacterium or fungus, is essential for choosing an effective control strategy. Anticipate which diseases are likely to be problems that could affect yield and be ready to take action as soon as symptoms are seen. Allowing pathogen populations to build can quickly lead to a situation where there are few or no options for control.

All currently available fungicides allowed for organic production are protectants, meaning they must be present on the plant surface before disease inoculum arrives to effectively prevent infection. They have no activity on pathogens once they are inside the plant. Biological products must be handled carefully to keep the microbes alive. Follow label instructions carefully to achieve the best results.

Contact your local cooperative extension office to see if newsletters and pest management updates are available for your region. For example, in western New York, the Cornell Vegetable Program offers subscriptions to *VegEdge,* a report that gives timely information regarding crop development, pest activity and control. Enrollment in the Eastern New York Commercial Horticulture Program includes a subscription to *Produce Pages* and weekly seasonal newsletters for vegetables, tree fruit, grapes and small fruit. On Long Island, see the *Long Island Fruit and Vegetable Update*.

Organic farms must comply with all regulations regarding pesticide applications. See Section 10: *Using Organic Pesticides* for details. **ALWAYS check with your organic farm certifier when planning pesticide applications**.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 11.0.1 Pesticides for Disease Management in Organic Lettuce

CLASS OF COMPOUND Product name *active ingredient*	Anthracnose	Bottom Rot	Damping-off	Downy Mildew	Drop	Gray Mold	Viruses
MICROBIAL							
Actinovate AG *Streptomyces lydicus*	X	X	X	X	X	X	
Actinovate STP *Streptomyces lydicus*		X	X				
BIO-TAM *Trichoderma asperellum, Trichoderma gamsii*		X	X				

ORGANIC LETTUCE PRODUCTION

CLASS OF COMPOUND Product name *active ingredient*	**Anthracnose**	**Bottom Rot**	**Damping-off**	**Downy Mildew**	**Drop**	**Gray Mold**	**Viruses**
BIO-TAM 2.0 *Trichoderma asperellum, Trichoderma gamsii*		X	X		X		
Contans WG *Coniothyrium minitans*					X		
Double Nickel 55 Biofungicide *Bacillus amyloliquefaciens str. D747*		X	X	X	X		
Double Nickel LC Biofungicide *Bacillus amyloliquefaciens str. D747*		X	X	X	X		
Mycostop Biofungicide *Streptomyces griseoviridis*			X			X	
Mycostop Mix *Streptomyces griseoviridis*			X				
Optiva *Bacillus subtilis str. QST 713*					X		
Prestop Biofungicide *Gliocladium catenulatum str. J1446*		X	X			X	
Regalia Biofungicide *Reynoutria sachalinensis*				X	X		
RootShield Granules *Trichoderma harzianum*		X	X				
RootShield PLUS+ Granules *Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*		X	X				
Rootshield WP *Trichoderma harzianum Rifai str. KRL-AG2*		X	X				
RootShield PLUS+ WP *Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*		X	X				
Serenade ASO *Bacillus subtilis* str QST 713 **Serenade MAX** *Bacillus subtilis* str QST 713 **Serenade SOIL** *Bacillus subtilis* str QST 713 **Serenade Opti** *Bacillus subtilis* str QST 713		 X		X X	X X X X X		
SoilGard *Gliocladium virens*		X	X				
Taegro Biofungicide *Bacillus subtilis*		X					
Taegro ECO *Bacillus subtilis*		X			X		
BOTANICAL							
Trilogy 🐝 *neem oil*	X			X		X	
COPPER							
Badge X2 *copper oxychloride, copper hydroxide*	X			X			
Basic Copper 53 *basic copper sulfate*	-			X			
ChampION++ *copper hydroxide*				X			
Cueva Fungicide Concentrate *copper octanoate*		X		X			
Nordox 75 WG *copper hydroxide*				X			
Nu-Cop 50 WP *copper hydroxide*				X			
Nu-Cop 50DF *copper hydroxide*				X			
Nu-Cop HB *cupric hydroxide*				X			
OIL							
PureSpray Green *mineral oil*							X
Organic JMS Stylet Oil *paraffinic oil*							X
Organocide 3-in-1 *sesame oil*				X			
MilStop *potassium bicarbonate*	X			X		X	
OTHER							
Agricure *potassium bicarbonate*	X			X		X	
Green Cure *potassium bicarbonate*	X			X		X	
OxiDate 2.0 *hydrogen dioxide, peroxyacetic acid*				X		X	
PERpose Plus *hydrogen peroxide/dioxide*	X	X	X	X	X	X	
TerraClean 5.0 *hydrogen dioxide, peroxyacetic acid*		X	X			X	

X –Product for use on lettuce in New York state and OMRI listed.

🐝 Active ingredient meets EPA criteria for acute toxicity to bees

11.1 Anthracnose, *Microdochium panattonianum*

Time for concern: Cool wet weather favors this fungus.

Key characteristics: Water-soaked, circular spots first appear on the undersides of leaves that when dry, give a shot hole appearance. These spots are often angular in shape, bounded by the larger leaf veins. Lesions on the midrib begin as water-soaked spots, but become markedly sunken. Young plants can be killed and older plants disfigured. The fungus survives in the soil and on crop debris and is spread locally by wind and rain (Reference 50).

Relative Risk: sporadic and normally of minor importance

Management Option	Recommendation for Anthracnose
Scouting/thresholds	**Scouting:** Look for spots on the outermost foliage and along the midrib on the lower leaf surface. **Thresholds** for organic production have not been established.
Crop rotation	Maintain a minimum of 1 year without lettuce or other susceptible crops.
Resistant varieties	Anthracnose affects most lettuce varieties.
Planting	Plant rows in the direction of the prevailing winds to promote quick drying of plants.
Seed selection	This pathogen is seed-borne. Plant disease-free seed. See reference 52 for treatment options for seed lots with suspected infestations.
Weed control	Remove alternate host weeds in the genus *Lactuca* such as prickly lettuce and wild lettuce, from areas in and around lettuce fields. Do not cultivate when plants are wet to reduce the spread of disease.
Cultural controls	Wet weather and irrigation provide conditions conducive to spore production and dispersal. Ground level irrigation is preferred over sprinklers. Irrigate early in the day when sun or wind are likely to dry leaves quickly. Avoid working in fields when the foliage is wet.
Harvest	Packing infected plants with healthy ones can spread disease.
Postharvest	The fungus survives in the soil and on crop debris. Fields should be deep plowed after harvest to bury infested plant debris.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 11.1 Pesticides for Management of Anthracnose

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (Streptomyces Lydicus WYEC 108)	3-12 oz/acre	0	1 or until dry	?	The label recommends use of a spreader sticker.
Agricure (potassium bicarbonate)	2-5 lb/acre	0	1	?	
Badge X2 (copper hydroxide, copper oxychloride)	0.75-1.5 lb/acre	0	48	?	
Milstop (Potassium bicarbonate)	2-5 lb/acre	0	1	?	

Table 11.1 Pesticides for Management of Anthracnose					
PERpose Plus (hydrogen peroxide)	1 fl.oz./ gal (initial/curative)	-	until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment.
PERpose Plus (hydrogen peroxide)	0.25-0.33 fl.oz./ gal (weekly/preventative)	-	until dry	?	For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Trilogy (neem oil)	0.5-1% solution	up to day	4	?	Apply no more than 2 gallons of Trilogy per acre per application. Bee Hazard. This product is toxic to bees exposed to direct contact

PHI = pre-harvest interval, REI = restricted entry interval - = pre-harvest interval isn't specified on label Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

Active ingredient meets EPA criteria for acute toxicity to bees

11.2 Botrytis Gray Mold, *Botrytis cinerea*

Time for concern: The fungus grows within a wide range of temperatures, but is favored by cool (65° to 75°F), moist conditions, either in greenhouses or field locations. Plants are susceptible at all stages.

Key characteristics: Gray mold is especially common in the cool moist conditions of greenhouses or high tunnels. Symptoms of affected seedlings are similar to those of damping-off. The pathogen initially develops on damaged or dead tissue when wet, or tissue that is touching soil. It can then spread to adjacent healthy tissue. Initial symptoms are brownish to black water-soaked lesions that become a mushy rot. The pathogen can spread from lesions on the margins of outer leaves to the stem. Profuse gray-brown conidia (spores) develop and may be followed by black resting bodies (sclerotia). Affected plant parts rapidly turn soft and rot. The fungus can also grow up the stem and rot the inside of a head causing the plant to collapse before any outward symptoms are visible. Infection can spread through heads after harvest affecting marketability. The gray mold fungus is widespread, surviving on the dead or dying tissue of many plants. Consequently management is largely dependent on selecting sites and planting dates which provide warmer and drier conditions. View photos (reference 2, page 93, reference 55 and reference 1).

Relative Risk: Gray mold is one of the three most important diseases of head lettuce, particularly in greenhouse or high tunnel lettuce. Because the fungus is ubiquitous, the risk of gray mold can be widespread dependent on favorable weather conditions.

Management Option	Recommendation for Gray Mold
Scouting/thresholds	Scout plantings weekly. Thresholds for organic production have not been established.
Site selection	Select a well-drained field with good air flow that will help dry leaves and soil quickly.
Crop rotation	Rotation alone will not manage this ubiquitous fungus, although it may help reduce the pathogen population.
Resistant varieties	Resistant varieties are not known.
Seed	This fungus is not seed-borne.
Planting	Orient rows parallel to the prevailing winds and use wide row spacing to encourage quick drying of leaves and soil. Plant in fields where crop debris is well decomposed at planting time. Wounded transplants are more prone to gray mold development: transplant before seedlings are large and overly mature. Since Romaine is particularly susceptible, direct seeding is recommended over transplanting.
Weed control	Avoid wounding plants during early cultivation to prevent infection.

Management Option	Recommendation for Gray Mold
Cultural controls	Maintain low moisture and humidity levels in greenhouse and high tunnel production. Strict hygiene is essential in plant bed and greenhouse settings
Harvest	Trim off affected leaves. Keep harvested plants refrigerated between 32oF and 36oF.
Postharvest	Plow under debris after harvest.
Note(s)	Avoid use of overhead irrigation to prevent extended periods of leaf wetness. If watering is necessary, irrigate early in the day when sun or wind are more likely to quickly dry leaves. Damage from frost, heat or other disease can predispose lettuce to infection by *Botrytis cinerea* as can physiological disorders such as tipburn.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 11.2 Pesticides for Management of Botrytis Gray Mold

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (*Streptomyces ydicus* WYEC 108)	3-12 oz/acre	0	1 or until dry	?	The label recommends use of a spreader sticker.
Agricure (potassium bicarbonate)	2-5 lb/acre	0	1	?	
Milstop (potassium bicarbonate)	2-5 lb/acre	0	1	?	
MycoStop (*Streptomyces grieoviridis* str. K61)	0.1% solution by weight	-	4	?	Only provides suppression of botrytis. Apply to runoff. Labeled only for greenhouse use.
Oxidate 2.0 (hydrogen dioxide, peroxyacetic acid)	128 fl oz/100 gal water	0	until dry	?	Apply consecutive applications until control is achieved and then follow directions for preventative treatment. Bee Hazard. This product is toxic to bees exposed to direct contact
Oxidate 2.0 (hydrogen dioxide, peroxyacetic acid)	32 fl oz/100 gal water	0	until dry	?	Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce to preventative rate after the completion of the third treatment and maintain 5-day interval spray cycle. Bee Hazard. This product is toxic to bees exposed to direct contact
PERpose Plus (hydrogen peroxide)	1 fl.oz./ gal initial/curative 0.25-0.33 fl.oz./ gal weekly/preventative	-	until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop (*Gliocladium catenulatum*)	1.4-3.5 oz/ 2.5 gal water soil treatment	-	0	?	Treat only the growth substrate when above-ground harvestable food commodities are present.

Table 11.2 Pesticides for Management of Botrytis Gray Mold					
Trilogy (neem oil)	0.5-1% solution	up to day	4	?	Apply no more than 2 gallons of Trilogy per acre per application. Bee Hazard. This product is toxic to bees exposed to direct contact

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
Active ingredient meets EPA criteria for acute toxicity to bees

11.3 Bottom Rot and Wirestem, *Rhizoctonia solani*

Time for concern: Warm, wet conditions favor this fungus. It is most prevalent soon after planting and as heads begin to form.

Key characteristics: Bottom rot and wirestem are two phases of the same disease.

Bottom rot is generally seen in late plantings near the time of harvest, on leaves that are in direct contact with the soil. Rust-colored lesions appear on the leaf midrib and may expand to the whole leaf. Lesions turn brown and desiccate when conditions are dry, but will resume infection when moisture increases. Bottom rot symptoms are similar to other fungal infections. Lettuce drop has white mycelium, but bottom rot does not, and gray mold has gray spore masses which are absent in bottom rot. The fungus overwinters in the soil or on decaying plants as either mycelia or sclerotia. See photo (reference 56) and reference 50.

Wirestem is a late damping-off disease. See Section 11.4.

Relative Risk: Bottom rot is one of the most important fungal diseases of lettuce.

Management Option	Recommendation for Bottom Rot and Wirestem
Scouting/thresholds	Scout plantings weekly. Thresholds have not been established for organic production.
Site selection	Select a well-drained field with good air flow to encourage quick drying of leaves and soil. In fields with a history of bottom rot, use 4" raised beds to create a drier field situation. Do not plant in fields with a significant quantity of incompletely decomposed crop residues.
Crop rotation	Rotate away from lettuce and endive for a minimum of 3 years. Cover crops in the grass family will help to reduce the pathogen population in the soil. Highly susceptible alternate hosts include beans, lettuce, cabbage, and potato, although many others are hosts too including broccoli, carrot, cress, cucumber, eggplant, endive, escarole, kale, pepper, potato, radish, tomato, and turnip.
Seed selection	This disease is not seed-borne.
Resistant varieties	A few resistant varieties are available (see Section 6: *Varieties*). Upright varieties are less susceptible because their leaves do not touch the soil.
Planting	Plant in widely spaced rows, parallel with the prevailing winds to encourage quick leaf drying.
Weed control	Control weeds to improve air flow and shorten leaf wetness periods throughout the field. Many common weeds serve as alternate hosts: barnyardgrass, field bindweed, annual bluegrass, wild buckwheat, corn chamomile, chickweed, large crabgrass, green foxtail, goosegrass, field horsetail, kochia, common lambsquarters, prickly lettuce, Venice mallow, black medic, common milkweed, mouseear, wild mustard, eastern black nightshade, common purslane, shepherd's purse, tumble pigweed, redroot pigweed, prostrate pigweed, common ragweed, Italian ryegrass, perennial sowthistle, and witchgrass (reference 3).
Cultural controls	Planting on raised beds improves air circulation and can reduce disease incidence. Avoid use of overhead irrigation to prevent extended periods of leaf wetness especially near the time of harvest.

Management Option	Recommendation for Bottom Rot and Wirestem
Postharvest	Deep plow to bury plant debris after harvest. Sclerotia do not survive well at deep soil depths, and the pathogen is less likely to come into contact with host plants.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 11.3 Pesticides for Management of Bottom Rot

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (*Streptomyces lydicus* WYEC 108)	3-12 oz/acre soil treatment	0	1 or until dry	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii)*	1.5-3 oz/1000 row feet in-furrow treatment	-	1	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii)*	2-3 lb/acre band	-	1	?	
BIO-TAM 2.0 (*Trichoderma asperellum, Trichoderma gamsii*)	2.5-5 lb/acre	-	4	?	
Double Nickel 55 (*Bacillus amyloliquefaciens* str D747)	0.125-1 lb/acre soil treatment	0	4	?	
Double Nickel LC (*Bacillus amyloliquefaciens* str D747)	0.5-4.5 pts/acre soil treatment	0	4	?	
PERpose Plus (hydrogen peroxide)	1 fl.oz./ gal (initial/curative) 0.25-0.33 fl.oz./ gal (weekly/preventative)	-	until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop (*Gliocladium catenulatum*)	1.4-3.5 oz/ 2.5 gal water soil drench	-	0	?	Treat only the growth substrate when above-ground harvestable food commodities are present.
RootShield Granules (*Trichoderma harzianum*)	2.5-6 lb/half acre in-furrow treatment	-	0	?	
RootShield PLUS+ Granules (*Trichoderma harzianum, Trichoderma virens*)	2.5-6 lb/half acre in-furrow treatment	-	0	?	
RootShield PLUS+ WP (*Trichoderma harzianum, Trichoderma virens*)	0.25-1.5 lb/ 20 gal water dip	0	4	?	Do not apply when above-ground harvestable food commodities are present.
RootShield PLUS+ WP (*Trichoderma harzianum, Trichoderma virens*)	16-32 oz/acre in-furrow treatment	0	4	?	Do not apply when above-ground harvestable food commodities are present.

Table 11.3 Pesticides for Management of Bottom Rot					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
RootShield WP (*Trichoderma harzianum*)	16-32 oz/acre	-	until dry	?	In-furrow or transplant starter solution.
Serenade Soil[1] (*Bacillus subtilis str* QST 713)	2-6 qt/acre soil drench	0	4	?	
Soilgard (*Gliocladium virens*)	1/2-2 lb/100 gal water	-	0	?	At transplant.
Soilgard (*Gliocladium virens*)	2-10 lb/acre	-	0	?	Used as a directed spray or drench at the base of the plant after transplanting.
Taegro (*Bacillus subtilis*)	2.6 oz/100 gal water in-furrow treatment	-	24	?	Soil drench or over furrow at time of planting.
Taegro ECO (*Bacillus subtilis var. amyloliquefaciens* str. FZB2)	2.6-5.2 oz/acre in-furrow treatment	-	24	?	In furrow with seed or at planting.
TerraClean 5.0 (hydrogen dioxide, peroxyacetic acid)	128 fl.oz./100 gal water Soil treatment	up to day	0	?	Soil treatment prior to seeding/transplanting.
TerraClean 5.0 (hydrogen dioxide, peroxyacetic acid)	25 fl.oz./ 200 gal water soil drench	up to day	0	?	Soil drench with established plants.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [1]Serenade Opti and Serenade ASO (labeled for foliar and soil uses) will be the only formulations in the future. Formulations may differ in efficacy, especially older and newer ones. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

11.4 Damping-off, *Pythium spp., Rhizoctonia solani*

Time for concern: Most common when conditions are excessively moist such as in a site that drains poorly in combination with cool temperatures that slow seed germination and early plant growth.

Key characteristics: These soil borne fungi are present in most soils, but are often kept in balance by other beneficial fungi in well-managed, biologically active soils. They can kill seeds and young seedlings. Damping-off is expressed as seed decay, rot of newly germinated roots, and infections of seedling stems at the soil line after emergence. See the Compendium of Lettuce Diseases (reference 50.)

Relative risk: Although rarely seen, given the right conditions, plantings can be severely reduced especially in early spring in direct seeded fields.

Management Option	Recommendation for Damping-off
Scouting/thresholds	Scout plantings weekly. Thresholds for organic production have not been established.
Seed selection	Because fresh seed is generally more vigorous than older seed, plants from fresh seeds may grow faster and exit the highly susceptible seedling state sooner.
Site selection	Avoid compacted, heavy, or poorly drained soils. High levels of decomposing organic matter can increase damping-off and reduce germination rates.
Resistant varieties	Resistant varieties are not known.
Weeds	Several weeds host *Pythium:* wild-proso millet, shattercane, barnyardgrass, quackgrass, and yellow foxtail (reference 3).

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Table 11.4 Pesticides for Management of Damping-off

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (*Streptomyces lydicus* WYEC 108)	3-12 oz/acre soil treatment	0	1 or until dry	?	
Actinovate AG (*Streptomyces lydicus* WYEC 108)	2-18 oz/acre seed treatment	0	1 or until dry	?	2-18 oz/4 oz water per acre of seed (seed spray). 2-18 oz/acre of seed (hopper box dry coating).
Actinovate STP (*Streptomyces lydicus*)	4-32 oz/cwt seed seed treatment	-	1 or until dry	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/ 1000 row feet in-furrow treatment	-	1	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	2-3 lb/acre band	-	1	?	
BIO-TAM 2.0 (*Trichoderma asperellum, Trichoderma gamsii*)	2.5-5 lb/acre	-	4	?	
Double Nickel 55 (*Bacillus amyloliquefaciens* str D747)	0.125-1 lb/acre soil treatment	0	4	?	
Double Nickel LC (*Bacillus amyloliquefaciens* str D747)	0.5-4.5 pts/acre soil treatment	0	4	?	
MycoStop (*Streptomyces grieoviridis* str K61)	.176 oz/ 1.5 lbs seed seed treatment	-	4	?	Greenhouse use only. Provides suppression.
MycoStop (*Streptomyces grieoviridis* str K61)	.07 oz/ 100-200 sq ft soil treatment	-	4	?	Greenhouse use only. Provides suppression. Irrigate within 6 hours after soil spray or drench with enough water to move Mycostop Biofungicide into the root zone.
MycoStop Mix (*Streptomyces grieoviridis* str K61)	0.015-0.03 oz/lb seed seed treatment	-	4	?	
MycoStop Mix (*Streptomyces grieoviridis* str K61)	0.0175-0.07 oz/ 100 sq ft soil treatment	-	4	?	
PERpose Plus (hydrogen peroxide)	1 fl oz/ gal initial/curative 0.25-0.33 fl oz/ gal weekly/preventative	-	until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.

Table 11.4 Pesticides for Management of Damping-off					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
Prestop (*Gliocladium catenulatum*)	1.4-3.5 oz/ 2.5 gal water soil drench	-	0	?	Treat only the growth substrate when above-ground harvestable food commodities are present.
RootShield Granules (*Trichoderma harzianum*)	2.5-6 lb/half acre in-furrow treatment	-	0	?	
RootShield PLUS+ Granules (*Trichoderma harzianum, Trichoderma virens*)	2.5-6 lb/half acre in-furrow treatment	-	0	?	
RootShield PLUS+ WP (*Trichoderma harzianum, Trichoderma virens*)	0.25-1.5 lb/ 20 gal water dip 16-32 oz/acre in-furrow treatment	0	4	?	Do not apply when above-ground harvestable food commodities are present.
RootShield WP (*Trichoderma harzianum*)	16-32 oz/acre	-	until dry	?	In-furrow or transplant starter solution.
Soilgard (*Gliocladium virens*)	0.5-2 lb/100 gal water soil drench	-	0	?	Before transplanting, apply 4 fl oz of finished drench per plant in flats 1 week prior to transplanting. At transplanting, apply 4-8 fl oz of finished drench in each transplant hole.
Soilgard (*Gliocladium virens*)	2-10 lb/acre	-	0	?	Used as a directed spray or drench at the base of the plant after transplanting.
TerraClean 5.0 (hydrogen dioxide, peroxyacetic acid)	128 fl.oz./100 gal water soil treatment	up to day	0	?	Soil treatment prior to seeding/transplanting.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

11.5 Downy Mildew, *Bremia lactucae*

Time for concern: Ideal conditions for disease development include night temperatures of 43 to 50^{0}F and day temperatures of 55 to 70^{0}F with 100% humidity or long periods of leaf wetness. As temperatures increase, the disease subsides.

Key characteristics: Downy mildew first appears on leaves as light green lesions, turning yellow and chlorotic. Older lesions are tan and papery. White sporangia and spores emerge on the underside of leaves and provide an avenue for other pathogens to enter. Downy mildew overwinters in New York on decomposing residue of infected plants. Spores can be spread by winds. See Cornell photo (reference 57).

Relative Risk: Downy mildew is sporadic but very destructive when present. Plants are susceptible at all stages of growth.

Management Option	Recommendation for Downy Mildew
Scouting/thresholds	Thresholds for organic production have not been established.
Site selection	Select a well- drained field with good air flow that encourages leaves and soil to dry quickly especially for early and late season plantings. Plant in fields where crop debris is well decomposed at planting time.

Management Option	Recommendation for Downy Mildew
Crop rotation	Crop rotation is the first line of defense. Rotate away from lettuce for a minimum of 2 to 3 years.
Seed selection	This fungus is not seed-borne.
Resistant varieties	Breeding resistant varieties is a challenge since the fungus readily produces new races. See resistant varieties in Section 6.
Planting	Orient rows parallel with the prevailing winds and use wide row spacing to promote quick drying of leaves and soil.
Cultural practices	Avoid overhead irrigation to prevent extended periods of leaf wetness. If watering is necessary, irrigate early in the day when sun or wind are likely to dry leaves rapidly.
Weed control	Control alternate hosts such as perennial sowthistle, annual sowthistle, and prickly lettuce (reference 3). Control weeds to improve air flow and shorten leaf wetness periods throughout the field.
Postharvest	Plow, rather than disk, to deeply bury diseased crop residue.

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Table 11.5 Pesticides for Management of Downy Mildew

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (*Streptomyces lydicus* WYEC 108)	3-12 oz/acre	0	1 or until dry	?	The label recommends use of a spreader sticker.
Agricure (potassium bicarbonate)	2-5 lb/acre	0	1	?	
Badge X2 (copper hydroxide, copper oxychloride)	0.75-1.5 lb/acre	0	48	?	
Basic Copper 53 (basic copper sulfate)	1-1.9 lb/acre	up to day	48	?	Copper will leave a visible residue on leaves.
ChampION++ (copper hydroxide)	0.75-1.5 lb/acre	0	48	?	
Cueva Fungicide Concentrate (copper octanoate)	0.5-2 gal/acre	up to day	4	?	Use lower rate for copper-sensitive lettuce varieties.
Double Nickel 55 (*Bacillus amyloliquefaciens* str D747)	2-3 lb/acre	0	4	?	
Double Nickel LC (*Bacillus amyloliquefaciens* str D747)	0.5-6 qt/acre foliar spray	0	4	?	
Milstop (potassium bicarbonate)	2-5 lb/acre	0	1	?	
Nordox 75 WG (cuprous oxide)	0.66-1.25 lb/acre	-	12	?	

Table 11.5 Pesticides for Management of Downy Mildew					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
Nu-Cop 50 WP (copper hydroxide)	1-2 lb/acre	1	24	?	Copper will leave a visible residue on leaves.
Nu-Cop 50DF (copper hydroxide)	1-2 lb/acre	1	48	?	Copper will leave a visible residue on leaves.
Nu-Cop HB (copper hydroxide)	1/2-1 lb/acre	-	48	?	Copper will leave a visible residue on leaves.
Organocide (sesame oil)	1-2 gal/100 gal water	0	0	?	25(b) pesticide.
Oxidate 2.0 (hydrogen dioxide, peroxyacetic acid)	128 fl oz/100 gal water Curative 32 fl oz/100 gal water Preventative	0	until dry	?	Apply consecutive applications until control is achieved and then follow directions for preventative treatment. Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce to preventative rate after the completion of the third treatment and maintain 5-day interval spray cycle. Bee Hazard. This product is toxic to bees exposed to direct contact
PERpose Plus (hydrogen peroxide)	1 fl.oz./ gal initial/curative 0.25-0.33 fl.oz./ gal weekly/preventative	-	until dry	3	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment. Hydrogen peroxide effective in 0/1 trial.
Regalia (*Reynoutria sachalinensis*)	0.5-4 qt/acre	0	4	?	
Serenade ASO[1] (*Bacillus subtilis* str QST 713)	2-6 qt/acre	0	4	?	
Serenade MAX[1] (*Bacillus subtilis* str QST 713)	1-3 lb/acre	0	4	?	
Taegro ECO (*Bacillus subtilis* var. amyloliquefaciens str. FZB2)	2.6-5.2 oz/acre	-	24	?	
Trilogy (neem oil)	0.5-1% solution	Up to day	4	?	Apply no more than 2 gallons of Trilogy per acre per application. Bee Hazard. This product is toxic to bees exposed to direct contact.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [1]Serenade Opti and Serenade ASO (labeled for foliar and soil uses) will be the only formulations in the future. Formulations may differ in efficacy, especially older and newer ones. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
Active ingredient meets EPA criteria for acute toxicity to bees

11.6 Drop, *Sclerotinia sclerotiorum, Sclerotinia minor*

Time for concern: This fungus is favored by warm, wet conditions and is primarily noticed at or near crop maturity, but may occur at any time during the season.

Key characteristics: Also referred to as lettuce drop, white mold, or watery soft rot. The fungus attacks the petioles of outer leaves that contact soil causing the outer leaves to wilt. It quickly progresses inward until the entire plant wilts. Look for soft watery decay, snowy white mycelium, and hard, seed-size, black sclerotia (*Sclerotinia minor* sclerotia are the size of mustard seed; *Sclerotinia sclerotiorum* are the size of pea seed). Sclerotia drop to the ground from decaying plant tissue where they can remain dormant for up to 5 years. Under favorable conditions, the fungus becomes active and spreads throughout soil. Preventing a buildup of the sclerotia in the soil is important, but can be difficult since *Sclerotinia* has many plant hosts. View University of California fact sheet (reference 58) and Cornell photo(reference 59) and reference 50.

Relative risk: Sclerotinia drop is one of the three most serious fungal diseases of lettuce, found wherever inoculum is present and weather is warm and wet. It can cause the entire plant to collapse in days.

Management Option	Recommendation for Drop
Scouting/thresholds	Scout plantings weekly. Thresholds for organic production have not been established.
Site selection	Growers who experience only occasional outbreaks during seasons of prolonged wet weather can adequately control lettuce drop with practices that promote quick leaf drying such as controlling weeds, planting in areas of good air movement and adequate drainage. Avoid fields with a history of *Sclerotinia* infections in other crops.
Crop rotation	*Sclerotinia* has a wide host range, making it difficult to manage with crop rotation alone. Under low to moderate disease pressure, a 3-year rotation with non-hosts, particularly grains such as corn, cereal, or forage grass is best, although rotations with onions and potatoes can also be used. In severe situations, a 5-year rotation is necessary. Drop has many hosts including weeds and vegetables such as carrots, cabbage, beans, tomatoes and celery. It is a major disease of chicory and endive. Although broccoli can be an alternate host for *Sclerotinia,* research has shown that planting late-season lettuce after a spring broccoli crop decreases the amount of lettuce drop if the broccoli residue is incorporated prior to planting. A biofumigant mustard cover crop may have a similar effect. See Section 3.5: *Biofumigant Cover Crops.*
Resistant varieties	A few varieties have shown some tolerance to lettuce drop. See section 6: *Varieties*.
Seed selection	This fungus is not seed-borne, but the seed-like fruiting structures (sclerotia) can contaminate seed lots. Do not plant seed if contaminated.
Planting	Orient rows with the prevailing winds and use wide row spacing to encourage quick drying of leaves and soil. Plant in fields where crop debris is well decomposed at planting time.
Weed control	Control weeds to improve air flow and shorten leaf wetness periods throughout the field. Weed hosts of *S. sclerotiorum* include common chickweed, green foxtail, common lambsquarters, prickly lettuce, wild mustard, eastern black nightshade, field pennycress, redroot pigweed, wild radish, common ragweed, shattercane, annual sowthistle, common sunflower, and Canada thistle. *S. minor* is hosted by yellow nutsedge (reference 3).
Cultural controls	Too much nitrogen causes excess quick growing tissue which is more susceptible to lettuce drop. Remove infected plants to prevent spread throughout the field.
Harvest	Trim outer leaves before packing to avoid spreading rot in storage. Refrigerate plants after harvest.
Postharvest	Immediately plow under plant residues after harvest. For extreme cases, flood the field between crops for 23-45 days to reduce inoculum. Flooding causes spores to release when no host is present.

Management Option	Recommendation for Drop
Note(s)	Avoid use of overhead irrigation to prevent extended periods of leaf wetness. If watering is necessary, irrigate early in the day when leaves are likely to dry quickly in the sun and wind.

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Table 11.6 Pesticides for Management of Drop

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Actinovate AG (*Streptomyces lydicus* WYEC 108)	3-12 oz/acre	0	1 or until dry	3	The label recommends use of a spreader sticker. Streptomyces lydicus products effective in 0/2 trials. Foliar spray and soil treatment.
Bio-Tam 2.0 (*Trichoderma asperellum, Trichoderma gamsii*)	2.5-5 lb/acre	-	4	?	
Contans WG (*Coniothyrium minitans*)	2 lb/acre soil treatment	-	4	2	Contans effective in 9/22 trials. See label for specific use instructions.
Double Nickel 55 (*Bacillus amyloliquefaciens* str D747)	0.25-3 lb/acre foliar spray	0	4	?	Make second application at thinning or cultivation in sufficient water and multiple nozzles to ensure thorough coverage of lower leaves and surrounding soil surface. Incorporation with light irrigation after application may improve disease control. Repeat at 10-14 day intervals if conditions promoting disease persist.
Double Nickel 55 (*Bacillus amyloliquefaciens* str D747)	0.125-1 lb/acre band	0	4	?	Banded seedline treatment.
Double Nickel LC (*Bacillus amyloliquefaciens* str D747)	0.5-4.5 pts/acre band	0	4	?	Banded seedline treatment.
Double Nickel LC (*Bacillus amyloliquefaciens* str D747)	0.5-6 qt/acre foliar spray	0	4	?	Make second application at thinning or cultivation in sufficient water and multiple nozzles to ensure thorough coverage of lower leaves and surrounding soil surface. Incorporation with light irrigation after application may improve disease control. Repeat at 10-14 day intervals if conditions promoting disease persist.
Optiva (*Bacillus subtilis* str. QST 713)	14-24 oz/acre	0	4	?	Repeat applications on 10-14 day intervals if conditions for disease development persist. Foliar spray and soil treatment.
PERpose Plus (hydrogen peroxide)	1 fl.oz./ gal initial/curative	-	until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment.
PERpose Plus (hydrogen peroxide)	0.25-0.33 fl.oz./ gal weekly/preventative	-	until dry	?	For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.

Table 11.6 Pesticides for Management of Drop					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
Regalia (*Reynoutria sachalinensis*)	0.5-4 qt/acre	0	4	?	
Serenade ASO[1] (*Bacillus subtilis* str QST 713)	2-6 qt/acre	0	4	?	Foliar spray and soil treatment.
Serenade MAX[1] (*Bacillus subtilis* str QST 713)	1-3 lb/acre	0	4	?	Foliar spray and soil treatment.
Serenade Opti [1] (*Bacillus subtilis* str QST 713)	14-20 oz/acre	0	4	?	Foliar spray and soil treatment.
Serenade Soil[1] (*Bacillus subtilis* str QST 713)	2-6 qt/acre Soil treatment	0	4	?	
Taegro ECO (*Bacillus subtilis* var. amyloliquefaciens str. FZB2)	2.6-5.2 oz/acre in-furrow treatment	-	24	?	In furrow with seed or at planting.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [1] Serenade Opti and Serenade ASO (labeled for foliar and soil uses) will be the only formulations in the future. Formulations may differ in efficacy, especially older and newer ones. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

11.7 Aster Yellows *aster yellows phytoplasma*, vectored by the aster leafhopper.

Time for concern: June through September; the occurrence of aster yellows (AY) follows the migration pattern of leafhoppers (Section 14.1).

Key characteristics: The disease is caused by a unicellular phytoplasma which overwinters in the body of the aster leafhopper as well as in perennial and biennial host plants, particularly grains. The disease is transmitted during leafhopper feeding. Leafhoppers must feed on an infected plant for about 8 hours to ingest enough phytoplasma to become infective, and can remain infectious for nearly 100 days. Symptoms include strikingly yellowed, blanched, or chlorotic leaves. Leaves are short and thick in the middle of the head, and the outside leaves become yellow, bitter, and unmarketable. See photo (reference 60), factsheet (reference 61) and reference 50.

Relative risk: Aster yellows causes plants to be severely stunted and yellowed, making them unmarketable. Damage varies from year to year according to the level of aster leafhopper present.

Management Option	Recommendations for Aster Yellows
Scouting/thresholds	Scout plantings weekly. Thresholds for organic production have not been established.
Site selection	Do not plant in fields with a previous history of aster yellows. Weeds surrounding these fields often harbor the pathogen.
Crop rotation	The aster yellows phytoplasma has a wide host range, including lettuce, carrot, escarole, endive, and celery. The aster leafhopper tends to overwinter on wheat, rye, barley and some grasses, therefore plant lettuce away from grain fields grown during the previous season. Over 300 species of plants are susceptible, including many ornamentals (reference 3).
Seed selection	Aster yellows phytoplasma is not seed-borne.

Management Option	Recommendations for Aster Yellows
Weed control	Weed hosts are the primary site where the disease overwinters. Control alternate weed host reservoirs including wild chicory, dandelion, fleabane, galinsoga, wild lettuce, plantain, common purslane, common ragweed, shepherd's purse, perennial sowthistle, Russian thistle, Canada thistle, and many others (reference 3). Ornamental hosts include gladiolus, poppy, chrysanthemum, phlox, and veronica.
Postharvest	Plow under lettuce fields immediately after harvest to reduce inoculum for future crops.
Note(s)	See aster leafhopper section (14.1) for management strategies of this important disease vector.

11.8 Lettuce Viruses, *Lettuce Mosaic Virus (LMV), Cucumber Mosaic Virus (CMV), Broadbean Wilt Virus (BBWV),* transmitted by aphids

Time for concern: Aphids can carry inoculum into and from fields during the entire season, especially when plantings overlap.

Key characteristics: See factsheet (reference 61), photo (reference 62) and reference 50.

LMV: Symptoms of LMV vary considerably depending on the age of the plant at infection, the variety, and temperature. "Mother" plants, grown from infected seeds, show mosaic symptoms, stunting, and lack of development as early as the seedling stage. They serve as an initial source of virus which is then spread by aphids to other plants. Secondary infected plants show mosaic, leaf puckering, yellow-green mottling, and deep or accentuated serration of the leaf margins, with leaf lettuce showing these symptoms most notably. Leaf edges may turn brown and die. Holding young leaves up to the sun illuminates brown flecks in the smaller veins. Roll back of leaves is especially diagnostic in crisphead varieties.

CMV: Symptoms of CMV are similar to LMV, but the mosaic is more pronounced than LMV. Veinal browning and necrosis occurs when temperatures are in the mid-50's or lower. It is transmitted by aphids and mechanical wounding. **BBWV:** Symptoms are similar to those of LMV and CMV, but at lower field temperatures, the infected plants develop severe veinal necrosis. BBWV is also aphid transmitted in a non-persistent manner.

Relative risk: Viruses can be serious when they occur.

LMV: is one of the most common and damaging viruses causing lettuce to be discolored and fail to form a head.

CMV: is very difficult to control and damaging when present.

BBWV: can be serious in susceptible varieties.

Management Option	Recommendations for Viruses
Scouting/thresholds	Scout plantings weekly. Thresholds for organic production have not been established.
Site selection	Plant upwind from weedy border areas or previous lettuce plantings to reduce inoculum from these areas which may serve as virus reservoirs.
Crop rotation	**LMV**: This virus affects all types of lettuce and many other hosts including other greens, pea, spinach, aster, marigold, and zinnia. **CMV**: can infect more than 775 plant species including weeds, therefore is very difficult to control.
Resistant varieties	**LMV**: See resistant varieties in Section 6. **CMV**: resistant varieties are not known. **BBMV**: Some varieties are highly susceptible while others show high tolerance. Check with seed suppliers for resistance information.

Management Option	Recommendations for Viruses
Seed selection	**LMV** is seed-borne in all lettuce types, but not in endive, and infected seed is the most common route for LMV to be introduced into a field. Purchase lettuce seed designated *mosaic tolerance zero* (MTO), meaning a sample shows zero infested seeds in 30,000. **CMV**: is not seed-borne. **BBMV**: is not seed-borne.
Weed control	**LMV:** Many weeds are hosts including cheeseweed, chickweed, common groundsel, henbit, common lambsquarters, milkweed, ox tongue, purslane, scarlet pimpernel, shepherd's purse, sowbane, annual sow-thistle, and milk thistle. Controlling weed hosts in and around the field can slow the rate of infection. **CMV**: Perennial weed sources include hedge bindweed, white campion, common chickweed, corn cockle, burr cucumber, hairy galinsoga, common groundsel, horsenettle, jimsonweed, common lambsquarters, prickly lettuce, marshcress, common milkweed, pitted morning glory, tall morning glory, wild mustard, eastern black nightshade, field pennycress, prostrate pigweed, redroot pigweed, common purslane, wild radish, common ragweed, yellow rocket, shepherd's purse, annual sowthistle, corn speedwell, Canada thistle, and marsh yellowcress (reference 3). **BBWV**: The major perennial weed sources are broadleaf plantain and buckhorn plantain.
Postharvest	Plow under early lettuce fields immediately after harvest to reduce inoculum for later-planted crops.
Note(s)	This disease is transmitted by aphids in a non-persistent manner. The aphid acquires the virus from infected plants almost immediately. However, it is only able to infect healthy plants for a short time, usually a few days to a week. Suppressing aphid populations aids virus control. Oil sprays in the field and on weedy field borders can help to control viruses. See Section 14.2: *Aphids.*

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 11.8 Pesticides for Management of Viruses

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Organic JMS Stylet-Oil (paraffinic oil)	3 qt/100 gal water	0	4	?	Oil products effective against aphids in 2/5 trials. May reduce transmission of stylet-borne pathogens such as LMV and CMV.
PureSpray Green (white mineral oil)	0.75 gal/acre	up to day	4	?	See comment for Organic JMS Stylet-Oil

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

12. NEMATODES

12.1 Northern Root-Knot Nematode, *Meloidogyne hapla*

Time for concern: Seedling through harvest, but control measures are only effective before or at planting.

Key characteristics: This nematode spends most of its life living in the roots of its host, although the eggs and second stage juveniles can be found in the soil. Larvae travel through the soil in search of host roots, attaching most often near the root tip to feed. Root cells near the feeding site swell into visible galls (knots). Infected roots often exhibit extensive secondary root formation. Severely infected plants are stunted and exhibit wilting in the middle of hot and sunny days. See Cornell Bulletin (reference 64) and photo of root-knot nematode (reference 65).

Relative risk: Lettuce is the second most sensitive crop to root-knot nematode after carrots. Severely infected plants can be stunted and grow unevenly. Heads are often loose and small, making them unsuitable for some markets. Yield weights in experimental research plots showed a 26 percent reduction due to root-knot nematode damage (reference 64).

Management Options	Recommendations for Root-Knot Nematode
Scouting/thresholds	**Scouting:** Record the occurrence and severity of root-knot nematode infection on roots. **Threshold:** Damage threshold for lettuce is 2 eggs/cc of soil.
Site selection	Use a soil bioassay with lettuce to assess soil root-knot nematode infestation levels. Or, submit the soil sample(s) for nematode analysis at a public or private nematology lab (reference 63). See Section 4: *Field Selection* for more information or refer to the following Cornell publications for instructions: Soil Sampling For Plant Parasitic Nematodes (reference 66). Visual Assessment of Root-Knot Nematode Soil Infestation Levels Using a Lettuce Bioassay (ref 67).
Crop rotation	Root-knot nematodes can be reduced through crop rotation, but because of their large host range, are unlikely to be eliminated. Particularly sensitive hosts are carrot and onion, but also alfalfa, soybean and clover. Many grain crops are non-hosts including corn, barley, oats, annual ryegrass, rye grain, tall fescue, and wheat. These crops are effective at reducing root-knot nematode populations. Sudangrass is not only a non-host, but if incorporated as a chopped green residue, may further suppress populations.
Resistant varieties	Resistant varieties are not known.
Cover crops	Winter grain cover crops, such as winter rye and oat, are non-hosts for the northern root-knot nematode, thus they are effective at reducing the population. Biofumigant cover crops, used as green manure, may be effective in reducing both root-knot nematode populations and lesion nematodes in soil populations. Many biofumigant crops will increase root-lesion nematode populations while the crop is growing, and exhibit their biofumigant effects when they are incorporated into the soil. Research suggests that Sudangrass hybrid 'Trudan 8' as well as selections of white clover and flax can be used effectively as a biofumigant to reduce nematode populations. Nemat is an arugula variety that functions as a trap crop, attracting nematodes but not enabling reproduction on its roots. Crucifer green manures are also effective as bio-fumigants. See Section 3: *Cover Crops* for more information.
Weed management	The following weeds host root-knot nematodes and should be controlled when possible: wild buckwheat, large crabgrass, dandelion, hairy galinsoga, common groundsel, prostrate knotweed, common lambsquarters, prickly lettuce, mallow, black medic, wild mustard, yellow nutsedge, field pennycress, field pepperweed, tumble pigweed, redroot pigweed, plantain, shepherd's purse, purslane, yellow rocket, speedwell, Canada thistle, and velvetleaf (references 3 and 64).
Cultural controls	Avoid moving soil from infested fields to uninfested fields on equipment and vehicles. Wash equipment after use in infested fields. Prevent surface run-off from infested fields.
Postharvest	If possible, plow under crop debris and plant a grain cover crop.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.1 Pesticides for Management of Nematodes

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
AzaGuard (🐝azadirachtin)	15 fl oz/acre soil drench	0	4	?	Apply in sufficient amount of water to penetrate soil to a depth of 12".
DiTera DF (*Myrothecium verrucaria*)	13-100 lb/acre soil treatment	-	4	?	
Ecozin Plus 1.2% ME (🐝azadirachtin)	15-30 fl oz/acre	0	4	?	Foliar spray and soil treatment.
MeloCon (*Paecilomyces lilacinus* str. 251)	2-4 lb/acre soil treatment	-	4	?	
Molt-X (🐝azadirachtin)	15 oz/acre	0	4	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
🐝Active ingredient meets EPA criteria for acute toxicity to bees

13. NONPATHOGENIC DISORDERS

Environmental factors can cause symptoms that appear to be diseases but are actually not caused by a pathogen or insect. See Section 6 for information on varieties resistant to the following disorders.

Table 13.1 Nonpathogenic Disorders of Lettuce

Disorder	Cause	Options
Tipburn	Tipburn is caused by insufficient calcium in plant tissue due to rapid plant growth, excessive fertilizer, or uneven water availability.	Plant resistant varieties. Irrigate with drip irrigation systems.
Poor stand	One cause is thermodormancy due to soil temperatures >80F. Other causes include planting too deep, old seed, and seed rots.	Irrigate when seeding in hot weather.
Bolting	High night temperatures during early summer and summer. Lettuce also bolts naturally when mature.	Plant heat tolerant varieties. Avoid summer plantings.
Russeting	Ethylene exposure during storage especially in crisphead varieties.	Do not store lettuce with ethylene producing crops.

14. INSECT MANAGEMENT

Effective insect management relies on accurate identification of pests and beneficial insects, an understanding of their biology and life cycle, knowledge of economically important levels of pest damage and a familiarity with allowable control practices, in other words, Integrated Pest Management (IPM).

Regular scouting and accurate pest identification are essential for effective insect management. Thresholds used for conventional production may not be useful for organic systems because of the typically lower percent mortality and shorter residual of control products allowed for organic

production. The use of pheromone traps or other monitoring and prediction techniques can provide an early warning for pest problems, and help effectively focus scouting efforts.

The contribution of crop rotation as an insect management strategy is highly dependent on the mobility of the pest. Crop rotation tends to make a greater impact on reducing pest populations if the pest has limited mobility. In cases where the insects are highly mobile, leaving a greater distance between past and present plantings is better.

Natural Enemies

Learn to identify naturally occurring beneficial insects, and attract and conserve them in your fields by providing a wide variety of flowering plants in or near the field, and avoiding broad-spectrum insecticides. In most cases, a variety of natural enemies are present in the field, each helping to reduce pest populations. The additive effects of multiple species of natural enemies, attacking different host stages, is more likely to make an important contribution to reducing pest populations than an individual natural enemy species operating alone. Natural enemies need a reason to be present in the field, either a substantial pest population, alternative hosts, or a source of pollen or nectar, and may not respond to the buildup of pests quickly enough to keep pest populations below damaging levels. Releasing insectary-reared beneficial organisms into the crop early in the pest outbreak may help control some pests, but sometimes these biocontrol agents simply leave the area. For more information, see Cornell's Natural Enemies of Vegetable Insect Pests (reference 68) and A Guide to Natural Enemies in North America (reference 70).

Regulations

Organic farms must comply with all regulations regarding pesticide applications. See Section 10: *Using Organic Pesticides* for details. **ALWAYS check with your organic farm certifier when planning pesticide applications**.

Efficacy

In general, insecticides allowed for organic production kill a smaller percentage of the pest population and have a shorter residual than non-organic insecticides. University-based efficacy testing is not available for many organic pesticides. See Section 10.3: *Optimizing Pesticide Effectiveness* for more information.

Resources:

Biological Control: A Guide to Natural Enemies in North America (reference 70)
Resource Guide for Organic Insect and Disease Management (reference 2).
Natural Enemies of Vegetable Insect Pests (reference 68).

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 14.0.1 Pesticides for Insect Control in Organic Lettuce

CLASS OF COMPOUND Product name *(Active ingredient)*	**Aphid**	**Leafhopper**	**Cabbage Looper**	**Tarnished Plant Bug**
MICROBIAL				
Agree (*Bt aizawai*)			X	
Biobit (*Bt kurstaki str. ABTS-351*)			X	
Deliver (*Bt kurstaki*)			X	
DiPel DF (*Bt kurstaki*)			X	
Grandevo (*Chromobacterium subtsugae* str. PRAA4-1)	X		X	
Javelin WG (*Bt kurstaki*)			X	
Entrust (*spinosad*)			X	
Entrust SC (*spinosad*)			X	
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	X		X	X
Preferal*(Isaria fumosorosea Apopka str. 97)*	X		X	X
XenTari (*Bacillus thuringiensis*)			X	

ORGANIC LETTUCE PRODUCTION

CLASS OF COMPOUND Product name *(Active ingredient)*	**Aphid**	**Leafhopper**	**Cabbage Looper**	**Tarnished Plant Bug**
BOTANICAL				
Aza-Direct (*azadirachtin*)	X	X	X	
AzaGuard (*azadirachtin*)	X	X	X	X
AzaMax (*azadirachtin*)	X	X	X	X
AzaSol (*azadirachtin*)	X		X	X
Azatrol EC (*azadirachtin*)	X	X	X	X
Azera (*azadirachtin, pyrethrins*)	X	X	X	X
BioLink Insect Repellant *(garlic juice)*	X	X	X	X
BioLink Insect & Bird Repellant *(garlic juice)*	X	X	X	X
BioRepel *(garlic oil)*	X	X		
Cedar Gard *(cedar oil)*		X		X
Ecozin Plus (*azadirachtin*)	X	X	X	X
Envirepel 20 *(garlic juice)*	X	X	X	
GC-Mite (*cottonseed, clove and garlic oils*)	X			
Molt-X *(azadirachtin)*	X	X	X	X
Neemix 4.5 (*azadirachtin*)	X	X	X	
Trilogy (*neem oil*)	X			
PyGanic EC 5.0 II (*pyrethrin*)	X	X	X	X
PyGanic EC 1.4 II(*pyrethrin*)	X	X	X	X
Garlic Barrier AG (*garlic juice*)	X	X	X	
SOAP				
DES-X (*insecticidal soap*)	X			X
M-Pede (*potassium salts of fatty acids*)	X	X		X
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentrate II (*pyrethrins, potassium salts of fatty acids*)	X	X	X	X
OIL				
GrasRoots (*cinnamon oil*)	X			
Oleotrol-I *(soybean oil)*	X			
Omni Supreme Spray *(mineral oil)*	X	X	X	X
Organic JMS Stylet Oil (*paraffinic oil*)		X		
Glacial Spray Fluid (*mineral oil*)	X	X		
Organocide 3-in-1 *(sesame oil)*	X			
PureSpray Green (*petroleum oil*)	X	X	X	
SuffOil-X *(mineral oil)*	X	X	X	X
TriTek*(mineral oil)*	X	X	X	X
OTHER				
Ecotec (*rosemary and peppermint oil*)	X		X	X
Nuke Em *(citric acid)*	X			

CLASS OF COMPOUND Product name *(Active ingredient)*	Aphid	Leafhopper	Cabbage Looper	Tarnished Plant Bug
Sil-Matrix (*potassium silicate*)	X			

Active ingredient meets EPA criteria for acute toxicity to bees

14.1 Aphids primarily Green Peach Aphid, *Myzus persicae*

Time for concern: Mid-July through the end of the growing season.

Key characteristics: Adult green peach aphids come in a range of color including light green, pink, red, and dark brown. Adults can be winged or wingless depending on the time of year and the density of the aphid population. They range in length from 1/32 to 1/16 inch. Aphids are characterized by two cornicles or "tailpipes" on their abdomen. Their host range is wide including weeds, ornamentals, and other vegetable crops. See photos and more information about aphids in the Ontario fact sheet (reference 72).

Relative risk: This annual, but sporadic, pest primarily serves as a vector of damaging virus diseases although large populations can contaminate the crop at harvest.

Management Options	Recommendations for Aphids
Scouting/thresholds	**Scouting:** Scout plantings weekly. Dispersal flights of winged adult aphids can be monitored using yellow sticky boards placed along the field borders. Monitor field populations by visually inspecting 30 plants, checking undersides of leaves and tender new growth. **Thresholds:** Thresholds depend on market tolerance. Community supported agriculture (CSA) outlets are normally more tolerant than the general market.
Resistant varieties	Resistant varieties are not available.
Cultural controls	Row covers can protect lettuce plants from infestation. Cover rows during planting with fine netting or floating row covers to protect them from egg-laying. Hoops may be needed to support the netting to prevent it from damaging the crop. Anchor the edges of the row cover to prevent insects from entering at the edges. Row covers may be left on until harvest.
Biological controls	Numerous natural enemies prey on aphids and can reduce the overall populations. However, some natural enemies can also be contaminants if present in the harvested product. Ladybird beetle larvae, lacewing larvae, cecidomyid fly larvae, syrphid fly larvae, and parasitic wasps are common parasites of aphids (reference 72). Choose practices that preserve these insects. See reference 68 or 70 for more information on natural enemies.
Chemical controls	Spraying aphids within a field will not eliminate the introduction of mosaic viruses borne by aphids immigrating from sources outside of the field, but may reduce virus spread from plant to plant within the field.
Postharvest	Plow under or remove all lettuce plant debris in the field immediately after harvest.
Note(s)	New York State lettuce entering the export market must be kept clean of aphids and other insect contaminants.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 14.1 Pesticides for Management of Aphids

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Aza-Direct (azadirachtin)	1-2 pts/acre	0	4	1	Azadirachtin based products effective in 4/7 trials against the green peach aphid. Up to 3.5 pts per acre can be used under extreme pest pressure.
AzaGuard (azadirachtin)	10-16 fl oz/acre	0	4	1	Azadirachtin based products effective in 4/7 trials against the green peach aphid. Apply with OMRI approved spray oil.
AzaMax (azadirachtin)	1.33 fl oz/1000 ft^2	0	4	1	Azadirachtin based products effective in 4/7 trials against the green peach aphid.
AzaSol (azadirachtin)	6 oz/acre	-	4	1	See comment for AzaMax
Azatrol-EC (azadirachtin)	0.24-0.96 fl/ 1000 ft^2	0	4	1	See comment for AzaMax
Azera (azadirachtin, pyrethrins)	1-3.5 pts/acre	-	12	1	See comment for AzaMax
BioLink (garlic juice)	0.5-2 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioLink Insect & Bird Repellant (garlic juice)	0.5-4 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioRepel (garlic oil)	1 part BioRepel with 100 parts water	-	-	2	25(b) pesticide. Oil products effective in 2/5 trials.
DES-X (insecticidal soap)	2% solution sprayed at 75-200 gallons/acre	1/2	12	?	
Ecotec (Rosemary oil, Peppermint oil)	1-4 pts/acre	-	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME (azadirachtin)	15-30 oz/acre	0	4	1	See comment for AzaMax Crops can be harvested as soon as spray has dried. May slow feeding and affect nymphal development.
Envirepel 20 (garlic juice)	10-32 fl oz/A	-	-	?	25(b) pesticide.
Garlic Barrier AG (garlic juice)	1-2% solution	-	-	?	25(b) pesticide.
GC-Mite (garlic oil, clove oil, cottonseed oil)	1 gal/100 gal water	-	-	2	25(b) pesticide. Oil products effective in 2/5 trials. Check compatibility by spraying a small number of plants.
Glacial Spray Fluid (mineral oil)	0.75-1 gal/100 gal water	up to day	4	2	Oil products effective in 2/5 trials. See label for specific application volumes and equipment.
Grandevo (Chromobacterium subtsugae str. PRAA4-1)	2-3 lb/acre	0	4	?	
GrasRoots (cinnamon oil)	1 part GrasRoots to 9 parts water	-	-	?	25(b) pesticide.
Molt-X (azadirachtin)	10 oz/acre	0	4	1	See comment for AzaMax

Table 14.1 Pesticides for Management of Aphids					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
M-Pede (insecticidal soap)	1-2% solution	0	12	3	Soap based products effective in 0/9 trials against green peach aphid. Tank mix M-Pede with a labeled companion insecticide for green peach aphid control.
Neemix 4.5 (azadirachtin)	5-7 fl oz/acre	0	4	1	See comment for AzaMax. May slow feeding and affect nymphal development. Only labeled for green peach aphid.
Nuke Em (citric acid)	1 fl oz/ 31 fl ozwater to 2 fl oz/30 fl oz water	-	-	?	
Oleotrol-I Bio-Insecticide Concentrate (soybean oil)	43-45 fl oz/100 gal water	-	-	2	25(b) pesticide. Oil products effective in 2/5 trials.
Omni Supreme Spray (mineral oil)	1-2 gal/acre	-	12	2	Oil products effective in 2/5 trials. Use in combination with other insecticides registered for use on lettuce.
Organocide (sesame oil)	1-2 gal/100 gal water	0	0	2	25(b) pesticide. Oil products effective in 2/5 trials.
PFR-97 20% WDG (Isaria fumosorosea Apopka str. 97)	1-2 lb/acre	-	4	?	Repeat applications at 3-10 day intervals as needed to maintain control.
Preferal (Isaria fumosorosea Apopka str. 97)	1-2 lb/acre	-	4	?	
PureSpray Green (white mineral oil)	0.75-1.5 gal/acre	up to day	4	2	Oil products effective in 2/5 trials.
PyGanic EC 1.4 II (pyrethrins)	16-64 fl.oz./acre	until dry	12	?	
PyGanic EC 5.0 II (pyrethrins)	4.5-17 fl.oz./acre	-	12	?	
Safer Brand #567 II (potassium laurate, pyrethrins)	6.4 oz/ gal water applied at 1 gal mix/700 sq ft	until dry	12	?	
Sil-Matrix (potassium silicate)	0.5-1% solution	0	4	?	Only provides suppression of aphids.
SuffOil-X (aliphatic petroleum solvent)	1-2 gal/100 gal water	up to day	4	2	Oil products effective in 2/5 trials. Do not mix with sulfur products.
Trilogy (neem oil)	0.5-1% solution	Up to day	4	?	Apply no more than 2 gallons of Trilogy per acre per application. May slow feeding and affect nymphal development. Bee Hazard. This product is toxic to bees exposed to direct contact
TriTek (mineral oil)	1-2 gal/100 gal water	up to day	4	2	Oil products effective in 2/5 trials. Apply as needed.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest. Active ingredient meets EPA criteria for acute toxicity to bees

14.2 Aster Leafhopper, *Macrosteles quadrilineatus*

Time for concern: Mid-June through the end of the growing season.

Key characteristics: Aster leafhoppers transmit the pathogen that causes aster yellows disease. This pest does not appear to overwinter in New York and early spring populations largely migrate from Gulf Coast states and other southern areas. See University of Minnesota fact sheet (reference 71). Aster leafhopper has a wide host range feeding on over 100 plant species although preferring cereals and grasses.

Relative risk: Aster leafhopper itself only causes minimal damage to lettuce, but is more importantly a vector for aster yellows disease. See Section 11.7: *Aster yellows.*

Management Options	Recommendations for Aster Leafhoppers
Scouting/thresholds	Thresholds have not been established for organic production.
Crop rotation	Crop rotation is ineffective due to the leafhopper's ability to travel long distances.
Resistant varieties	Resistant varieties are not available.
Weed control	Control both broadleaf and grassy weeds near lettuce plantings. See Section 11.7: *Aster Yellows* for more information on alternate host weeds. Where possible, mow headlands around fields.
Mechanical controls	Row covers protect against adult leafhoppers.
Traps	Do not place yellow or white sticky traps directly within lettuce fields since they tend to attract migrating adult leafhoppers.
Note(s)	Reducing aster yellows inoculum is more critical than controlling leafhopper populations since the insect rarely causes direct feeding damage, but instead spreads inoculum throughout the lettuce fields.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 14.2 Pesticides for Management of Aster Leafhopper

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2](Days)	REI (Hours)	Efficacy	Comments
Aza-Direct (azadirachtin)	1-2 pts/acre	0	4	?	Up to 3.5 pts per acre can be used under extreme pest pressure.
AzaGuard (azadirachtin)	10-16 fl.oz./acre	0	4	?	Apply with OMRI approved spray oil.
AzaMax (azadirachtin)	1.33 fl oz/1000 sq ft	0	4	?	
Azatrol-EC (azadirachtin)	0.24-0.96 fl oz/1000 sq ft	0	4	?	
Azera (azadirachtin, pyrethrins)	1-3.5 pts/acre	-	12	?	
BioLink (garlic juice)	0.5-2 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioLink Insect & Bird Repellant (garlic juice)	0.5-4 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioRepel (garlic oil)	1 part BioRepel with 100 parts water	-	-	?	25(b) pesticide.
Cedar Gard (cedar oil)	1 qt/acre	-	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME	15-30 oz/acre	0	4	?	May affect nymphal development.

Table 14.2 Pesticides for Management of Aster Leafhopper					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2](Days)**	**REI (Hours)**	**Efficacy**	**Comments**
(azadirachtin)					Crops can be harvested as soon as spray has dried.
Envirepel 20 (garlic juice)	10-32 fl oz/A	-	-	?	25(b) pesticide. Repellent.
Garlic Barrier AG (garlic juice)	1-2% solution	-	-	?	25(b) pesticide. Repellent.
Glacial Spray Fluid (mineral oil)	0.75-1 gal/100 gal water	up to day	4	?	See label for specific application volumes and equipment.
Molt-X (azadirachtin)	10 oz/acre	0	4	?	
M-Pede (insecticidal soap)	0.25-2% v/v solution	0	12	3	Not effective in 1/1 trial against potato leafhopper. Spray material must contact pest to be effective.
Neemix 4.5 (azadirachtin)	7-16 fl oz/acre	0	4	?	May affect nymphal development.
Omni Supreme Spray (mineral oil)	1-2 gal/acre	-	12	?	Use in combination with other insecticides registered for use on lettuce.
Organic JMS Stylet Oil	3-6 qt/100 gal water	0	4		
PureSpray Green (white mineral oil)	0.75-1.5 gal/acre	up to day	4	?	
PyGanic EC 1.4 II (pyrethrins)	16-64 fl oz/acre	until dry	12	1	Pyrethrin based products effective in 2/3 trials against leafhopper species.
PyGanic EC 5.0 II (pyrethrins)	4.5-17 fl oz/acre	-	12	1	See comment for PyGanic EC 1.4 II.
Safer Brand #567 II (potassium laurate, pyrethrins)	6.4 oz/ gal water applied at 1 gal mix/700 sq ft	until dry	12	1	See comment for PyGanic EC 1.4 II.
SuffOil-X (aliphatic petroleum solvent)	1-2 gal/100 gal water	up to day	4	?	Do not mix with sulfur products.
TriTek (mineral oil)	1-2 gal/100 gal water	up to day	4	?	Apply as needed.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
Active ingredient meets EPA criteria for acute toxicity to bees

14.3 Cabbage Looper, *Trichoplusia ni*

Time for concern: August 1 through harvest. Cold, wet weather conditions will reduce cabbage looper populations. Favorable weather fronts from the south may suddenly increase populations.

Key characteristics: Because adults are nocturnal, the gray, non-descript moths are seldom seen. Adult moths are mottled gray-brown, 3/4 inch long, with a distinct silver-white round mark on the wing. White, round eggs, the size of a pinhead, are laid on the undersides of leaves. Larvae hatch in less than a week and will feed on lettuce for 2 to 4 weeks, chewing ragged holes in the leaves. Larvae are up to 1 ½ inches long, light green with white stripes along each side of the body and can be distinguished by

the looping movement they use to travel. See Cornell factsheet (reference 73), University of Illinois photos (reference 74), and references 4 and 75.

Relative risk: Because cabbage looper does not overwinter in New York, infestations are variable and depend on weather fronts to move them in from areas further south. Both larvae and associated feces are considered contaminants of the crop at harvest. Loopers are mainly a concern for fall-harvested plantings.

Management Option	Recommendation for Cabbage Looper
Crop rotation	Since cabbage looper does not overwinter in New York, crop rotation will not help manage this pest.
Planting methods	Cabbage loopers don't reach significant levels until late July or early August. Early season lettuce will escape most cabbage looper damage.
Scouting/thresholds	Thresholds and scouting techniques have not been developed for organic lettuce.
Traps	Bucket-type pheromone or UV light traps can be used to monitor moth flight. See reference 76, Pheromone Traps for Insect Pest Management, for more information.
Weed control	Cabbage loopers have many broadleaf hosts so weed control may be helpful in reducing field attractiveness for egg laying by dispersing moths.
Cultural controls	Lettuce plantings that are harvested early in the season usually avoid cabbage looper damage.
Biological controls	Naturally-occurring predators, parasitoids, and pathogens help suppress infestations. See A Guide to Natural Enemies in North America (reference 70) for identification of natural enemies.
Floating row covers	For smaller plantings, row covers can be used as a barrier to egg-laying adults, provided they are installed prior to migration of adult moths into the area. Row covers can remain in place until harvest. See Cornell insect traps and barriers factsheet (reference 77) for more on row covers.
Vacuum/leaf blower	Larvae can be vacuumed from leaves using a retail or commercial-duty leaf blower operated for suction.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 14.3 Pesticides for Management of Cabbage Looper

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
Agree WG (*Bacillus thuringiensis*)	0.5-2 lb/acre	up to day	4	1	Bt products effective in 6/7 trials. Good coverage is essential.
Aza-Direct (azadirachtin)	1-2 pts/acre	0	4	1	Up to 3.5 pts per acre can be used under extreme pest pressure. Azadirachtin based products effective in 2/4 trials.
AzaGuard (azadirachtin)	8-16 fl.oz./acre	0	4	1	Apply with OMRI approved spray oil. Azadirachtin based products effective in 2/4 trials.
AzaMax (azadirachtin)	1.33 fl oz/1000 ft^2	0	4	1	Azadirachtin based products effective in 2/4 trials.
AzaSol (azadirachtin)	6 oz/acre	-	4	1	See comment for AzaMax.
Azatrol-EC (azadirachtin)	0.19-0.96 fl	0	4	1	See comment for AzaMax.

Table 14.3 Pesticides for Management of Cabbage Looper					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
	oz/1000 ft^2				
Azera (azadirachtin, pyrethrins)	1-3.5 pts/acre	-	12	1	See comment for AzaMax.
Biobit HP *(Bacillus thuringinensis* subsp. Kurstaki)	0.5-1 lb/acre	0	4	1	Bt products effective in 6/7 trials.
BioLink (garlic juice)	0.5-2 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioLink Insect & Bird Repellant (garlic juice)	0.5-4 qt/acre	-	-	?	25(b) pesticide. Repellent.
Deliver (*Bacillus thuringine*nsis subsp. Kurstaki)	0.25-1.5 lb/acre	0	4	1	Bt products effective in 6/7 trials.
Dipel DF (*Bacillus thuringinensis* subsp. Kurstaki)	0.5-2 lb/acre	0	4	1	Bt products effective in 6/7 trials.
Ecotec (rosemary oil, Peppermint oil)	1-4 pts/acre	-	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME (azadirachtin)	15-30 oz/acre	0	4	1	Crops can be harvested as soon as spray has dried.Azadirachtin based products effective in 2/4 trials.Will not control adults.
Entrust (spinosad)	1-2 oz/acre	1	4	1	Spinosad products effective in 41/47 trials against caterpillar species including cabbage looper.
Entrust SC (spinosad)	3-6 fl.oz./acre	1	4	1	See comment for Entrust.
Envirepel 20 (garlic juice)	10-32 fl oz/A	-	-	?	25(b) pesticide. Repellent.
Garlic Barrier AG (garlic juice)	1-2% solution	-	-	?	25(b) pesticide. Repellent.
Grandevo (*Chromobacterium subtsugae* str. PRAA4-1)	1-3 lb/acre	0	4	?	
Javelin WG (*Bacillus thuringinensis* subsp. Kurstaki)	0.12-1.5 lb/acre	0	4	1	Bt products effective in 6/7 trials.
Molt-X (azadirachtin)	8 oz/acre	0	4	1	See comment for AzaMax.
Neemix 4.5 (azadirachtin)	7-16 fl oz/acre	0	4	1	See comment for AzaMax.
Omni Supreme Spray (mineral oil)	1-2 gal/acre	-	12	?	Use in combination with other insecticides registered for use on lettuce.
PureSpray Green (white mineral oil)	0.75-1.5 gal/acre	up to day	4	?	
PyGanic EC 1.4 II (pyrethrins)	16-64 fl oz/acre	until dry	12	?	
PyGanic EC 5.0 II (pyrethrins)	4.5-17 fl oz/acre	-	12	?	
Safer Brand #567 II (potassium laurate, pyrethrins)	6.4 oz/ gal of water applied at 1 gal mix/700 sq ft	until dry	12	?	
SuffOil-X (aliphatic petroleum solvent)	1-2 gal/100 gal water	up to day	4	?	Do not mix with sulfur products.

Table 14.3 Pesticides for Management of Cabbage Looper					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
TriTek (mineral oil)	1-2 gal/100 gal water	up to day	4	?	Apply as needed.
XenTari (Bacillus thuringiensis, var. aizawai)	0.5-1.5 lb/acre	0	4	1	Bt products effective in 6/7 trials.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.

Active ingredient meets EPA criteria for acute toxicity to bees

14.4 Tarnished Plant Bug, *Lygus lineolaris*

Time for concern: Throughout the season

Key characteristics: The tarnished plant bug (TPB) introduces a plant toxin while feeding that causes brown lesions along the midrib. After overwintering as adults in plant debris, they lay eggs in early spring which hatch in about a week and become adults in approximately 30 days. There are normally 3 generations per season, peaking from mid-June to mid-July. Feeding by the nymphs is the main source of damage. See Cornell fact sheet with photos (reference 78) and Ontario photo of damage to lettuce (reference 79).

Relative Risk: Brown spots on the mid-rib reduce marketability.

Management Options	Recommendations for Tarnished Plant Bug
Scouting/thresholds	Thresholds and scouting protocols have not been established for organic production.
Crop rotation	Crop rotation is not a useful management tool since TPB is very mobile and has many hosts including most legumes, flowering buckwheat, pigweed, brassicas, a number of plants in the Rosaceae family, and many more.
Weed control	Control weeds and keep headlands mowed to prevent TPB buildup.
Cultural controls	Row covers may raise temperatures too much to be useful for summer lettuce crops. TPB can harbor in cover crops, neighboring plantings, or weeds surrounding fields and, when mowed or harvested, will then move to lettuce fields. Legume cover crops, such as hairy vetch, can lure TPB out of lettuce fields or prevent them from entering. Managing TPBs requires an approach to limit their overall population and movement throughout the farm. Be aware of high populations that can quickly move from field to field. Consider strip cutting of crops harboring large populations of TPB.
Biological controls	Natural enemies of the TPB include the big-eyed bug (*Geocoris punctipes*), and various wasps (*Peristenus digoneutis*, *Leiophron uniformis, Anaphes ovijentatus*, and *Peristenus pallipes*). *Peristenus digoneutis* is non-native but is becoming established as a biological control in some areas. See reference 68 and 70 for more information on natural enemies.
Traps	Yellow and white sticky ribbons may reduce adult populations.
Note(s)	Most organic pesticides have not been effective against TPB.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 14.4 Pesticides for Management of Tarnished Plant Bug

Class of Compounds Product Name (Active Ingredient)	Product Rate	PHI[2] (Days)	REI (Hours)	Efficacy	Comments
AzaGuard (azadirachtin)	10-16 fl oz/acre	0	4	3	Apply with OMRI approved spray oil. Azadirachtin based products effective in 0/2 trials.
AzaMax (azadirachtin)	1.33 fl oz/1000 ft²	0	4	3	Azadirachtin based products effective in 0/2 trials.
AzaSol (azadirachtin)	6 oz/acre	-	4	3	See comment for AzaMax. Nymphs only.
Azatrol-EC (azadirachtin)	0.24-0.96 fl oz/1000 ft²	0	4	3	See comment for AzaMax.
Azera (azadirachtin, pyrethrins)	1-3.5 pts/acre	-	12	3	See comment for AzaMax.
BioLink (garlic juice)	0.5-2 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioLink Insect & Bird Repellant (garlic juice)	0.5-4 qt/acre	-	-	?	25(b) pesticide. Repellent.
Cedar Gard (cedar oil)	1 qt/acre	-	-	?	25(b) pesticide.
DES-X (insecticidal soap)	2% solution sprayed at 75-200 gallons/acre	1/2	12	?	
Ecotec (Rosemary oil, Peppermint oil)	1-4 pts/acre	-	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME (azadirachtin)	15-30 oz/acre	0	4	3	Crops can be harvested as soon as spray has dried. Will not control adults. Azadirachtin based products effective in 0/2 trials.
Molt-X (azadirachtin)	10 oz/acre	0	4	3	See comment for AzaMax.
M-Pede (insecticidal soap)	0.25-2% v/v solution	0	12	?	Spray material must contact pest to be effective. Activity of this product is directly related to the solution concentration and contact with the pest, not the amount of product applied per acre.
Omni Supreme Spray (mineral oil)	1-2 gal/acre	-	12	?	Use in combination with other insecticides registered for use on lettuce.
PFR-97 20% WDG (Isaria fumosorosea Apopka str. 97)	1-2 lb/acre	-	4	?	Repeat applications at 3-10 day intervals as needed to maintain control.
Preferal (Isaria fumosorosea Apopka str. 97)	1-2 lb/acre	-	4	?	
PyGanic EC 1.4 II (pyrethrins)	16-64 fl.oz./acre	until dry	12	3	Pyrethrin based products effective in 0/1 trial.
PyGanic EC 5.0 II (pyrethrins)	4.5-17 fl.oz./acre	-	12	3	Pyrethrin based products effective in 0/1 trial.

Table 14.4 Pesticides for Management of Tarnished Plant Bug					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2] (Days)**	**REI (Hours)**	**Efficacy**	**Comments**
Safer Brand #567 II (potassium laurate, pyrethrins)	6.4 oz/ gal of water applied at 1 gal mix/700 sq ft	until dry	12	?	
SuffOil-X (aliphatic petroleum solvent)	1-2 gal/100 gal water	up to day	4	?	Do not mix with sulfur products.
TriTek (mineral oil)	1-2 gal/100 gal water	up to day	4	?	Apply as needed.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
Active ingredient meets EPA criteria for acute toxicity to bees

15. SLUGS

Time for concern: Early spring and fall or when conditions are moist.

Key characteristics: Adult slugs are between one and two inches in length. Slugs can overwinter at any stage of development. Although slugs cannot survive prolonged subzero temperatures or desiccation, the burrows of small mammals and worms provide shelter. Slugs begin to move, hatch, feed, and lay eggs in the spring when temperatures are consistently above 40°F. There is often little or no slug activity in the field during periods of dry weather; however, there may be extensive feeding in damp areas or during wet years. Slug damage is often worse in fields where organic matter is decomposing. See Cornell fact sheet(reference 80).

Relative risk: Contamination by, and damage from, slugs in the marketable product is the biggest concern, although slugs can also injure young seedlings.

Management Options	Recommendations for Slugs
Scouting/thresholds	Scouting and thresholds for slugs have not been established for organic production.
Weed Control	Control weeds to deprive slugs of protected resting sites.
Cultural Controls	Practices that dry the soil surface (e.g. conventional tillage and weed control) will reduce slug populations. Fields with higher levels of decomposing organic matter are more prone to slug damage.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Pesticides for Management of Slugs					
Class of Compounds Product Name (Active Ingredient)	**Product Rate**	**PHI[2](Days)**	**REI (Hours)**	**Efficacy**	**Comments**
BioLink (garlic juice)	0.5-2 qt/acre	-	-	?	25(b) pesticide. Repellent.
BioLink Insect & Bird Repellant (garlic juice)	0.5-4 qt/acre	-	-	?	25(b) pesticide. Repellent.

Pesticides for Management of Slugs					
Bug-N-Sluggo (spinosad, iron phosphate)	20-44 lb/acre soil treatment	1	4	?	
Sluggo AG (iron phosphate)	24-44 lb/acre soil treatment	-	0	?	Scatter bait around perimeter of plantings to provide a barrier from entry. If slugs are inside the rows, scatter bait on the soil around and between the rows.
Sluggo Slug and Snail Bait (iron phosphate)	20-44 lb/acre soil treatment	0	0	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, X-product for use on lettuce, but efficacy not known. [2]Note that when the REI is longer than the PHI, Worker Protection Standard requirements may necessitate waiting until after REI to harvest.
Active ingredient meets EPA criteria for acute toxicity to bees

16. Pesticides and Abbreviations Mentioned in this Publication

Table 16.1 Insecticides and Molluscides

TRADE NAME	ACTIVE INGREDIENTS	EPA REG. NO.
Agree	*Bacillus thuringiensis subsp. aizawai str.*GC-91	70051-47
Aza-Direct	*azadirachtin*	71908-1-10163
AzaGuard	*azadirachtin*	70299-17
Azamax	*azadirachtin*	71908-1-81268
AzaSol	*azadirachtin*	81899-4
Azatrol EC	*azadirachtin*	2217-836
Azera	*azadirachtin, pyrethrins*	1021-1872
Biobit HP	*Bacillus thuringiensis subsp. kurstaki*	73049-54
BioLink Insect Repellant	*garlic juice*	Exempt - 25(b) pesticide
BioLink Insect & Bird Repellant	*garlic juice*	Exempt - 25(b) pesticide
BioRepel	*garlic oil*	Exempt - 25(b) pesticide
Bug-N-Sluggo Insect, Slug and Snail Bait	*iron phosphate and spinosad*	67702-24-70051
Cedar Gard	*cedar oil*	Exempt - 25(b) pesticide
Deliver	*Bacillus thuringiensis subsp. kurstaki*	70051-69
DES-X	*insecticidal soap*	67702-22-70051
DiPel DF	*Bacillus thuringiensis subsp. kurstaki*	73049-39
Ecotec	*rosemary and peppermint oil*	Exempt - 25(b) pesticide
Ecozin Plus	*azadirachtin*	5481-559
Entrust	*spinosad*	62719-282
Entrust SC	*spinosad*	62719-621
Envirepel 20	*garlic juice*	Exempt - 25(b) pesticide
GC-Mite	*cottonseed, clove and garlic oils*	Exempt - 25(b) pesticide
Garlic Barrier AG	*garlic juice*	Exempt - 25(b) pesticide
Glacial Spray Fluid	*mineral oil*	34704-849
Grandevo	*Chromobacterium subtsugae str. PRAA4-1*	84059-17
GrasRoots	*cinnamon oil*	Exempt - 25(b) pesticide
Javelin WG	*Bacillus thuringiensis subsp. kurstaki*	70051-66
M-Pede	*potassium salts of fatty acids*	10163-324
Molt-X	*azadirachtin*	68539-11
Neemix 4.5	*azadirachtin*	70051-9
Nuke Em	*citric acid*	Exempt - 25(b) pesticide
Oleotrol-I	*soybean oil*	Exempt - 25(b) pesticide
Omni Supreme Spray	*mineral oil*	5905-368

Table 16.1 Insecticides and Molluscides

TRADE NAME	ACTIVE INGREDIENTS	EPA REG. NO.
Organic JMS Stylet-Oil	*paraffinic oil*	65564-1
Organocide 3-in-1	*sesame oil*	Exempt - 25(b) pesticide
PFR-97 20% WDG	*Isaria fumosorosea Apopka str. 97*	70051-19
Preferal	*Isaria fumosorosea Apopka str. 97*	70051-19-67690
PureSpray Green	*petroleum oil*	69526-9
PyGanic EC 1.4$_{II}$	*pyrethrin*	1021-1771
PyGanic EC 5.0$_{II}$	*pyrethrin*	1021-1772
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentrate II	*pyrethrins + potassium salts of fatty acids*	59913-9
Sil-Matrix	*potassium silicate*	82100-1
Sluggo AG	*iron phosphate*	67702-3-54705
Sluggo Slug and Snail Bait	*iron phosphate*	67702-3-70051
SuffOil-X	*mineral oil*	48813-1-68539
Trilogy	*neem oil*	70051-2
TriTek	*mineral oil*	48813-1
XenTari	*Bacillus thuringiensis subsp. aizawai*	73049-40

Active ingredient meets EPA criteria for acute toxicity to bees

Table 16.2 Fungicides and Nematicides

TRADE NAME	ACTIVE INGREDIENTS	EPA REG. NO.
Actinovate AG	*Streptomyces lydicus WYEC 108*)	73314-1
Actinovate STP Fungicide	*Streptomyces lydicus WYEC 108*	73314-4
Agricure	*potassium bicarbonate*	70870-1
AzaGuard	*Azadirachtin*	70299-17
Badge X2	*copper oxychloride, copper hydroxide*	80289-12
Basic Copper 53	*basic copper sulfate*	45002-8
BIO-TAM	*Trichoderma asperellum, Trichoderma gamsii*	80289-9-69592
BIO-TAM 2.0	*Trichoderma asperellum, Trichoderma gamsii*	80289-9
ChampION++	*copper hydroxide*	55146-115
Contans WG	*Coniothyrium minitans*	72444-1
Cueva Fungicide Concentrate	*copper octanoate*	67702-2-70051
DiTera DF	*Myrothecium verrucaria str. AARC-0255*	73049-67
Double Nickel 55 Biofungicide	*Bacillus amyloliquefaciens str. D747*	70051-108
Double Nickel LC Biofungicide	*Bacillus amyloliquefaciens str. D747*	70051-107
Ecozin Plus	*azadirachtin*	5481-559
*GreenClean PRO	*sodium carbonate peroxyhydrate*	70299-15
MeloCon WG Biological Nematicide	*Paecilomyces lilacinus str. 251*	72444-2
MilStop	*potassium bicarbonate*	70870-1-68539
Mycostop Biofungicide	*Streptomyces griseoviridis*	64137-5
Mycostop Mix	*Streptomyces griseoviridis*	64137-9
Nordox 75 WG	*copper hydroxide*	48142-4
Nu-Cop 50DF	*cupric hydroxide*	45002-4
Nu-Cop 50 WP	*cupric hydroxide*	45002-7
Nu-Cop HB	*cupric hydroxide*	42750-132
Optiva	*Bacillus subtilis str. QST 713*	69592-26
Organic JMS Stylet Oil	*paraffinic oil*	65564-1
Organocide 3-in-1	*sesame oil*	Exempt – 25(b) pesticide
OxiDate 2.0	*hydrogen dioxide, peroxyacetic acid*	70299-12
PERpose Plus	*hydrogen peroxide/dioxide*	86729-1
Prestop Biofungicide	*Gliocladium catenulatum str. J1446*	64137-11
Regalia Biofungicide	*Reynoutria sachalinensis*	84059-3
RootShield WP	*Trichoderma harzianum Rifai str. KRL-AG2*	68539-7
RootShield PLUS+ WP	*Trichoderma harzianum str. T-22, Trichoderma*	68539-9

Table 16.2 Fungicides and Nematicides

TRADE NAME	ACTIVE INGREDIENTS	EPA REG. NO.
	virens str. G-41	
RootShield Granules	*Trichoderma harzianum str. T-22*	68539-3
RootShield PLUS+ Granules	*Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*	68539-10
Serenade ASO	*Bacillus subtilis* str QST 713	69592-12 and 264-1152
Serenade MAX	*Bacillus subtilis* str QST 713	69592-11 and 264-1151
Serenade Opti	*Bacillus subtilis* str. *QST 713*	264-1160
Serenade SOIL	*Bacillus subtilis* str QST 713	69592-12 and 264-1152
SoilGard	*Gliocladium virens*	70051-3
Taegro Biofungicide	*Bacillus subtilis var. amyloliquefaciens str. FZB24*	70127-5
Taegro ECO	*Bacillus subtilis var. amyloliquefaciens str. FZB24*	70127-5-100
TerraClean 5.0	*hydrogen dioxide, peroxyacetic acid*	70299-13
Trilogy	*neem oil*	70051-2

* Restricted-use pesticide in New York State; may be purchased and used only by certified applicators

Active ingredient meets EPA criteria for acute toxicity to bees

Table 13.4 Sanitizers mentioned in this publication

TRADE NAME	COMMON NAME	EPA REG. NO.
CDG Solution 3000	*chlorine dioxide*	75757-2
Enviroguard Sanitizer	*hydrogen peroxide/peroxyacetic acid*	63838-1-527
Oxine	*chlorine dioxide*	9804-1
Oxonia Active	*hydrogen peroxide/peroxyacetic acid*	1677-129
Peraclean 5	*hydrogen peroxide/peroxyacetic acid*	54289-3
Peraclean 15	*hydrogen peroxide/peroxyacetic acid*	54289-4
Perasan 'A'	*Peroxy acetic acid/hydrogen peroxide*	63838-1
Per-Ox	*Peroxy acetic acid/hydrogen peroxide*	833-4
Pro Oxine	*chlorine dioxide*	9804-9
SaniDate 5.0	*hydrogen peroxide/peroxyacetic acid*	70299-19
SaniDate 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18
San-I-King No. 451	*sodium hypochlorite*	2686-20001
Shield-Brite PAA 5.0	*Peroxy acetic acid/hydrogen peroxide*	70299-19-64864
Shield-Brite PAA 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18-64864
StorOx 2.0	*hydrogen peroxide/peroxyacetic acid*	70299-7
Tsunami 100	*hydrogen peroxide/peroxyacetic acid*	1677-164
Victory	*hydrogen peroxide/peroxyacetic acid*	1677-186
VigorOx 15 F & V	*hydrogen peroxide/peroxyacetic acid*	65402-3
VigorOx LS-15	*hydrogen peroxide/peroxyacetic acid*	65402-3

Abbreviations Used in This Publication

A	acre	NI	no information
ASO	aqueous suspension-organic	NOP	National Organic Program
EC	emulsifiable concentrate	OMRI	Organic Materials Review Institute
G	granular	P	phosphorus
HC	high concentrate	REI	restricted-entry interval
K	potassium	WP	wettable powder
L	liquid	WPS	Worker Protection Standard
N	nitrogen	WG, WDG	water dispersible granular

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Lettuce Production Systems in High Tunnels

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Because lettuce can be grown in high tunnels 12 months of the year in many locations throughout the U.S., lettuce is the number 2 crop grown in high tunnels in the U.S. There are several lettuce types and several hundred lettuce varieties that are commercially available for growers and differ by color, texture, maturity and head size. They include the following types; Romaine - green and red, Bibb – green, Oakleaf - green and red, Butterhead - green and red, Summer Crisp (Batavia) - green and red and Baby lettuce mixtures including mild mesclun mix, spicy greens mix, braising mix. Depending on the location of the high tunnel, maturity of the lettuce variety is very important for scheduling production and implementing marketing strategies. Lettuce types range in maturity from 42 to 58 days for full size heads. Baby lettuce types are ready from seeding to harvest in 28 to 30 days. Cooler air temperatures, below 40°F will slow growth of lettuce plants and increase time to maturity 7 to 10 days.

Environmental Requirements for Seeding Lettuce

Lettuce types are a hardy, cool season crop that can be grown in high tunnels 12 months of the year. Optimum growth occurs at temperatures between 60°F to 65°F. Seeds will germinate at soil temperatures as low as 40°F, but germinate very poorly at soil temperatures above 75°F. Successful and vigorous lettuce seed germination requires a firm seedbed and continuous soil moisture for germination.

Environmental Requirements for Lettuce Transplants

Seed lettuce in 128 or 200 cell trays with shallow placement in the soil (an optimum seeding depth of 0.25" deep) and cover with fine vermiculite. If temperature in the greenhouse or high tunnel exceeds 75°F during the day, place a shade cloth above trays to keep the soil cool and maintain active germination of the lettuce seeds. Prior to transplanting the lettuce transplants in the high tunnel, harden the transplants for 2 or 3 days by reducing water application to the transplants (but don't let the soil cube dry out) or reduce the air temperature for 2 to 3 days before planting in high tunnel. Hardened transplants can survive air temperatures as low as 20°F in high tunnels after transplanting in the spring or fall. There are several techniques available that growers can use to grow lettuce in high tunnels.

Conventional Production in soil after bed preparation in the high tunnel. Either direct seeding or transplants can be used too establish the lettuce crop. Recommend use of transplants when planting in September and October. In most cases, the crop would be maintained with drip irrigation applied during the growing season. With this particular production system, a very dense plant population of lettuce can be grown (6" x 8" spacing) that would reduce volunteer weed problems, but may increase insect and disease pressure. Lettuce plants should be monitored weekly for aphid or whitefly problems and control measures applied as necessary. Certainly cool, damp soil is ideal for the development of Botrytis Gray Mold and Sclerotinia Drop.

Annual Raised Beds with plastic mulch and drip irrigation. Using a bed forming implement that produces an 18" wide bed 3" to 4" tall and applying the black plastic

mulch and drip tape placed 2” beneath the soil surface has been used for many years in both field and high tunnel production. Most growers would establish the lettuce crops as transplants either in double rows with an in-row-spacing of 8”. The black plastic will help eliminate weeds in the row and reduce the incidence of both Botrytis Gray Mold and Sclerotinia Drop.

Permanent Raised Beds come in all sizes and orientation. Generally they are 12 “ in height, but can be shorter or taller based on individual growers’ needs. If common lumber is used to construct the raised bed, than 6-mil greenhouse plastic film can be used to line the sides and ends of the bed to prevent long term wood rot. Applying organic matter to the soil in the bed will eventually increase soil organic matter to 4.5% or higher value and increase the water holding capacity of the soil. If lettuce seeds or transplants are planted in the bed without a piece of polyethylene plastic film covering the surface of the raised bed, than both weed problems and Botrytis Gray Mold and Sclerotinia Drop infection may occur. Lettuce is generally watered with drip tape with this technique.

Non-Circulating Hydroponic System

Since June 1, 2007, Dr. Bernie Kratky from the University of Hawaii has been on sabbatical leave here at the Penn State Center for Plasticulture. One of Bernie’s objectives here at Penn State was the production of lettuce in a non-circulating hydroponic system. The two tanks for the hydroponic system were constructed in the high tunnel and lined with 6 mil greenhouse-grade plastic. Each tank was 50” x 24’ and 5" deep. When filled with water, each tank held 300 gallons of water. Blue, Styrofoam insulation board floats on top of the water and comes to rest on 2 plastic pipes supported by the tank floor when the nutrient solution level decreases as the crop grows. Holes are cut into the insulation board such that lettuce plants are spaced 8" x 12" – each tank will then grow 144 lettuce plants. Plastic net pots are filled with the lettuce transplants grown in soilless media and than placed into the holes cut into the Styrofoam board. Fertilizer is added to the water before the lettuce plants are placed into the Styrofoam boards and no additional water or fertilizer is added to the crop. Equal amounts of 2 stock nutrient solutions were added once per crop prior to transplanting such that the EC (electrical conductivity) of the nutrient solution in the raceways ranged between 1.5 to 2.0 mS. One nutrient stock solution consisted of 120 grams of soluble greenhouse grade calcium nitrate per liter of water, and the other stock solution consisted of a mixture of 72 grams of magnesium sulfate and 120 grams of Chem-Gro 8-15-36 Lettuce Formula (Hydro-Gardens, Colorado) per liter of water. The Chem-Gro formulation also contained micronutrients. Large batches of stock solutions (95 liters) were stored in 2 opaque plastic trash containers and mixed prior to use. One preparation of these stock solutions was more than adequate for these trials To date, Dr. Kratky has grown 4 lettuce crops that required 28 to 39 days from transplanting. Bibb, romaine and leafy lettuce types have been grown successfully in this hydroponic system without any disease problems and a minor insect problem – grasshoppers. At the High Tunnel Research and Education Center at Rock Springs, there must have been 100 grasshoppers per square yard at the peak of their population this summer, but screening the sides of the tunnel helped moderate the problem. This large grasshopper population ate everything from lettuce to cucumber and broccoli transplants. When harvested, the lettuce heads have averaged about 0.5 pounds in weight and were of excellent quality. There have been no incidence of diseases on the lettuce plants on either of the four plantings to date.

Winter Production?

While lettuce transplants can be placed in the soil as late as October, cooler day and night air temperatures, below 40°F will slow growth of lettuce plants and increase time to maturity by at least 7 to 10 days. While temperature may not totally restrict lettuce growth, the short days of November, December and January also reduce the amount of photosynthetic light required by lettuce plants for optimum growth and development. If a major investment in supplemental lighting is not made, than for all practical purposes, a high tunnel becomes a cold storage facility during November, December and January.

Figure 1. Mature lettuce crop on left and juvenile crop on right growing in non-circulating hydroponic system (B. Kratky, Univ. of Hawaii – 2007) and grown on Styrofoam insulation boards floating on the top of water.

Greens

NC STATE EXTENSION

Horticulture Information Leaflets

Introduction

Leafy greens, such as turnips, mustard, collards, kale, and spinach are cool season crops. They should be grown during early spring or fall for maximum yields and quality, but this season can be extended if desired. Kale and spinach can withstand temperature into the upper teens and are often harvested through winter in the east. The other greens may withstand medium frosts.

Soils

Greens may be grown on a variety of soils. Loams will generally produce the greatest yields but for early spring growth and overwintering, sandy loams are best. Soils should be well drained, rich in organic matter and thoroughly tilled. A pH of 6.0 to 6.5 is desirable for all of the greens except spinach, which thrives best in a soil pH 6.5 to 6.8.

Fertilizers

Leafy vegetables require quick, continuous growth for best quality. They especially need nitrogen for good color and tenderness. Follow soil test results.

Commercial Growers -- For the average soils, use 600 lb of 10-10-10 fertilizer per acre before planting. Sidedress with 15 to 30 lb of nitrogen per acre 3 to 5 times after seeding or transplanting.

Home Gardeners -- For the average soils, use 3 lb of 10-10-10 per 100 square feet before planting. Sidedress with 3 oz of 10-10-10 per 100 feet of row 3 to 5 times after seeding or transplanting.

Culture

Weeds must be controlled by cultivation or with chemicals. Shallow cultivation is a must. Use a rolling cultivator or bunting cultivator. Irrigation is essential, especially for the fall crop, since leafy vegetables require adequate moisture for continuous growth and high quality.

Insects

Cabbage worms, loopers, and aphids are major insect pests. Once aphids become established, they are difficult to control. A frequent program will be necessary throughout the production season. Insect problems are much worse in fall crops.

Harvesting

Harvest only healthy and well-formed plants, roots, or leaves. Remove all discolored or damaged leaves. When bunching, use rubber bands, tape, raffia, or similar material and make sure bunches are tied tightly and neatly. Wash thoroughly in clean water to remove sand and dirt.

Commercial Growers - If weather is warm, and hauling distance is over 50 miles, crushed ice should be used to retain quality. Greens have a high respiration rate, so decay of leaves may start immediately after harvest. Put crushed ice in the middle and on top of each crate. When packing loose in bulk, put crushed ice on top of the stack. In hauling to market use a closed truck or cover the load with a tarpaulin to prevent drying and wind damage.

Turnips

Grow Purple Top White Globe variety when roots and tops are desired. Grow Seven Top or Shoegoin for tops only. Plant rows 12 to 18 inches apart. Space plants ½- to 1-inch apart for tops, or 2 to 3 inches apart for roots. One to 1.5 lb of seed will plant one acre. Harvest turnips when tops are 4 to 8 inches high. Leaves may be cut above or below the crown and tied in 1 to 2 lb bunches or sold loose in bushel hampers. Pull roots when 2 inches in diameter and tie 4 to 6 uniform sized roots in a tight bunch.

Mustard

Grow Southern Giant Curled or Tendergreen (Mustard Spinach) varieties. Plant rows 12 to 30 inches apart, and plants 1 to 4 inches apart. One to 1.5 lb of seed will plant one acre. The whole plant may be cut off or the individual leaves may be harvested. Mustard is sold loose in hampers or tied in 1 to 2 lb bunches.

Collards and Kale

Grow the Vates, Morris Heading, or Carolina collard varieties and Winterbor or Toscano kale varieties. Spacing depends on how plants will be harvested. If seed is drilled in the row and the young collard plants are to be harvested, similar to turnip greens, the rows may be 12 to 18 inches apart and the plants 2 to 4 inches apart. If 'head collards' are grown, the rows should be 18 to 35 inches apart and plants set or thinned to 12 to 18 inches apart in the row. For transplants about 4 ounces of seed are required for each acre. About 2 lb is required per acre for direct seeding. For spring collards, do not use young plants that have been in the open field all winter because they will often go to seed very early. Seed may be planted in protected beds in late winter for transplanting in early spring; seeded in the row in late winter and either cut as young greens or thinned; seeded in the row in late spring to mid-summer to be either transplanted, thinned, or left just as they were seeded and cut for young greens.

Spinach

Grow Chesapeake, Hybrid #7, Tyee, Melody, or Old Dominion varieties. Rows should be 12 to 18 inches apart. Plants should be 1 to 4 inches apart, if young plants are to be harvested. If older plants are to be harvested, plant 3 to 6 inches apart. Ten to 12 lb of seed are required to seed one acre. Spinach may be harvested when 6 or more leaves have been formed. Cut the tap root with a knife or hoe just below the lower leaves for selling the entire plant. Cut ½ to 1 inch above the ground for loose leaves. Spinach may be sold loose in hampers, in bags, or in 1 to 2 lb bunches.

Specialty Greens

Arugula, cress, corn salad, New Zealand spinach, sorrel and specialty salad mixes all do well in North Carolina. One or more of those greens can be produced throughout the year. Try some of these greens to expand your culinary tastes.

Planting Dates for Greens

	Coastal Plain	Piedmont	Mountains
Spring	Feb. 1 - April 15	Feb. 15 - April 30	March 1
Fall	Aug. 1 - Sept. 15	July 15 - Sept. 15	Aug. 15

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SPRING MIX

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SPRING MIX

This production summary provides an overview of spring mix growing, harvesting, and post harvesting practices. There are some common practices that many large commercial growers use when producing spring mix, and though there are variations in these practices, having an understanding of the most common methods used will be helpful when carrying out regulatory activities.

By the end of this summary, you will be able to:

1. *List the types of leafy greens that may be included in spring mix.*
2. *List the top producing regions in the U.S. for spring mix.*
3. *Identify the most common farming practices used in the production of spring mix.*

INTRODUCTION

It may be surprising to learn that the term "spring mix" can be applied to a variety of different packaged salad products. It isn't always made up of the same mix of leafy greens but in general, it usually contains tender baby lettuce, spinach, and other edible leaves. Leafy greens that make up spring mix may include red and green romaine, red and green oak leaf, chard, arugula, spinach, endive, radicchio, and other heirloom lettuces.

Spring mix is primarily grown in California, Arizona, and Florida (Fig 1). In California, the largest production areas are located in the Salinas Valley including Monterey and San Benito counties. In Florida, the major spring mix production is located in the Everglades Agricultural Area in South Florida.

GROWING

Spring mix components have distinct temperature requirements. Optimal growing temperatures are 73°F during the day and 45°F at night. Freezing can damage the leaves of the young plants, leading to decay. Spring mix components grow best in silt loams and sandy soils. These types of soils provide better drainage during cold weather and warm up more readily during the day, which is especially important in cooler times of the growing season.

Prior to planting, the soil is typically amended to loosen clods and to improve the overall quality for root development. There are a number of different implements pulled by tractors to prepare a field for cultivation. Some are used to spread soil amendments, others to loosen and aerate the soil, and still others to form uniform and parallel raised beds.

Pre-irrigation water is applied to fields after beds are formed in preparation for planting using overhead sprinklers. Spring mix components are planted using pelleted seed in wide, raised beds that consist of 20 to 25 rows per bed. Commercial growers will often plant different greens in parallel rows.

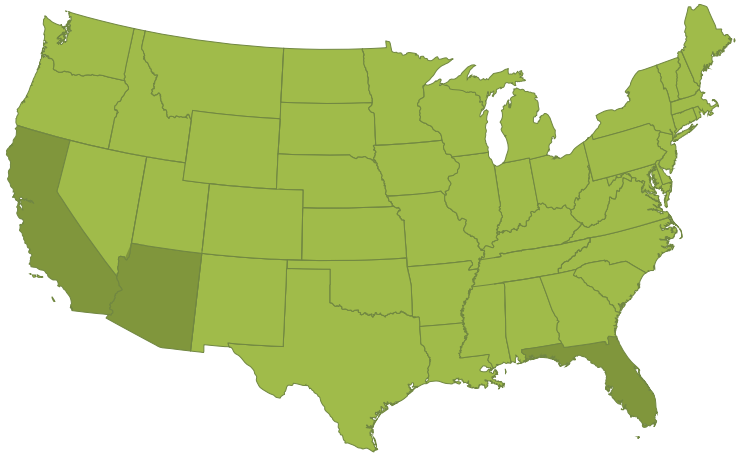

Fig 1 - Top Spring Mix Producing States in the US

In California and Arizona, spring mix is produced nearly all year round. Planting starts in January and continues through October. Harvesting begins in February and the last crops of the season are usually harvested by the end of November. In Florida, the summer months are too wet and hot for optimal growth of baby greens, so the production period runs September through April. The overlapping production timelines of California, Arizona, and Florida ensure the availability of spring mix year round for the U.S.

Commercial growers use chemical fertilizers or properly composted organic materials to provide nutrients to growing plants. Fertilizers can be added by injection into the soil, through the irrigation system, or added as a side dressing in the furrow that is distributed when it rains or during irrigation.

Weeds and insects can be a problem for leafy green growers. Several commercial herbicides and pesticides are available for use. These chemicals can be applied with tractors fitted with sprayers or injected into the irrigation system much like fertilizers. Growers use traps and bait stations to control rodents around lettuce fields.

HARVESTING

One or two days prior to harvest, the final irrigation is applied and the irrigation equipment is removed. Food safety checks are conducted each time a field, or section of a field, is harvested. Before workers or equipment enter the field, a food safety or field manager will walk the harvest area looking for signs of animal intrusion, pooling water, and foreign debris that may cause an area of a field to be flagged as non-harvestable.

Spring mix components are harvested mechanically at a very young age, before they reach five inches in height.

Commercial growers prefer to harvest baby spring mix components at night when temperatures are cooler, the air is still and there is less humidity which allows the greens to stand up making them easier to cut.

The mechanical harvesting equipment uses a horizontal saw blade that cuts the leaves at the base. The height of the blade is adjustable. The cut leaves are carried on a conveyor belt to an air gap, where heavier contaminants such as weeds or debris will fall through. The young spring mix leaves fall onto a secondary conveyor belt and are transferred into a bulk harvest bin.

PACKING

The totes and bins are transported from the field to a packinghouse where they are kept in a cooled warehouse at 34°F until they are processed. Some greens are grown with multiple lettuce varieties in the same bed and arrive at the packinghouse in totes already mixed and ready to be washed and packed.

Alternatively, some spring mix operations may mix the components at the packinghouse. Uniform batches of greens are mixed together using various conveyor systems. Depending on the size of the operation, the mixing may be automated or manual. All greens whether premixed at harvest or mixed at the packinghouse, are washed, dried, and packaged.

Boxes of packaged mix are held in refrigerated holding rooms at 34°F before being shipped to retail warehouses in temperature controlled trucks. As stated at the beginning of this production summary, there is no identity standard for "spring mix." Each company or customer may have their own special blend of ingredients consisting of various ratios of lettuce varieties.

CONCLUSION

Having a basic understanding of the way spring mix greens are grown, harvested, cooled, and prepared will provide the basic background information that will be helpful to regulators when completing inspections or investigations in the field.

The agricultural practices described in this production summary are common on most large commercial farms like those found in major spring mix producing regions in the United States. There are undoubtedly variations in these practices depending on the region, operation size, and individual grower preferences. This is especially true of farms outside of the U.S.

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Specialty Lettuce & Greens: Organic Production

Current Topic

By George Kuepper, Janet Bachmann, and
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January 2002

The terms "specialty" and "gourmet" mean different things to different people when applied to lettuce, and in some markets any high-quality lettuce that isn't an iceberg is a specialty crop. Specialty lettuces and "mesclun" (mixed baby lettuces and other greens) began receiving a lot of interest from both producers and consumers in the late 1980s. Consumer interest in salads generally, but especially in unusual or "new" salads such as mesclun, increased rapidly, and prices soared as demand outstripped supply.

Such high prices and rapidly growing markets always attract a lot of attention from growers seeking greater returns per acre, and the resulting increase in production eventually exerts downward

pressure on prices. Specialty lettuces are no exception to this phenomenon. For example, farmgate specialty-lettuce prices were roughly $16/lb. in 1992. In 1997, salad-mix prices had collapsed to $3/lb. at retail (1). In fall of 2001, *Growing for Market* reported "spring mix" greens wholesaling for slightly more than $3.80/lb. (2), which translates to roughly $4.95-$5.35 at the retail level.

It is also worth noting that a study by USDA-ERS (3) at the Boston wholesale market found that new growers attracted to mesclun expanded into both the organic and regular markets, depressing the organic premium. At the time of the study (1997), the average monthly organic premium was only 14%, though it varied from 8% in November to 22% in December. Industry insiders said that as long as there was a large supply of regular mesclun, organic prices would continue to stay low. The market appeared to bear only a very small premium for organic mesclun. But according to the authors of the study, organic mesclun producers could remain in the market even with organic prices approaching conventional, because variable production costs are not much higher than for

regular mesclun. Since the lettuce and greens are harvested while still small, they are not in the ground very long and are thus less susceptible to insect and disease problems than are most other organic crops (3).

Direct marketing may still allow farmers to receive premiums for organic mesclun and other specialty lettuces in markets where competition from wholesale supply is not as great.

Organic Production

Organic agriculture has now come under federal regulation. All growers wishing to label and market their produce as organic must become certified; only those small farmers who market less than $5,000 of organic products annually are exempt from this requirement. For more information on organic agriculture and the developing federal regulations, ask for ATTRA's *Overview of Organic Crop Production* and the *Organic Certification and National Organic Program* information package.

While federal regulation of organics is new, the essential nature of organic farming remains the same. Organic production still entails the growing of crops without synthetic pesticides or standard commercial fertilizers. Organic growers utilize a wide range of cultural practices and alternative inputs to manage crops in a manner believed to be safer for the environment and better for the consumer.

Specialty Mixes

While a mesclun mix may contain any mixture of lettuces, greens, and herbs, young leaf lettuces are normally the primary component. Leaf lettuces are generally tastier and less watery than head lettuce, while the variety of leaf shapes (smooth to crinkled edges) and colors (pale green to red) makes them attractive in leafy salads. Chefs like the texture of the leaves, which hold dressing well. Growers like these lettuces because they are generally the earliest maturing, are relatively trouble-free, and may resprout if cut young as a baby lettuce. Many "old fashioned" looseleaf lettuce cultivars are consequently making a comeback as specialty lettuces. Of particular note are the "oakleaf" types, with their attractive leaf shape and texture.

Apart from the standard iceberg-type lettuces, there are a number of lettuce "families" that may or may not be considered gourmet or specialty crops, depending on how wide a definition is used. The closer to the top of the following list a family is, the more "mainstream" it is, meaning that its price will usually be lower; the market for that type of lettuce, however, will be deeper than the market for types lower on the list. There are both green and red members of most of these families.

- Batavian lettuces are somewhat more open than icebergs, but form a distinct head nevertheless; they tend to be more flavorful than iceberg.
- Romaine types are upright and deep-colored, with a robust flavor and somewhat coarse texture.
- Bibb varieties are low-growing, tender, and sweet, forming a small, loose head as they approach maturity. Bibbs are sometimes called "Boston lettuce" or "Butter lettuce."
- Smooth-leaf lettuces are open-growing and tender, with generally pale leaves and delicate flavor when young.
- Crinkle-leaf sorts are similar to smooth-leaf lettuces except that their leaves are more "frilly" and their flavor is often slightly more pronounced.

- Unusual types have particular characteristics, such as a pronounced oakleaf shape, differentiating them from the other families.

Several non-lettuce species are also regarded as specialty greens and may be grown either alone (for very limited markets) or with an assortment of small lettuces. The major types of non-lettuces include:

- Arugula, a plant of the mustard family; when eaten the initial flavor is somewhat peanutty, followed by spicy-hot.
- Mâche, while well known in Europe, is uncommon in North America outside Québec. With a delicate nutty flavor, the mildest of any greens, mâche (also known as "corn salad") will get lost in almost any blend and is best sold alone.
- Sorrel is also well known in Europe, but is almost totally unfamiliar to consumers this side of the Atlantic. It is a tart cool-weather plant, most commonly used in potato-based soups.
- Chicory embodies a range of species, including radicchio, witloof (Belgian endive), and leafy chicories. All have a bitter flavor and very particular cultural requirements.
- Oriental greens include a number of pungent species, most of them in the mustard and chrysanthemum families. Some examples are mizuna, tatsoi, and red mustard.
- Unusual types encompass several species (dandelion, fennel, and so on) best known in their traditional ethnic markets. They are particularly useful for adding an accent to otherwise ordinary mixes.

Many of the cultural techniques for lettuce and salad-mix production are similar, regardless of whether the crop is grown in a greenhouse or in the field. Contact Cooperative Extension or seed suppliers for varietal recommendations specific to your growing region. Take note that organically grown seed is required for organic production. Conventionally-grown untreated seed is permitted only if its organic equivalent is not available. Fungicide-treated seed is completely prohibited. For assistance in locating seed sources, please ask for the ATTRA publication *Suppliers of Organic and/or Non-GE Seeds and Plants*.

Soil Preparation

Lettuce prefers a sandy-loam soil high in organic matter. Lettuce is sensitive to soil acidity; lime should be added, if necessary, to adjust the pH to 6.5-7.0. Lettuce is also sensitive to excess salts, especially at germination. If the previous crop was heavily fertilized, leaching the soil through heavy irrigation might be advisable. Field-grown lettuce, especially, requires good drainage to avoid certain fungal diseases such as bottom rot.

Certified organic production requires that fertility be managed without the use of conventional fertilizers. Some ATTRA publications that may be useful in this regard are *Sustainable Soil Management*, *Overview of Cover Crops and Green Manures*, *Sources for Organic Fertilizers and Amendments*, *Alternative Soil Amendments*, and *Manures for Organic Crop Production*.

Propagation

Lettuce production frequently entails transplanting. There are a variety of methods for raising transplants. Most growers prefer plug trays for seedling production. Since the potting mix does not have to be screened thoroughly, as blocking mixes do, commercially available organic potting-

soil products can be used. This saves the screening and mixing time necessary when making your own soil-blocking mix. Since many commercially-available potting mixes contain wetting agents and chemical fertilizers, be certain the product is organic before purchasing or consider making your own with approved ingredients. For more information, please request ATTRA's *Organic Potting Mixes*.

If a large percentage of the crop is sold as mesclun, "baby-lettuce," or salad mix, many growers will seed specialty lettuce directly and skip the transplanting stage—after all, the market crop is often no bigger than a robust transplant. Transplanting is a more realistic option in situations where the target market desires full-sized greens. Lettuce seed germinates better if left uncovered. Germination temperature should be between 15 and 18°C (60-65°F), with relative humidity around 70%.

Some small-scale producers have expressed a preference for soil blocks—ejection-molded cubes of specially prepared potting mix. If you choose to adopt this transplant production system, soil blockers are available through Johnny's Selected Seeds (4) and other sources.

Crop Scheduling

The primary challenge of specialty lettuce growing is to ensure a steady supply through the marketing season; careful planning and timing of planting dates is critical, and difficult to do well without considerable experience growing lettuces and similar greens.

If the plan is to maintain a continuous supply of lettuce throughout the growing season, it is necessary to follow a different planting schedule than one might expect. Lettuces, like most plants, grow and mature at varying rates during different seasons. In cooler temperatures, short days, and the low light levels of autumn and winter, it is especially challenging to maintain a reasonably steady supply. In summer, for lettuce in the field, it is the length and severity of the hot dry period of midsummer that becomes a problem. The maturity time (planting to harvest) will double or triple for plantings to be harvested from September through February, so fall planting dates should be adjusted accordingly. It may be desirable to harvest every week, but this does not necessarily mean that crops should be planted at seven-day intervals.

The following schedule, recommended by a greenhouse lettuce producer in Britain, provides an example of seeding intervals required to time weekly harvesting from early November through April (5). The seemingly conflicting intervals probably reflect adjustments for varying day length, which has an effect on the growth rate of winter greens (6).

September 1-10	sow every 3 1/2 days
September 10-18	sow every 2 days
September 18-October 10	sow every 3 1/2 days
October 10-November 15	sow every 7 days
November 15-December 15	sow every 10 days

Adapt this schedule to suit your local conditions. By keeping detailed planting and harvesting records over time, you can gradually develop a fine-tuned schedule that suits your farm location and mix of greens. Your state's Cooperative Extension vegetable specialist may also have a sowing schedule that can be adapted.

Dutch growers space lettuces at 15 to 20 plants per square yard. The growing period determines the actual density. A 12" x 12" spacing equates to approximately 16 plants per square yard, while

a 10" x 10" spacing is 20 plants per square yard. The tighter spacing is used in the slower growing period of winter. Equal spacing between plants and between rows produces more uniform heads.

For production on a small scale, a lawn roller, with studs attached at appropriate spacing, will both mark the correct spacing and punch transplant holes in the soil. It will save a lot of time, both at planting and at cultivation time. In general, lettuce plants held as seedlings for more than three to four weeks take a relatively long time to mature and don't produce good heads. Seedlings that might appear too young to transplant often grow very quickly and make beautiful heads. Considerable field experience suggests it is wise to transplant a small, healthy, hearty plant.

Deeper, less-frequent waterings are preferred to lighter, more-frequent irrigation. Spot watering may be necessary in places (such as the edges of beds) that dry out quickly. The crop should not suffer for water, but it is also important to keep the soil surface from being wet for long periods of time. This reduces disease pressure.

Summer Lettuce in the Midsouth

Lettuce is a cool-weather crop, and growing it in hot weather takes special care. In fact, some people insist it is impossible to grow good lettuce in the summer in the South. On the other hand, some people are doing it. Berryville, Arkansas market gardener Patrice Gros says his trick is to use 50% shade cloth. Since lettuce seeds do not germinate well at high temperatures, many summer growers either plant lettuce in flats in cooler rooms or pretreat the seed. Mr. Gros plants three times as much seed as usual to obtain the same number of plants. He also finds that variety selection is important. Some cultivars have been bred to perform better than others in hot weather. Plenty of water is crictical—he always waters his summer lettuces mid-day (7).

Pest Management: Insects

Luckily, lettuce is attacked by relatively few insect pests, primarily aphids and thrips. Both are fairly well controlled with an insecticidal soap, such as M-Pede™ brand (also sold to gardeners as the Safer™ brand). If the water is hard, the spray solution should be mixed with softened or distilled water because the calcium in hard water sequesters the fatty acids and greatly reduces the potency of the spray.

Young plants are sometimes subject to pressure from flea beetles. Arugula seems especially attractive to this pest. The most effective non-chemical control is a light row cover such as Agribon+™ AG-12 insect barrier, which can exclude most pests while providing a more sheltered microclimate. To learn about a wider range of control options, ask for ATTRA's *Flea Beetle: Organic Control Options* publication. For additional information about types and sources of row covers, see ATTRA's *Season Extension Techniques for Market Gardeners*.

Cutworms can also be a problem. If present in the soil, the best non-chemical approach may be to hunt them down (dig in the soil near affected plants) and crush them. Cutworms curl up when dug out of the soil. ATTRA provides additional information on control of cutworms in its *Organic Field Corn Production* publication.

Insect and disease pest problems in greenhouse production are similar to those of field production, yet unique because of the modified enclosed environment inside a greenhouse. Fortunately, great strides have been made in recent years in developing effective greenhouse IPM programs. European and Canadian researchers have developed the use of many control tactics for greenhouse pests.

Integrated pest management (IPM) programs monitor pest levels with such tools as pheromone traps, yellow sticky cards, and on-site examination of plants with a hand lens. Buildup of pest populations can be detected and treated before they reach injurious levels. Cultural methods may be altered to make the environment less favorable for particular pests. Physical barriers such as insect screens may be used to prevent some types of pests from entering a greenhouse. It is helpful to remove infested material from the greenhouse to physically reduce pest populations. Screening air intakes to the greenhouse is also effective—especially as a means to control thrips. Several natural predators can be obtained and released to reduce aphid and thrips numbers to acceptable levels. ATTRA has additional information on this subject in its *Integrated Pest Management for Greenhouse Crops* publication.

Pest Management: Diseases

While few diseases other than damping-off affect *young* lettuces and greens, older plants face more challenges. The limited number of fungicides and other disease control agents available to organic growers makes disease prevention crucial in organic production. The cool moist conditions typical of fall and spring production may encourage diseases in the field. *Sclerotinia* drop is caused by fungi that attack the lower leaves in contact with the soil, producing a cottony growth. Eventually the entire plant may "collapse," with the leaves dropping down on one another in succession. Bottom rot, caused by *Rhizoctonia* species, is another potentially serious soil-borne fungal disease of cool-season lettuce. It occurs on nearly mature plants, first appearing as slightly-sunken rust-colored lesions (plus or minus some amber ooze) of varying size. Affected plants will have a very short shelf life if harvested, and may decompose into a slimy black mass.

New biofungicides have been developed that can assist in disease management. An example is SoilGard™, a product of Thermo Trilogy, Inc. It contains the naturally-occurring fungus *Gliocadium virens*, which can be used to control disease-causing *Fusarium*, *Pythium*, *Rhizoctonia*, and *Sclerotinia* fungi. For more information on managing soil-borne pathogens, ask for the ATTRA publication *Sustainable Management of Soil-borne Plant Diseases*.

Foliar sprays of compost- and plant-extracts (e.g., horsetail, stinging nettle, valerian) are being tested for their use as fungal-disease suppressants. To test the disease-suppressive potential of compost watery extracts, researchers in Germany combined one part well-rotted manure-based compost to six parts water and let it sit for one week. It was then filtered and used as a spray. Applied every five to ten days, the extract prevented powdery mildew, downy mildew, late blight, botrytis blight, and anthracnose on tomatoes, beans, potatoes, grapes, and sugar beets. It was also effective in preventing damping-off diseases (8). ATTRA has additional information on this subject, if you are interested.

A disease (actually, "physiological disorder") of particular concern on lettuce is tipburn. Tipburn occurs when a sudden change in weather causes more rapid transpiration than water uptake. Symptoms include browning and rotting of the edges of internal leaves, which may not be visible from the outside of the head. This disorder is related to calcium deficiency and is aggravated by high soil fertility and high temperatures. On greenhouse lettuce it is particularly a problem during sunny early-spring days; in the field, it can be a problem if irrigation is mismanaged during hot

weather. Assurance of adequate calcium and avoidance of excess nitrogen and potassium will work to minimize problems. Minimal venting (thus decreased transpiration) during the critical period is also important for greenhouse-grown lettuces. Shading may also be used to reduce transpiration, as may watering by mist or spray as long as it doesn't compromise disease control. Acid soils and high soil salt content increase risk.

Pest Management: Weeds

Many greens crops are poor competitors with weeds. Additionally, weeds growing within rows can inadvertantly be harvested along with the crop and contaminate the product. As a result, considerable effort may be expended in cultivation and handweeding to assure a clean field.

Crop rotations that include careful selection of cover crops can go a long way in reducing weeds in vegetable crops. In some instances, the residues of cover crops are left in place and the crop is seeded or transplanted into it. The residue mulch conserves moisture, reduces erosion, and may suppress weeds through smothering (if the residue cover is dense) and through allelopathy. (Allelopathy refers to natural chemicals in some crop residues that suppress weed seed germination; rye straw is especially well noted for this characteristic.) The sensitivity of small-seeded crops like lettuce, however, may require extra pains in making such systems work well.

Nitrate Accumulation

If lettuces or other leafy greens are to be grown during periods of reduced light, there is a significant health risk associated with nitrate accumulation in the crop. See the enclosure on nitrate accumulation for further details.

Harvesting

Small-scale production usually entails laborious hand-cutting of greens using a sharp knife. In recent years, however, some small greens harvesters have come onto the market. Unfortunately, small-scale salad harvesting equipment is still a rather new phenomenon—especially in this country—and very little information has been published to date. A 1997 article by Byczynski (9) indicated that three different harvesters were on the U.S. market at that time. These were the Green Crop Harvester™, the Quick Cut Salad Harvester, and the Enha Pro. A production guide from Oregon State University (10) provides the following updated information on these machines:

- The Green Crop Harvester is made in England. The sole U.S. distributors are C. and K. Anderson, Fresh Herb Co., 4114 Oxford Rd., Longmont, CO. The cost is in the neighborhood of $20,000 for a four-foot-wide model which hold the greens upright by chain-driven sweeps and cuts the greens with a reciprocating knife (like a hedge trimmer).
- The Quick Cut harvester is an Italian battery-powered walk-behind machine with a 39", 48" or 54"-wide head and a band-saw cutter. Cost is approximately $11,000. The Quick Cut is sold by Ferrari Tractor CIE, P.O. Box 1045, Gridley, CA 95948; and by David Washburn and Meg Anderson of Red Cardinal Farm, 9694 75th St. North, Stillwater, MN 55082.
- The Enha Pro is a human-powered machine designed by Norbert Hufnagl, Field of Dreams, 117 Fredon Springdale Rd., Newton, NJ 07860. Cost is around $2,400 for a two-head unit and $3,000 for a three-head unit.

A fourth unit is the Ortomec™, sold by Sutton Ag Enterprises (11). The pull-type model sells for $25,465; the self-propelled model sells for $49,303.

Post-harvest Handling

While specialty lettuces command higher prices than ordinary iceberg, they also demand specialty handling. They should be immersed in near-freezing water almost immediately after harvest. Rapid removal of field heat is essential to maintaining product quality, and is a key element of professional handling. Depending on how the greens are cut, it may be helpful to pack any free leaves or smaller plants loosely into a mesh sack to keep them "corralled" during the hydro-cooling process. The University of Wisconsin has developed an excellent fact sheet on the use of mesh produce bags for this purpose (12).

Another critical (and demanding) component of handling is careful and thorough washing, followed by equally careful and thorough sorting. Greens are almost always eaten raw, and many consumers do not wish to go to the trouble of re-washing or picking through the evening's salad. Most professional lettuce growers will say that few things drive customers away faster than dirty, gritty, or poor-quality greens. Once the greens are well washed, gently drained dry, and ruthlessly graded, they should be packed into their final retail container (one that allows a bit of breathing), and returned immediately to a near-freezing high-humidity (95%) environment. They should be kept under those conditions until delivery to the retailer or the final consumer.

Commonly, greens are harvested from individual beds and are mixed after harvest. One mesclun grower advised extra care be taken at this stage since the tender leaves are very susceptible to bruising during the mixing process. He only mixes the greens as he bags them, after the washing and drying process.

After cutting, the salad greens need to be pre-washed and dried for best post-harvest quality. A restaurant- or industrial-scale salad spinner is an efficient machine for washing and drying the greens. These machines can be ordered through restaurant supply stores; prices range from $650 to $1,500. You could also order direct from a company in California that manufactures the "Greens Machine," available in five- and ten-gallon capacity models. Contact them at:

Dito Deans
4231 Pacific (#27)
Rockland, California, 95677
916-652-5824

In recent years, Johnny's Selected Seeds (3) has also been marketing salad spinners. Johnny's 2000 catalog featured a five-gallon unit that sold for $214.50. The 2001 catalog features a smaller spinner for $25.75.

Homemade greens spinners are not uncommon among small-scale producers. Jay Fulbright (13), a greenhouse mesclun grower in Arkansas, uses Kenmore extra-large-capacity washers (with the agitators removed) to spin-dry his salad mix. Prior to spinning, the ingredients are mixed in 100-gallon tanks, then transfered to a rinsing tank. Approximately 10 pounds of the loose mix is spun for about three minutes per load.

For additional information on post-harvest requirements for vegetables, ask for ATTRA's *Post-harvest Handling of Fruits & Vegetables* publication.

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1 Foss Hill Road
Albion, ME 04910-9731
207-437-4395
800-437-4290 Fax
http://www.johnnyseeds.com

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746 Vertin Ave.
Salinas, CA 93901
831-422-9693
831-422-4201 Fax

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http://www.ipgri.cgiar.org
Click on "Crops/Species" and read the document entitled "Rocket: A Mediterranean Crop for the World."

http://www.sfc.ucdavis.edu/cgi-bin/spec_crop.exe/
This website of the University of California Small Farm Center features several vegetable links, including Arugula, Radicchio, Endive, and Belgian Endive.

http://www.ces.ncsu.edu/depts/hort/hil/hil-11.html
This website of North Carolina State University has many useful links, including "Lettuce Production and Greens for Market."

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The electronic version of **Specialty Lettuce & Greens: Organic Production** is located at:
HTML
http://attra.ncat.org/attra-pub/lettuce.html
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What Are Microgreens?

— Written By Eli Snyder *Links to: /profile/eli-snyder/* and last updated by Tina Lovejoy *Links to: /profile/tina-lovejoy/*

Sprouts, microgreens, and baby greens are very young, tender plants, used as salads or garnishes on many types of dishes. Each of the names- sprouts, microgreens, and baby greens are all considered different products, as the plant is harvested for eating at different times. They add can add color, texture, and interesting flavors to meals. Microgreens in particular are gaining popularity among chefs and more farmers are growing them. These are easy to grow and sprouts and microgreens can be grown indoors at home.

Sprouts are the youngest of the three. They are exactly as the name describes—seeds that have just germinated. They may not have any green color to them. Typically, the entire plant is eaten including the shoots, the roots, and the seed, which may still be visible. Popular seeds for sprouting include mung beans, alfalfa, sunflower seeds, lentils, peas, mustards, and others. Sprouts can be grown in a simple sterilized jar, covered with a couple of inches of water, and then by a food grade cloth

The real key with sprouts is sanitation. There is risk of contamination with *Salmonella* and *E. coli*, which is often the result of contaminated seed. Commercial sprout operations must adhere to very strict sanitation standards but there have still been several outbreaks of illness from consuming commercial sprouts. Growing them at home does not mean they are safer since seeds are often the source of infection. Therefore it is very important to purchase seeds that are sold specifically for sprouting and that have been tested for the presence of microorganisms. Keep sprouts away from other food production areas and animals, and always wash hands thoroughly before setting up your sprouting operation.

Microgreens are the next size up from sprouts. The first green leaf-like structures to emerge on a seedling are called the cotyledons. The seedling has one or two cotyledons, and they are not typically the same shape as the leaves on the mature plant. The leaf-like cotyledons may also be different colors such as purple or red. Microgreens are harvested for eating when the first leaf after the cotyledons, or the first true leaf, emerges. Many

edible plants make excellent microgreens, including plants whose greens are not often consumed, such as carrots. Lettuces do not make good microgreens because they are too delicate. Common choices are broccoli, dill, basil, arugula, beets, and mustards, but there are many others. They each add a unique flavor and texture to any dish. The flavors are often similar to the mature version of the plant but tend to be more subtle.

Growing your own microgreens at home is easy. Microgreens are grown in soilless potting media, such as a peat moss-based mix with vermiculite or perlite. To grow your own, put potting media from ½" to 1" into a sterile tray with drainage holes. Broadcast seeds across the entire tray or plant in rows and gently press into the media. Some seeds benefit from having a thin layer of media placed on top and others do not need it. Some harder seeds, like beets, will germinate more easily if they are soaked in water before sowing. Keep the seeds moist with a misting system until they germinate. After germination, keep moisture in the media from below the tray, either with a solid tray that holds water or with a food grade burlap cloth located under the media. Avoid watering the microgreens directly because this can encourage disease to develop.

Because they grow in media, do not eat the root. Instead, harvest microgreens by cutting the plant above the soil line when they are approximately 1.5-2.5" tall. Use clean scissors to cut them and gently scoop the harvested handfuls into a clean receptacle. The different plants used for microgreens vary in time from planting to harvest, but typically the process takes 7-21 days. It is easiest to sow only one cultivar in a tray but if you would like variety, consider planting cultivars that germinate and reach harvest stage in the same amount of time.

Baby greens are the next size up. Plants used for baby greens are typically more familiar to us as greens- baby spinach, lettuces, kale, beet greens, and others. We only eat the leaves from baby greens and they are often used in salad or mesclun mixes. Unusual greens and herbs add different colors and flavors. Some to try might be

amaranth greens or chervil. These are also relatively easy to grow, though unlike most microgreens, may require some fertilizer to reach the ideal size and quality.

Next time you're out at a restaurant or farmers' market, look for microgreens and give them a try! If you like them, and enjoy growing things at home, consider growing a tray yourself, to add variety to winter cuisine. For more information on sprout safety and growing, see: https://www.clemson.edu/extension/food/food2market/factsheets/7-the-food-safety-of-sprouts-factsheets.html . For more information on growing microgreens, see: http://gardeningsolutions.ifas.ufl.edu/plants/edibles/vegetables/microgreens.html . With any other questions about growing food at home or gardening, contact the NC Cooperative Extension-Caldwell County Center at 828-757-1290.

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Center for Crop Diversification Crop Profile
CCD-CP-104

Microgreens

Cheryl Kaiser[1] and Matt Ernst[2]

Introduction

Microgreens are young, tender, edible crops that are harvested as seedlings. These tiny plants are grown to the first true leaf stage. They should not be confused with sprouts, which are germinated seeds lacking true leaves. Microgreens are sold as a raw product for use in salads, on sandwiches, and as a garnish.

Microgreens production requires a protected environment, such as a greenhouse or high tunnel. It is also possible to produce microgreens indoors under artificial lights. The short turnaround time and potentially high value of microgreens can seem attractive to producers; however, production is very labor-intensive.

Marketing

Although interest in microgreens has expanded since their introduction into high-end culinary establishments in the late 1990s, the main market continues to be restaurant chefs. Other direct market opportunities could include upscale or gourmet grocery stores, as well as health food stores.

Market Outlook

Microgreens, known in the past as vegetable confetti, increased in popularity after being introduced in haute cuisine around 2006. Many restaurants now routinely use microgreens as garnishes or flavorings, and consumers are more aware of microgreens as a highly nutritious food that can be grown hydroponically. Microgreens are also offered by some community supported agriculture farms and year-round farmers market vendors to extend the produce season. Some specialty grocers and health-food stores are interested in supplying microgreens to consumers, but the highly perishable nature of the crop can create substantial marketing challenges, particularly for inexperienced growers.

One possible marketing strategy for producers interested in growing microgreens is to work directly with a restaurant or chef, growing and delivering microgreens at the requests and preferences of the restaurateur. Microgreens are typically purchased and used by restaurants in small amounts, and the quick growing and harvest time may make this a more attractive crop for very small growers interested in developing nearby, high-end specialty markets for fresh produce. Regulations and food safety requirements may evolve and change for newer products like microgreens, and growers should check with state or federal agencies for any specific requirements or considerations.

Production Considerations

Crop selection

A large number of vegetable, herb and agronomic crops and crop varieties can be used for microgreen production. Lettuces may be too delicate, and are

CENTER FOR CROP DIVERSIFICATION
www.uky.edu/CCD

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often not considered good candidates for microgreens. Refer to Table 1, below, for a partial listing of potential crops.

Crop selection is often based on seedling color, texture, flavor and market demand. How quickly and easily the seed germinates should be another consideration for the producer. Growers may need to evaluate a number of crops, in consultation with end-user markets, before selecting the ones most suitable to their production system and market.

Table 1. Potential Microgreen Crops

Amaranth	Fennel
Arugula	Kale
Asian greens	Kohlrabi
Basil	Lemongrass
Beet	Mizuna
Broccoli	Mustard
Buckwheat	Nasturtium
Cabbage	Onion
Carrot	Parsley
Celery	Popcorn
Chives	Radish
Cilantro	Spinach
Collards	Sweet pea
Cress	Swiss chard
Dill	Tatsoi

Production site and planting

The delicate nature of microgreens requires that they be protected from rainfall and other environmental stresses; thus they need to be grown in a greenhouse, high tunnel, shade structure or indoors. These crops may be grown in conventional bench-top production or hydroponically. Growers should note that fertilizer is not needed for fast growing microgreens such as the brassicas. Fertilizer may be helpful for slower growing microgreens such as carrot, lemongrass and onion.

Plastic flats with drainage holes at the bottom are generally used for microgreen production. The trays are either lined with a sterile fiber-like seeding mat or partially filled with a peat-based soilless germinating media. Hydroponic producers may utilize aggregate culture with rockwool as the inert growing medium. Pesticide-free and highly viable seeds of the desired crop are broadcast densely over the media. Treated seeds may have elevated levels of chemical residue in the small seedlings and are discouraged. The optimum seed density is one that maximizes production space while avoiding stands so thick that stems become elongated and/or disease issues develop. Depending on the crop and production system, a light layer of growing media may be spread over the seeds. It is best to seed only one type or cultivar per flat; however, if more than one species will be seeded in the same flat, the crops should have similar germination rates so the whole flat can be harvested at the same time. Irrigation with overhead mist or an ebb and flow bench system is common. Well or county water should be used for irrigation as surface water sources, such as ponds, pose a disease and product contamination risk.

Pest management

The microgreen high density cropping system provides the ideal environment for the development of seedling diseases. These young tender plants are particularly vulnerable to Pythium and Phytophthora damping-off; however, Botrytis, Sclerotinia and Rhizoctonia diseases may pose a problem on some hosts. Sanitation, proper plant density for good air circulation, and good cultural practices will be necessary to prevent these diseases from gaining a foothold. In addition, the use of a sterile soilless media, which is required for success, should reduce any potential disease problems. Potential insect problems include aphids and thrips.

Harvest and storage

The time from seed to harvest varies between crop species; however, many seedlings will be ready for harvest in seven to 14 days. Microgreens are harvested at the first true-leaf stage; seedlings will be approximately 1½ to 2 inches tall. Only the stems with leaves attached are harvested; roots are left behind. Whether grown in a bench-top system or hydroponically, stems should be cut high enough above the growing media to prevent contamination of the harvested crop. Plants grown in soilless media are cut by hand just above the soil line using scissors. An electric knife or trimmer can be used to harvest microgreens grown on seeding mats. Mats are held vertically while the crop is “shaved” from the mat into a clean container.

Microgreens are highly perishable and need to be washed and cooled as soon after harvest as possible.

Food safety good handling practices should be followed. Microgreens are packaged into plastic clamshell containers for grocers. Often the entire tray is sent intact to a restaurant where the chef harvests the microgreens as needed. However, only those microgreens grown in a rockwool slab or growing mat (or something similar) could be marketed to restaurants in this manner since any sort of loose growing media would not be permitted in the food preparation area.

Labor requirements

Microgreen production is a highly labor-intensive endeavor. Labor will be needed for preparing growing trays, seeding and harvest. Because of the short crop turnaround and necessity of a continuous succession of plantings, labor needs will also be continuous. Labor requirements will vary considerably between production scale and systems. Harvest and handling are the most labor-intensive parts of microgreen production.

Economic Considerations

Initial investments include greenhouse or high tunnel construction, installation of an irrigation system, plus equipment purchases. Additional start-up costs include purchase of seed, flats, growing media and other inputs. Seed purchase costs may be significant for this enterprise.

Establishment costs for high tunnels and greenhouses can greatly vary and may be especially impacted by site preparation and equipment purchases. Establishing a high tunnel can cost around $1.50 per square foot, plus labor costs. Greenhouse establishment can range from $8 to $30 per square foot.

Harvest labor for microgreens will be greater than leaf lettuces grown under shelter due to more intensive harvest operations.

Because of the significant variations between microgreen market prices and production systems, a producer should estimate potential production costs based on their individual situation. Production budget templates for lettuce may be modified to individual microgreen production situations. Template budgets for high tunnel and greenhouse production are listed in the resources, below.

Producers able to market high-quality microgreens at $25 to $50 per pound are likely to generate positive economic returns from this crop under both high tunnel and greenhouse production systems.

Selected Resources

- High Tunnel Sample budgets and Spreadsheets (Cornell University) http://blogs.cornell.edu/hightunnels/economics/sample-budgets-spreadsheets/
- Hydroponic Crop Program Budgets (Ohio State University) http://u.osu.edu/greenhouse/hydroponic-crop-program-economic-budgets/
- Microgreens: A New Specialty Crop (University of Florida, 2016) http://edis.ifas.ufl.edu/hs1164

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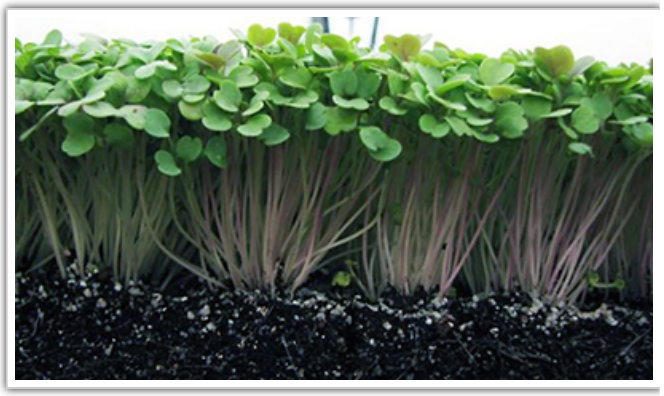
Microgreens



Microgreens are young, tender greens that people add to enhance the color, texture, and flavor of salads. These greens are harvested at the *cotyledon stage*, or just when the first true leaves emerge. The stem is snipped just above the soil and includes both the stems and leaves.

Microgreens are harvested when they are about 2 inches tall, including the stems and the leaves which are consumed as a whole. The flavor of microgreens is often more intense than when the same plants are harvested later for just their leaves. Microgreens are not the same as baby greens, which are larger, or sprouts, which are harvested earlier and contain the roots but not the true leaves.

Microgreens are sometimes called vegetable confetti; these tiny greens can sure add a lot of fun color and nutrients to any dish you prepare. They are great for use in soups, stews, salads, sandwiches, main dishes, and as garnishes. The kitchen window is an ideal place to grow them — you can keep a close eye on them and have them right where you need them when you're ready to use them.

Choosing Greens

There are dozens of crops to choose from for growing microgreens; between 80–100 different crop varieties have been reportedly used! You won't typically find lettuces used for microgreens though, as they are a bit too delicate and wilt easily.

Fast Growing Microgreens

Red cabbage, Chinese cabbage (Kogane), collards (Champion), cress (Cressida and Persian), hon tsai tai, kale (Red Russion and Tuscano), kohlrabi, mizuna, mustards (**except** Red Giant), pac choi (Rosie), radish, tatsoi

Slow Growing Microgreens

Anise, anise hyssop, amaranth (Garnet Red), arugula, basils, beets, carrots, chards, chervil, cilantro, cutting celery, dill, fennel, komatsuna, lemon balm, magenta spreen, marigold (Gem), mustard (Red Giant), orach (Ruby Red), pac choi (Red Pac), parsley, purslane (Red Gruner), salad burnet, scallion (Evergreen Hardy White), shungiku, saltwort, shiso (Britton)

Growing

Microgreens should be grown in a standard, sterile, loose, soilless, germinating media.

For growing microgreens use a container that is 2 to 3 ½ inches deep, food grade, and sterile. If you grow your microgreens in small trays, you'll need to harvest with scissors. Ideal media for germinating your seeds includes peat moss, coconut fibers, shredded sphagnum (all three hold water well), vermiculite (which holds water and is lightweight), perlite (which is light with great air flower and drainage) or a combination of any of the above. You can also use a commercial mix like Sungrow Fafard® Germination Mix, which is a very fine media with high water-holding capacity.

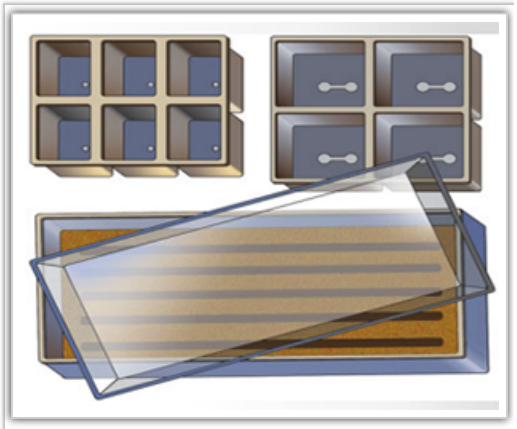
Start by filling your containers with moistened growing medium. You can broadcast or plant your seeds in rows. A general rule of thumb for growing microgreens is to plant 10–12 seeds per square inch if seeds are small and 6–8 seeds per square inch for large seeds.

Some seeds benefit from soaking before planting: beets (24 hours), cilantro (2 hours), buckwheat (12 hours – rinse and drain seeds twice daily for 2 days), peas (8–12 hours), sunflower (8 hours), nasturtium (8 hours), popcorn (8 hours), winter wheat (8 hours).

Seeds should be gently pressed into the surface. Some seeds benefit from being covered lightly with media or fine vermiculite; this optional step is more important for larger seeds. After you've gently pressed the seeds onto the surface of the media, mist them with water and then cover them. Seeds may need some warmth to germinate; the temperature needs vary between seeds.

Seeds that do not need a cover are broccoli, cabbage, lemon balm, mint, oregano, and thyme. Light cover works best for amaranth, arugula, basil, beets, chervil, dill, fennel, kale, mustard, pea, sage, shiso, sorrel, tatsoi, and wasabi. Cover is best for carrots, celery, Swiss chard, chive, cilantro, parsley, radish, sunflower, and watercress.

The time it takes a seed to germinate will vary between the crops. It also depends on the temperatures. Keep your trays covered and in a dark place for 4–5 days (or until seeds germinate). During this time, remove the cover and mist the seeds twice a day. The day after leaves emerge, remove the cover and move the tray to an area where it will get sunlight. Place your seeds in a south-facing window for best light and turn your container 180 degrees each day so that the entire tray gets sunlight.



Any container will work that is sterile and is 2 to 3½ inches deep; drainage is a plus.

The best time to harvest your microgreens is at night or in the morning. They should be cut with scissors or an electric knife just above the soil line. They can be washed and used fresh or stored in the refrigerator in a plastic container; they generally keep for 5–6 days in the fridge. For best storage results, store microgreens in a container that has air holes.

Depending on the crop, you may be able to get more than one more small harvest—however, the initial harvest is definitely the best. Once you are done you can mix the leftover soil and vegetables into your planting area or compost.

Sunflower microgreens

Special thanks to UF/IFAS expert Terry DelValle. For more information, check out her presentation "Growing Microgreens Can Be For Everyone,"

(http://conference.ifas.ufl.edu/gardener/presentations/1%201100%20DELVALLE%20grow%20your%20own%20microgreens.pdf) from the 2017 Master Gardener Conference (pdf).

UF/IFAS Publications

Microgreens: A New Specialty Crop (http://edis.ifas.ufl.edu/hs1164)

UF IFAS Extension UNIVERSITY of FLORIDA

HS1164

Microgreens: A New Specialty Crop[1]

Danielle D. Treadwell, Robert Hochmuth, Linda Landrum, and Wanda Laughlin[2]

Frequently called "vegetable confetti," microgreens are young, tender greens that are used to enhance the color, texture, or flavor of salads, or to garnish a wide variety of main dishes (Figures 1 and 2). Harvested at the first true leaf stage and sold with the stem, cotyledons (seed leaves), and first true leaves attached, they are among a variety of novel salad greens available on the market that are typically distinguished categorically by their size and age. Sprouts, microgreens, and baby greens are simply those greens harvested and consumed in an immature state. Based on size or age of salad crop categories, sprouts are the youngest and smallest, microgreens are slightly larger and older (usually 2 in. tall), and baby greens are the oldest and largest (usually 3–4 in. tall).

Figure 1. Microgreens in this photo are predominantly in the cotyledon stage and are a few days away from harvest.
Credits: UF/IFAS

Figure 2. Microgreens are often termed "vegetable confetti."
Credits: UF/IFAS

Both baby greens and microgreens lack any legal definition. The terms "baby greens" and "microgreens" are marketing terms used to describe their respective categories. Sprouts are germinated seeds and are typically consumed as an entire plant (root, seed, and shoot), depending on the species. For example, sprouts from almond, pumpkin, and peanut reportedly have a preferred flavor when harvested prior to root development. Sprouts are legally defined, and have additional regulations concerning their production and marketing due to their relatively high risk of microbial contamination compared to other greens. Growers interested in producing sprouts for sale need to be aware of the risks and precautions summarized in the FDA publication

1. This document is HS1164, one of a series of the Horticultural Sciences Department, UF/IFAS Extension. Original publication date April 2010. Revised July 2013. Reviewed October 2016. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Danielle D. Treadwell, associate professor, Horticultural Sciences Department; Robert Hochmuth, regional specialized Extension agent and center director; Linda Landrum, retired Extension agent IV; and Wanda Laughlin, greenhouse manager; UF/IFAS Suwannee Valley Agricultural Extension Center; UF/IFAS Extension, Gainesville, FL 32611.

Guidance for Industry: Reducing Microbial Food Safety Hazards for Sprouted Seeds (FDA 1999).

The crops used for microgreens usually do not include lettuces because they are too delicate and wilt easily. The kinds of crops that are selected for production and sale as microgreens have value in terms of color (like red or purple), unique textures, or distinct flavors. In fact, microgreens are often marketed as specialty mixes, such as "sweet," "mild," "colorful," or "spicy."

Certain crops of microgreens germinate easily and grow quickly. These include cabbage, beet, kale, kohlrabi, mizuna, mustard, radish, swiss chard, and amaranth. Soaking some seeds prior to sowing, such as beets, helps facilitate germination. As many as 80–100 crops and crop varieties have reportedly been used as microgreens (Figure 3). Others that have been used include carrot, cress, arugula, basil, onion, chive, broccoli, fennel, lemongrass, popcorn, buckwheat, spinach, sweet pea, and celery. Growers should evaluate various crop varieties to determine their value as microgreens. Many seed companies are very knowledgeable about the crops and varieties to grow, and a number of them offer organic seed.

Figure 3. A variety of crops can be grown and sold as microgreens. Credits: UF/IFAS

The commercial marketing of microgreens is mainly targeted toward restaurant chefs or upscale grocery stores. Prices for microgreens generally range from $30 to $50 per pound. The product is packaged in plastic clamshell containers that are typically 4–8 oz by weight but can be sold in 1 lb containers as well.

Production

Microgreens may be grown by individuals for home use. Growing small quantities at home is relatively easy; however, growing and marketing high-quality microgreens commercially is much more difficult. Having the right mix at the perfect stage for harvest is one of the most critical production strategies for success. The time from seeding to harvest varies greatly from crop to crop. When seeding a mixture of crops in a single planting flat, growers should select crops that have a similar growth rate so the entire flat can be harvested at once. Alternatively, growers can seed the various crops singularly and mix them after harvest.

Microgreens can be grown in a standard, sterile, loose, soilless germinating media. Many mixes have been used successfully with peat, vermiculite, perlite, coconut fiber, and others. Partially fill a tray with the media of choice to a depth of 1/2 in. to 1 or 2 in., depending on irrigation programs. Overhead mist irrigation is generally used only through the germination stage in these media systems. After germination, trays should be subirrigated to avoid excess moisture in the plant canopy.

An alternative production system uses one of several materials as a mat or lining to be placed in the bottom of a tray or longer trough. These materials are generally fiberlike and provide an excellent seeding bed. Materials may include burlap or a food-grade plastic specifically designed for microgreens such as those made by Sure to Grow (Beachwood, OH). These mat systems are often used in a commercially available production system using wide NFT-type troughs. The burlap mat may be sufficient alone for certain crops or may require a light topping with a media after seeding. Seeding may be done as a broadcast or in rows. Seeding density is difficult to recommend. Most growers indicate they want to seed as thickly as possible to maximize production, but not too thickly because crowding encourages elongated stems and increases the risk of disease. Most crops require little or no fertilizer, as the seed provides adequate nutrition for the young crop. Some longer-growing microgreen crops, such as micro carrot, dill, and celery, may benefit from a light fertilization applied to the tray bottom. Some of the faster-growing greens, such as mustard cress and chard, may also benefit from a light fertilization because they germinate quickly and exhaust their self-contained nutrient supply quickly. Light fertilization is best achieved by floating each tray of microgreens for 30 seconds in a prepared nutrient solution of approximately 80 ppm nitrogen.

Microgreens are ready for harvest when they reach the first true leaf stage, usually at about 2 in. tall. Time from seeding to harvest can vary greatly by crop from 7 to 21 days. Production in small trays will likely require harvesting with scissors. This is a very time-consuming part of the production cycle and is often mentioned by growers as a major drawback. The seeding mat type of production system has gained popularity with many growers because it facilitates faster harvesting. The mats can be picked up by hand and held vertically while an electric knife or trimmer is used for harvesting, allowing cut microgreens to fall from the mat into a clean harvest container. Harvested microgreens are highly perishable and should be washed and cooled as quickly as possible. Some chefs are asking growers to deliver in the trays or mats and they will cut the microgreens as needed to improve quality. Wash the microgreens using good handling practices for food safety. Microgreens are usually packed in small, plastic clamshell packages and cooled to recommended temperatures for the crops in the mix. Growers should be aware that marketing agreements such as the National Leafy Green Marketing Agreement (NLGMA) have been proposed to reduce the risk of microbial contamination of mature and immature leafy greens. For the current status of the NLGMA, visit http://www.nlgma.org/.

Reference

Food and Drug Administration. 1999. *Guidance for industry: Reducing microbial food safety hazards for sprouted seeds*. *http://www.fda.gov/food/guidanceregulation/ucm120244.htm* (October 2016)

What Are Microgreens?

— Written By Eli Snyder *Links to: /profile/eli-snyder/* and last updated by Tina Lovejoy *Links to: /profile/tina-lovejoy/*

Sprouts, microgreens, and baby greens are very young, tender plants, used as salads or garnishes on many types of dishes. Each of the names- sprouts, microgreens, and baby greens are all considered different products, as the plant is harvested for eating at different times. They add can add color, texture, and interesting flavors to meals. Microgreens in particular are gaining popularity among chefs and more farmers are growing them. These are easy to grow and sprouts and microgreens can be grown indoors at home.

Sprouts are the youngest of the three. They are exactly as the name describes—seeds that have just germinated. They may not have any green color to them. Typically, the entire plant is eaten including the shoots, the roots, and the seed, which may still be visible. Popular seeds for sprouting include mung beans, alfalfa, sunflower seeds, lentils, peas, mustards, and others. Sprouts can be grown in a simple sterilized jar, covered with a couple of inches of water, and then by a food grade cloth

The real key with sprouts is sanitation. There is risk of contamination with *Salmonella* and *E. coli*, which is often the result of contaminated seed. Commercial sprout operations must adhere to very strict sanitation standards but there have still been several outbreaks of illness from consuming commercial sprouts. Growing them at home does not mean they are safer since seeds are often the source of infection. Therefore it is very important to purchase seeds that are sold specifically for sprouting and that have been tested

for the presence of microorganisms. Keep sprouts away from other food production areas and animals, and always wash hands thoroughly before setting up your sprouting operation.

Microgreens are the next size up from sprouts. The first green leaf-like structures to emerge on a seedling are called the cotyledons. The seedling has one or two cotyledons, and they are not typically the same shape as the leaves on the mature plant. The leaf-like cotyledons may also be different colors such as purple or red. Microgreens are harvested for eating when the first leaf after the cotyledons, or the first true leaf, emerges. Many edible plants make excellent microgreens, including plants whose greens are not often consumed, such as carrots. Lettuces do not make good microgreens because they are too delicate. Common choices are broccoli, dill, basil, arugula, beets, and mustards, but there are many others. They each add a unique flavor and texture to any dish. The flavors are often similar to the mature version of the plant but tend to be more subtle.

Growing your own microgreens at home is easy. Microgreens are grown in soilless potting media, such as a peat moss-based mix with vermiculite or perlite. To grow your own, put potting media from ½" to 1" into a sterile tray with drainage holes. Broadcast seeds across the entire tray or plant in rows and gently press into the media. Some seeds benefit from having a thin layer of media placed on top and others do not need it. Some harder seeds, like beets, will germinate more easily if they are soaked in water before sowing. Keep the seeds moist with a misting system until they germinate. After germination, keep moisture in the media from below the tray, either with a solid tray that holds water or with a food grade burlap cloth located under the media. Avoid watering the microgreens directly because this can encourage disease to develop.

Because they grow in media, do not eat the root. Instead, harvest microgreens by cutting the plant above the soil line when they are approximately 1.5-2.5" tall. Use clean scissors to cut them and gently scoop the harvested handfuls into a clean receptacle. The different plants used for microgreens vary in time from planting to harvest, but typically the process takes 7-21 days. It is easiest to sow only one cultivar in a tray but if you would like variety, consider planting cultivars that germinate and reach harvest stage in the same amount of time.

Baby greens are the next size up. Plants used for baby greens are typically more familiar to us as greens- baby spinach, lettuces, kale, beet greens, and others. We only eat the leaves from baby greens and they are often used in salad or mesclun mixes. Unusual greens and herbs add different colors and flavors. Some to try might be amaranth greens or chervil. These are also relatively easy to grow, though unlike most microgreens, may require some fertilizer to reach the ideal size and quality.

Next time you're out at a restaurant or farmers' market, look for microgreens and give them a try! If you like them, and enjoy growing things at home, consider growing a tray yourself, to add variety to winter cuisine. For more information on sprout safety and growing, see: https://www.clemson.edu/extension/food/food2market/factsheets/7-the-food-safety-of-sprouts-factsheets.html . For more information on growing microgreens, see: http://gardeningsolutions.ifas.ufl.edu/plants/edibles/vegetables/microgreens.html . With any other questions about growing food at home or gardening, contact the NC Cooperative Extension-Caldwell County Center at 828-757-1290.

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RPD No. 915
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VEGETABLE SEED TREATMENT

Treatment of vegetable seeds to kill disease-causing organisms (pathogens) carried within or on the seed has repeatedly been shown to prevent plant disease epidemics (epiphytotics). Chemical seed treatments also protect the seed or seedling from the common soil-inhabiting fungi that cause seed rots and damping-off diseases. When seed is planted in cold wet soil or is slow to germinate, it may be necessary to treat seed in order to obtain satisfactory plant stands. Seed treatment can be useful in reducing the amount of pesticide required to manage a disease, because an effective seed treatment can eliminate the need to make foliar applications of fungicides or bactericides later in the season. This reduction in pesticide use is both economically and environmentally beneficial. Treatments may disinfect (kill pathogens borne within the seed), disinfest (kill externally born pathogens), or protect the seed.

SEED DISINFECTION

The purpose of seed disinfection is to eradicate seed-infecting pathogens from the seed coat, the embryo, or both. If properly used, hot-water soaks will kill most seedborne fungi and bacteria without killing the seed. Seed lots of poor quality or lots more than one year old may not germinate well after hot-water treatment. Therefore, a small sample of each seed lot should be treated and tested for germination before the entire lot is treated. The water temperature must be carefully controlled, since a slight reduction in temperature may result in a failure to kill the fungi or bacteria, and a slight increase may result in severe seed injury. It is generally best to purchase seed that has been hot water treated by a commercial seed company. However, the following procedures should be strictly followed when commercially treated seed is not available or desirable.

1. Prewarm seed in a loosely woven cotton bag for 10 minutes in water at 100°F. Fill the treatment bag no more than half full and gently squeeze it during this soak to eliminate all air pockets and to make sure all seeds are wetted.

2. Place prewarmed seed in a water bath (5 to 10 times the volume of seed to be treated) that will hold the water at the recommended temperatures (Table 2). **The time and temperature of treatment must be exact.**

3. Immediately after the required treatment time has elapsed, place the sacks in cold water for a few minutes.

4. Spread the seeds out to dry. Old screens make excellent drying racks.

5. Apply a protective seed treatment.

For further information contact Mohammad Babadoost, Extension Specialist in Fruit and Vegetable Pathology, Department of Crop Sciences, University of Illinois at Urbana-Champaign. (Phone: 217-333-1523; email: babadoos@uiuc.edu)

Crop	Water temperature (°F)	Time (minutes)
Broccoli	122	20-25
Brussels Sprout	122	25
Cabbage	122	25
Carrot	122	15-20
Cauliflower	122	20
Celery	122	25
Chinese Cabbage	122	20
Collard	122	20
Coriander	127	30
Cress	122	15
Cucumber	122	20
Eggplant	122	25
Garlic	120	20
Kale, Kohlrabi	122	20
Lettuce	118	30
Mint	112	10
Mustard	122	15
New Zealand Spinach	120	60-120
Onion (sets)	115	60
Pepper	125	30
Rape, Rutabaga	122	20
Shallot	115	60
Spinach	122	25
Sweetpotato (roots)	115	65
(cuttings, sprouts)	120	10
Tomato	122	25
Turnip	122	20
Yam (tubers)	112	30

Note: Other kinds of seed may be injured by hot water treatment or may not benefit from it.

SEED DISINFESTATION

The purpose of seed disinfestation is to kill pathogens living on the surface of the seed. Fungicides and bactericides, such as streptomycin, can be used. Some bacterial pathogens that are carried on the seed surface, such as those causing bacterial spot on pepper and tomato and bacterial canker on tomato, can be eliminated by dipping the seed in a solution of 1.0 quart household bleach (5.25 to 5.45 percent sodium hypochlorite) and 3 quarts of water for 1 to 2 minutes. Use 1 gallon of solution per pound of seed.

Bleach soaks are also used to free asparagus seed from the Fusarium wilt and root rot fungus. Seed in a cheesecloth bag should be continuously agitated for 40 minutes to a solution containing 1.0 pint of liquid household bleach (5.25 to 5.45 percent sodium hypochlorite) and 8.0 pints of water. Use 1 gallon of solution per pound of seed.

Transmission of tobacco mosaic virus on pepper and tomato seed can be eliminated or reduced by soaking seeds in a solution of a trisodium phosphate. Use 1 pound of trisodium phosphate per gallon of water; soak seed for 30 minutes, rinse, and dry before treating with household bleach.

After the seed is treated using bleach or trisodium phosphate, it should be air-dried and treated with a protectant fungicide such as captan.

SEED PROTECTION

The purpose of seed protection is to prevent seed rots and damping-off caused by soil-inhabiting fungi. Fungicides such as thiram, captan, etridiazole, metalaxyl, chloroneb, maneb, mancozeb, and PCNB are commonly used as seed protectants. Specific recommendations are given in Table 2.

Pretreated seed is available from most vegetable seed supply houses. Be certain to read the label carefully to determine what, if any, treatment has been used. Many growers combine both a fungicide and an insecticide in a seed treatment. Current insecticide recommendations, label precautions, and a compatibility chart should be consulted before combining a fungicide and an insecticide.

TREATMENT METHODS

Seed treatment chemicals, used in seed disinfestation or protection, may be applied by either the dust method or the slurry method.

Dust Method

Place the seed and fungicide in a closed container (Mason jar or drum) and agitate vigorously for several minutes until the seed is uniformly coated with dust. Best results are obtained when the container is twice the volume of the seed to be treated.

Slurry Method

Add enough water to a wettable powdery formulation of the selected fungicide to make a sloppy paste. Place the seed in the slurry and stir or swirl until the seeds are thoroughly coated. Dry the seed before planting. Precaution: Remember that 1 to 3 ounces of seed protectant are sufficient to treat an entire bushel of seed. Do not overdose.

All seed-treatment chemicals are poisonous to man and animals when taken internally, and some may cause mild to severe skin irritation if allowed to accumulate. Avoid inhaling the dusts or fumes. Treat seed outdoors or in a well-ventilated room. Wear protective clothing, eye wear, rubber gloves, and a respirator to reduce the risk of exposure. After treatment or at frequent intervals, wash exposed skin with soap and water.

Carefully mark treated seed and **do not use** it for feed, food, or oil purposes. Keep seed-treatment chemicals in a locked cabinet in their original containers. Make sure that containers used for treated seed are thoroughly cleaned before they are reused as seed bags–never use such bags for feed or food. Follow the manufacturer's directions given on the container regarding concentration, dosage, mixing, and other handling precautions.

Please note: label registrations can change at any time. Thus, information provided in this publication may become invalid. The user is encouraged to read carefully the entire, most recent label and follow all directions and restrictions.

Table 2. Seed Treatment, Materials, and Disease Control for Vegetable Crops

Crop	Chemical & method[a]	Disease controlled, remarks
Asparagus Seed	bleach soak	Bleach soak controls Fusarium wilt
Crowns	captan D mancozeb D	Mancozeb controls crown rots
Bean[b]	captan D, S, PB chloroneb S,PB etridiazole and PCNB D,S,PB[c] metalaxyl S PCNB D,S streptomycin S thiram D,S	Seed rot, damping-off, Pythium and Rhizoctonia root rot. Streptomycin is partially effective in eliminating surface contamination by the halo blight organism. PCNB can be used for better protection against *Rhizoctonia*. Metalaxyl will provide optimal control of *Pythium*.
Beet	captan D,S thiram D,S	Seed rot, damping-off, black rot (seedling stage). Application of Solubor may reduce damping-off if boron is deficient.
Carrot	hot water soak, followed by thiram D,S	Hot water soak controls seedborne bacterial blight. Thiram controls seed rot and damping-off.
Corn (Pop and sweet)	captan D,S metalaxyl S thiram D,S,[a] carboxin S,PB	Most of these products control seed rot and damping-off. Metalaxyl controls only *Pythium*.

Table 2. Seed Treatment, Materials, and Disease Control for Vegetable Crops (Cont)

Crop	Chemical & method[a]	Disease controlled, remarks
Crucifers[b] (cabbage, broccoli, brussels sprouts, cauliflower, collards, kale, kohlrabi, mustard, radish, turnip)	hot water soak, followed by captan D,S thiram D,S	Hot water soak controls seedborne black rot, blackleg, downy mildew, anthracnose, and Alternaria leaf spot and blight. Fungicides control seed rot and damping-off.
Eggplant	hot water soak, followed by captan, D,S thiram D,S	Hot water soak controls seedborne Phomopsis blight and Collectotrichum fruit rot. Thiram controls seed rot and damping-off.
Endive	thiram D,S	Seed rot, damping-off
Garlic (cloves)	PCNB D,S	White rot
Okra	metalaxyl S thiram D,S	Seed rot, damping-off
Onion	thiram D,S, pelleted with methocel sticker	Seed rot, damping-off, smut.
Pea	captan D,S,PB etridiazole and PCNB M,PB metalaxyl S PCNB M,D,S thiram D,S	Seed rot, damping-off. Give partial control of Ascochyta and Mycosphaerella blights.
Pepper[b]	hot water soak or bleach soak, followed by captan D,S thiram D,S	Soaks control seedborne anthracnose and bacterial spot. Fungicides control seed rot and damping-off.

Table 2. Seed Treatment, Materials, and Disease Control for Vegetable Crops (Cont)

Crop	Chemical & method[a]	Disease controlled, remarks
Potato[b]	captan D maneb D mancozeb D, dip thiophanate methyl and fir bark, D	Fusarium or seed piece rots or decays
	Streptomycin, D	Blackleg (bacterial)
Spinach	hot water soak, followed by captan D,S thiram D,S	Soak controls seedborne downy mildew and anthracnose. Fungicides control seed rot and damping-off.
Sweet potato	Botran dip Thiabendazole dip	Black rot, stem rot, scurf
Swiss chard[b]	captan D,S thiram D,S	Seed rot, damping-off, leaf spot.
Tomato	hot water soak, followed by captan S, thiram D,S, or mancozeb S	Soak controls seedborne bacterial spot, anthracnose, and Phoma rot. Fungicides control seed rots and damping-off.
	trisodium phosphate soak, followed by captan S, thiram D,S, or mancozeb S	Soak controls seedborne tobacco mosaic virus. Fungicides control seed rots and damping-off.
	trisodium phosphate and bleach soak, followed by captan S, thiram D,S, or mancozeb S	Soaks control seedborne tobacco mosaic virus, anthracnose, and bacterial spot. Fungicides control seed rots and damping-off.
Vine crops (cantaloupe, cucumber, pumpkin, squash, watermelon)	captan D,S,PB thiram D,S	Seed rot, damping-off, seedborne *Fusarium*, foot rot of squash, black rot.

Table 2. Seed Treatment, Materials, and Disease Control for Vegetable Crops (Cont)

Crop	Chemical & method[a]	Disease controlled, remarks
(Other melons)	Seed rot, damping-off.	captan D,S

[a]D = Dust; S = Slurry; PB = Planter Box; M = Machine.
[b]Obtain certified disease-free seed or seed grown in the semi-arid areas of the western United States.
[c]Field, kidney, snap, and lima beans.
[d]Sweet corn only

Captan is sold as Gustafson Captan 30DD, 300, 400, 400-D, and Captan 75 Seed Protectant.

Carboxin is sold as Vitavax and Vitavax 34 and in combination with PCNB as Vitavax-PCNB.

Chloroneb is sold as Chloroneb 65W.

Etridiazol is sold as Terrazole 35%. It is sold in combination with PCNB as Gustafson Terracoat L-205N, Terraclor Super-X 20-5 Dust, and Terracoat 5D 205 Seed Dust Fungicide.

Maneb is sold as Maneb 80.

Metalaxyl is sold as Apron Dry, Apron FL, and Apron 25W. It is also sold in combination with PCNB as Apron-terrachlore.

Thiabendazole is sold as Mertect 340F.

Mancozeb is sold as Manzate 200, Dithane M-45, and Penncozeb.

PCNB is sold as Terraclor 10G and 75% WP Dust.

Streptomycin is sold as Agri-strep, Agrimycin 17, and Streptomycin 17.

Thiram is sold as Chipco Thiram 75, Gustafson Thiram-30 Fungicide, 50WP, and 42-S.

Thiophanate methyl plus fir bark is sold as TOPS 2.5D.

OKLAHOMA COOPERATIVE EXTENSION SERVICE [EPP-7666]

Diseases of Leafy Crucifer Vegetables (collards, kale, mustard, turnips)

February 2017

Vegetable crops in the crucifer family, grown for their edible leaves include collards, kale, mustard, turnips, and turnip x mustard hybrids. These cool-season crops are well adapted for spring and fall production in Oklahoma. While most of the production is for processing, both processing and fresh markets demand high-quality produce free of blemishes. Diseases are important factors limiting the production of leafy greens. Diseases mainly cause damage by reducing crop quality. Severe disease development can reduce quality to the point where the crop is unmarketable.

Agents (pathogens) that cause the most common diseases of leafy greens are molds (fungi) and bacteria, but diseases caused by viruses and nematodes also can be a problem. This Fact Sheet is intended to aid growers in identifying these diseases and to provide general guidelines for managing them. Accurate identification of a disease is critical to an effective management program. For example, use of a fungicide to control a leaf spot disease will not be effective if the pathogen is a bacteria. Some diseases can routinely be identified in the field with a little experience. For diseases that are difficult to identify in the field, consider submitting samples through local Extension offices to the OSU Plant Disease Diagnostic Laboratory. Consult Fact Sheet
EPP-7612, *Plant Disease and Insect Diagnostic Services*, for recommended procedures in taking and submitting good samples. Because registrations of pesticides for disease management change from year to year, consult the latest edition of the *Extension Agent's Handbook for Insect, Plant Disease, and Weed Control* (Extension Circular E-832).

Strategies for Disease Management

Diseases are best managed by minimizing pathogen populations and/or slowing the increase of disease during the growing season. Integrated pest management (IPM) refers to the use of several different management strategies within a crop management system and the judicious use of pesticides where needed. Better, more economical pest control is achieved when IPM is practiced, compared to reliance on a single management strategy such as pesticide application. Disease management strategies that are effective components of IPM programs are listed below. Many of these strategies help prevent diseases from becoming established.

Crop rotation – Fungi, bacteria, and nematodes that cause root and foliar diseases persist in soil or crop debris in the soil. These pathogens build to damaging levels with repeated cropping of crucifer crops. Crop rotation is effective where crops in the crucifer family (also includes cabbage, cauliflower, broccoli, radish, etc.) are avoided for at least two years. Rotations with corn, grain sorghum, or another summer grass crops particularly are beneficial for reducing levels of root-knot nematodes.

Site selection and preparation – Selecting well-drained soils and forming raised beds helps avoid damping-off, root rot, and wilt diseases promoted by water-logged soils. Preparing a good seed bed promotes rapid seedbed germination and seedling growth. Acid soils should be avoided or corrected with lime. Maintaining records on the disease history of fields helps avoid disease problems and the timely use of control measures.

Seed health – Seed contamination, particularly for bacterial diseases such as black rot, is an important means of introducing diseases into non-infested fields. Purchasing high-quality seed from reputable sources helps ensure that seed is pathogen-free. Many seed companies produce seed in dry climates where disease pressure is low and implement quality control programs to minimize the chances for seed contamination. Some seed companies directly test crucifer seed for the presence of the black rot bacterium. Seed lots passing the test are certified black-rot free. Questionable seed lots should soaked in hot water for 20 minutes at exactly 122°F.

Sanitation – Foliar diseases can be spread by equipment and workers moving in and between fields. Soil clinging to equipment and boots is a means of introducing pathogens such as nematodes into clean fields. Equipment and boots should be cleaned when moving from infested fields to clean fields. Clean fields also can be worked before entering infested fields. Fields should not be worked when leaves are wet to limit disease spread.

Irrigation – In sprinkler irrigation, excessive irrigation, or frequent irrigations with small amounts of water favors spread and development of many diseases and should be avoided. Water should be applied during periods when foliage dries rapidly.

Weed control – Weeds in and around fields may harbor viruses and bacteria. For example, common weeds in the crucifer family such as swinecress and Virginia pepperweed are known to harbor black rot bacteria. Practicing good weed control minimizes chances of disease carryover and spread.

Scouting – Crops should regularly be inspected (at least once a week) for symptoms and signs of diseases and other pests. Scouting permits the early detection of pest problems so timely management practices can be implemented.

Chemical control – Fungicide sprays may be needed for effective management of diseases caused by fungi. Copper compounds are used to reduce diseases caused by bacteria as well as fungi. Fungicides and copper sprays help prevent healthy plants from becoming infected, but cannot cure plants already diseased. Therefore, applications should be made before symptoms appear where disease is anticipated or shortly after the disease is first detected. Because fungicides degrade over time, repeated applications on a seven to 14-day schedule typically are required to maintain protection. Sprays should be applied before anticipated

rains rather than after, since protection is afforded during wet periods that favor infection. Sprays should be applied in a sufficient volume to achieve thorough plant coverage. The number of fungicides registered for use on leafy greens is limited; therefore it is critical to use IPM strategies along with chemical control.

Seed and soil-applied fungicides also are used to manage soilborne diseases. Seed treatments are recommended to help prevent damping-off of seedlings. Soil-applied fungicide is pre-plant incorporated, applied to the seed furrow, or banded over the row and watered in. Soil-applied fungicide provides additional damping-off control, and may help reduce root-rot diseases.

Residue management – Since many pathogens survive in and on crop debris, crop residue should be incorporated by disking or plowing soon after harvest to promote rapid decomposition.

Soilborne Diseases

Damping-off (*Fusarium, Rhizoctonia,* and *Pythium* spp.)

Damping-off is a term used to describe the different phases of seed and seedling disease. Several fungi that commonly inhabit agricultural soils may contribute to damping-off problems within a single field. Damage results from reduced plant stand, which in severe cases results in reduced yield or the added expense of replanting. Damping-off is favored by poor drainage, compacted soil, and soil crusting. Most species of *Pythium* are active when soil is cold while *Rhizoctonia* prefers warm soil temperatures. Plants beyond the third or fourth leaf stage are no longer susceptible.

Symptoms – Failure of seedlings to emerge from the soil, as a result of seed or seedling decay, is called pre-emergence damping-off. The collapse and sudden death of emerged seedlings is called seedling blight or post-emergence damping-off. Roots and lower stems of emerged seedlings become soft and watery, and may be reddish-brown in color. Seedlings die when roots are completely decayed or stems are girdled.

Control – A good seedbed, free of crop debris, should be prepared in a well-drained site. A registered, fungicide seed treatment should be applied or pre-treated seed should be purchased. If possible, avoid planting in cold soils (below 55°F).

Root-knot (*Meloidogyne* spp.)

Root-knot is caused by several species of nematodes, which are microscopic roundworms that live in soil and feed on plant roots. Crucifers are susceptible to all root-knot species. In Oklahoma, both northern and southern root-knot nematodes are present and both cause damage to vegetable crops in isolated fields. Where nematode populations are high, yield loss results from poor plant growth. Nematodes are most severe on sandy, well-drained soils. Fortunately, nematodes are most active during the summer when these crops are not grown.

Symptoms – Affected plants are pale green to yellow, stunted, and may occur in patches along rows or in circular areas. Roots of affected plants show the characteristic galls or swellings caused by nematode feeding. The southern root-knot nematode causes large galls that may be up to a half-inch thick, while galls caused by the northern root-knot nematode are finer in appearance.

Control – Crop rotation with grass crops for at least two years effectively reduces nematode populations below damaging levels. Rotations with other broadleaf vegetable crops should be avoided, since most are susceptible to root-knot. Soil should be tested for nematodes prior to planting in fields with a history of nematode problems to ensure that the populations are below damaging levels. See OSU Extension Fact Sheet EPP-7610 for more information on sampling procedures for nematodes.

Bacterial Leaf Diseases

Bacterial diseases have been important foliar diseases of leafy greens in Oklahoma. Bacterial diseases are serious, since they spread rapidly and cause direct damage to the marketed portion of the crop. In addition, chemical controls are not very effective. While the causes and symptoms of each disease are different, management programs are similar.

Black rot (*Xanthomonas campestris* pv. *campestris*)

Black rot is a widespread and destructive disease of crucifer crops in Oklahoma. Entire fields can be destroyed when conditions are favorable for disease development. The disease is caused by a bacterium that survives on seed, weedy crucifers, and crop debris in infested fields. Extended periods of warm and wet weather favor rapid spread and infection. Therefore, black rot is most severe in the spring production season as temperatures warm. The disease is spread rapidly by splashing and running water, insects, and workers or equipment moving through fields. Infection primarily occurs through the hydathodes, which are natural openings at the leaf margins, during periods of prolonged dew or rainy weather. If infected plants survive to harvest, leaves with symptoms are not marketable.

Symptoms – Plants at any stage of development are susceptible. Seedlings from infected seed die quickly and serve as sources of the bacteria that infect other plants. On true leaves, the disease is easily recognized by the presence of yellow V-shaped lesions extending inward from the leaf margins (Figure 1). The center of the lesion dries out and turns brown, and veins within the lesion appear blackened. The lesions extend into the leaf, killing large areas of affected leaves. Older leaves with lesions may develop numerous black, oval spots on the petioles and soon drop from the plant. Cutting into stems and petioles of severely affected plants reveals a black discoloration of the vascular system.

Figure 1. Kale with V-shaped lesions at the leaf margin caused by black rot.

Xanthomonas leaf spot (*Xanthomonas campestris* pv. *armoraciae*)

Xanthomonas leaf spot is caused by a bacterium nearly identical to the one causing black rot, except that it causes leaf spot and does not invade the vascular system. Xanthomonas leaf spot, along with bacterial leaf spot, have been important causes of poor quality of leafy greens in recent years. When leaf spotting is widespread and severe, greens may not be suitable for harvest. Turnips, kale, and collards are very susceptible while mustard and turnip x mustard hybrids are less severely affected. Sources of bacteria and conditions favoring infection and disease development are the same as those for black rot.

Symptoms – Numerous small, circular, leaf spots (lesions) appear scattered over leaves. Lesions are about 1/8-inch in diameter, tan to dark brown in color and are often surrounded by a yellow border (Figure 2). Spots often appear oily or water-soaked on the undersides of leaves. Where numerous, spots coalesce and turn large areas of leaves yellow. (Figure 3) Spots later dry and turn papery brown. Severely diseased leaves may develop numerous black, oval spots on the petioles.

Figure 2. Kale leaf with Xanthomonas leaf spot.

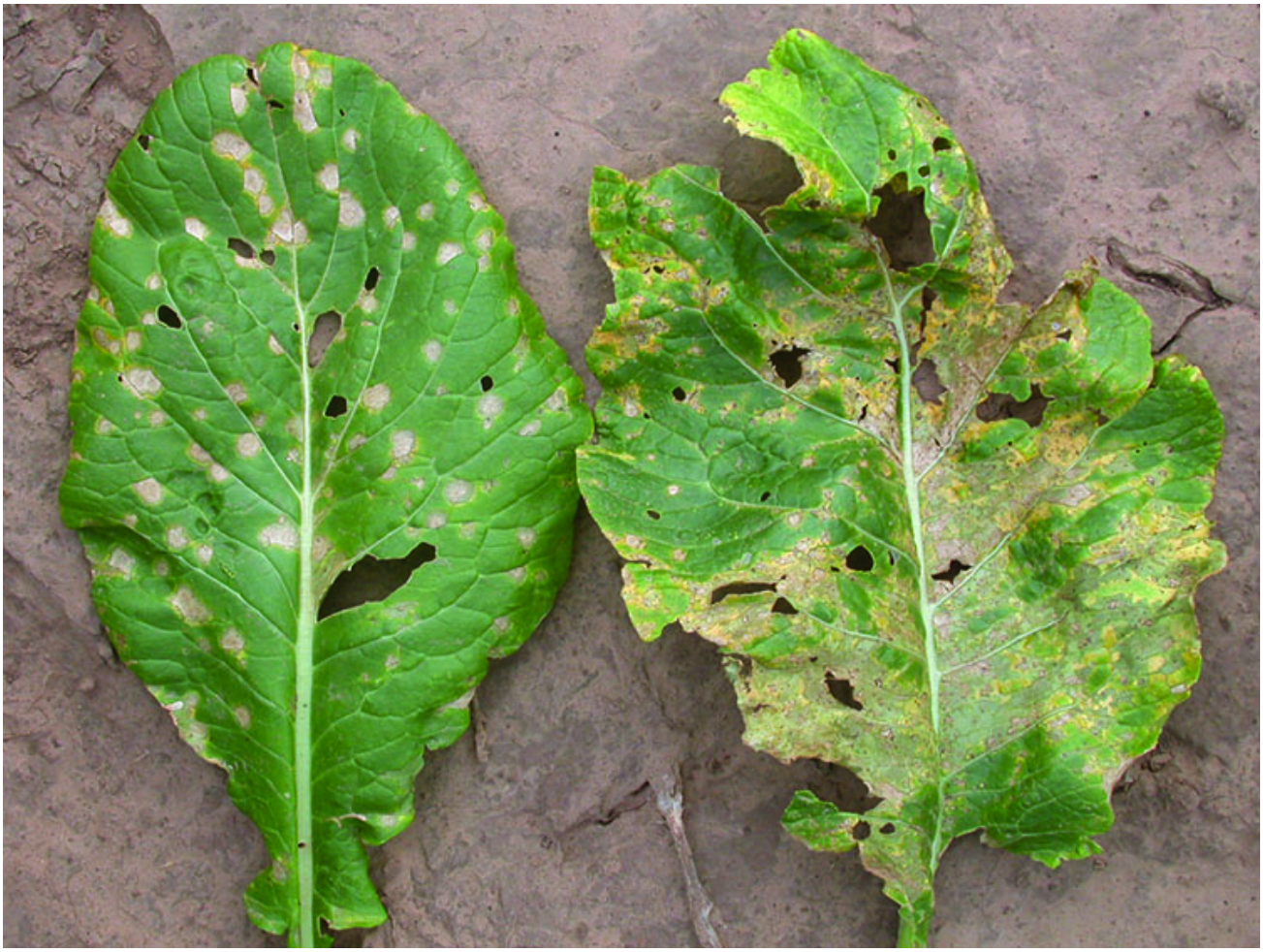

Figure 3. Turnip leaves with white spot caused by the fungus Cercospora (left) and Xanthomonas leaf spot caused by bacteria (right).

Bacterial leaf spot (*Pseudomonas syringae* pv. *maculicola*)

This leaf spot disease resembles Xanthomonas leaf spot caused, and has commonly been found in fields severely infested with bacterial diseases. Bacterial leaf spot is favored by cooler temperatures than black rot and Xanthomonas leaf spot, and is likely to be a problem in the fall and early spring.

Symptoms – Leaf spots are at first small, circular to angular in shape, grey to light brown in color, and appear oily or water-soaked on the lower leaf surface (Figure 4). Bacterial leaf spots typically lacks the pronounced yellow border that surrounds spots caused by Xanthomonas leaf spot. Spots expand, coalesce into irregular shapes, turn light brown in color, and may advance along leaf veins (Figure 5). Severely infected leaves dry and become brittle as they are killed.

Figure 4. Underside of turnip leaf with bacterial leaf spot.

Figure 5. Upper side of turnip leaf with bacterial leaf spot.

Control – Control of bacterial diseases is effective only when the pathogen(s) are excluded from fields. Once bacterial pathogens are present in a field, control will be impossible under conditions favorable for infection. Purchase seed that has been tested and certified to be free of black-rot bacteria or hot-water treat seed as previously described. Because the bacterium that causes Xanthomonas leaf spot is closely related to the one that causes black rot, seed testing procedures for black rot also will detect this bacterium. However, seed testing procedures for bacterial leaf spot have not been developed. Plant seed in fields that have not been planted to crucifer crops for at least two years so that residue from previous crops is completely decomposed. Manage old crop residue to hasten its decomposition because the bacteria survive best on the soil surface and are poor soil competitors. Control of wild crucifers that may harbor bacteria in and around fields may reduce disease. Fields should not be worked while plants are wet because the bacteria are efficiently spread by mechanical means. While crucifers grown for production of leafy greens are usually direct seeded; nearby gardens, transplanted fields, and diseased fields also can serve as sources of the bacterium.

Foliar Diseases Caused by Fungi

Leaf spotting diseases are caused by several different fungi that attack one or more of the leafy greens crops grown in Oklahoma. These diseases are important because they have a direct effect on the quality of the harvested leaves. Even slight damage reduces marketability. The relative importance of each disease and their symptoms is described separately for each disease. However, management practices for disease control are similar.

White leaf spot (*Cercospora* or *Cercosporella* spp.)

Leaf spot diseases caused by these two fungi are similar in their symptoms, biology, and damage. *Cercospora* has been more frequent in recent years, but both are probably present. White spot is most severe on turnip, mustard, and turnip x mustard hybrids. The disease is less important on collards and kale. The fungi persist on infested crop residue and possibly wild crucifer weeds. Spores from debris, weeds, or neighboring fields become airborne and are blown to new fields. The disease has been most severe in the fall production season, but can occur whenever prolonged leaf wetness occurs at temperatures of 55 to 65°F.

Symptoms – Circular white spots ranging in size from 1/4 to 1/2-inch in diameter are scattered over leaves (Figure 4). As the spots age, they may develop darkened borders (Figure 6). Severely affected leaves turn yellow, become dry, and wither, while remaining attached to the plant.

Figure 6. White spot on turnip leaf producing circular spots with dark borders and leaf yellowing.

Black leaf spot (*Alternaria brassicae*)

Black leaf spot is less common than white leaf spot in Oklahoma, but it can be a problem on turnips and collards. The fungus can be carried on seed, but also persists in infested crop debris and alternate weed hosts. Spores of the fungus are spread mainly by wind and splashing rain. At least nine continuous hours of dew or rain are required for infection. Optimum temperatures for infection range from 75 to 82°F.

Symptoms – Leaf spots are circular, brown, and may develop a target-like appearance with dark brown to black circles within the circles (Figure 7). Spots, which may expand up to one inch in diameter, are more frequent on older leaves.

Figure 7. Black spot on turnip leaf.

Anthracnose (*Colletotrichum higginsianum*)

Anthracnose occurs in Oklahoma, but is less common than white spot. The disease is most severe on turnip, but can also attack kale, collard, mustard, and turnip x mustard. The fungus persists in infested crop residue and crucifer weeds but also may be carried on seed. Warm (79 to 86°F), wet weather favors infection and disease development.

Symptoms – Leaf spots are small, dry, circular, and pale gray to straw colored (Figure 8). Darker colored areas within the older spots are reproductive structures of the fungus. Severely infected leaves are killed. Spots on petioles are elongated, sunken, grey to brown, and have a dark black border.

Figure 8. Anthacnose on turnip x mustard leaf.

Downy mildew (*Peronospora parasitica*)

Downy mildew is caused by a fungus closely related to the one that causes white rust. The disease occurs sporadically in Oklahoma, but is potentially destructive. The fungus persists in fields as resistant spores embedded in old crucifer roots and tops. The fungus grows to seedlings where it produces wind-blown spores that infect other plants or new fields during prolonged periods of wet weather when temperatures are cool (below 75°F).

Symptoms – The disease can attack plants at any stage of development. Downy mildew first appears as a white to grey mildew mostly found on the undersides of leaves (Figure 9). Yellow areas later develop on the corresponding upper sides (Figure 10). Infected areas enlarge and their centers turn tan to light brown in color and papery in texture. When the disease is severe, entire leaves turn yellow and die.

Figure 9. White mildew on lower side of turnip leaf caused by downy mildew. (Photo courtesy S.C. Bost, University of Tennessee)

Figure 10. Yellow leaf spots on upper side of turnip leaf caused by downy mildew. (Photo courtesy S.C. Bost, University of Tennessee)**White rust** (*Albugo candida*)

White rust is a chronic disease problem for spinach production in Oklahoma. White rust of crucifers, which is caused by a different species of the white rust fungus, has not been severe in Oklahoma, but has been reported. The fungus persists in soil as resistant spores that can survive for many years and initiate disease cycles. Thereafter, disease increases from airborne spores that spread within and between fields. Cool (60 to 77°F) and wet weather is favors infection.

Symptoms – Yellow spots occur on the upper surface of infected leaves. Numerous small, white, blister-like pustules are scattered on the undersides of leaves (Figure 11). The pustules, which contain spores of the fungus, appear as a white chalky dust. Severely affected leaves may become distorted.

Figure 11. White rust on mustard leaves. (Photo courtesy J.D. Gay, University of Georgia)

Control – Cultural practices help prevent foliar diseases from becoming established in a crop. Incorporate crop residue soon after harvest to hasten its decomposition and reduce pathogen survival. Practice crop rotation with non-crucifer crops for at least two years. These cultural practices reduce pathogen populations and delay initial infections. Prepare a well-drained seed bed that is free of plant residues. Plant high-quality seed produced in dry climates and treated with a fungicide to reduce the likelihood of introducing disease on seed. Seed testing procedures are not available for fungal diseases. Therefore, seed treatment with

a fungicide is recommended. Control weeds in and around fields, particularly wild crucifers, which may harbor fungal diseases. Leaf spot diseases may develop during periods favorable for infection in spite of these preventive practices. A fungicide spray program is the only effective method of control. Fungicides should be applied according to label directions and repeated if conditions favorable for infection persist. If possible, anticipate disease problems and begin a spray schedule before economic damage occurs. Consult the *Extension Agents Handbook of Insect, Disease and Weed Control* (Extension Circular E-832) for more information on fungicides currently registered for disease control on leafy greens.

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Oklahoma Cooperative Extension Service

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Pests of Lettuce

NC STATE EXTENSION

Key to Lettuce Pests

Caterpillars attacking the fall crop are usually the most troublesome field pests of lettuce. In the greenhouse, aphid and cabbage looper infestations often give problems. Cutworms, whiteflies, leafminers, and slugs are slightly less important greenhouse pests. Regardless of growing site, aphids cause additional problems by transmitting several virus diseases, including lettuce mosaic.

A. Caterpillars that sever or leave holes in foliage

1. **Beet armyworm** – Green or black larva, up to 30 mm long; three pairs of legs near head; five pairs of fleshy prolegs; three lightly colored stripes running length of body; black spot on each side of the second segment behind the head (Figure 1); damages bud and young leaves
2. **Cabbage looper** – Green caterpillar with longitudinal white stripes; body up to 30 mm long, tapers toward the head; three pairs of legs near head; three pairs of fleshy prolegs (Figure 2); young larva on underside of leaf; mature larva deep within head; consumes tender leaf tissue, leaving most veins intact
3. **Cutworms** – Fat, basically gray, brown, or black caterpillars 40 to 50 mm long when fully grown; three pairs of legs near head; five pairs of fleshy prolegs (Figure 3); young larva on underside of leaf; mature larva deep within head; consumes tender leaf tissue, leaving most veins intact
4. **Imported cabbageworm** – Velvety green caterpillar up to 32 mm long; yellow stripe down back; row of yellow spots down each side; three pairs of legs near head; five pairs of prolegs (Figure 4); feeds deeper in plant and more likely to eat small veins than the cabbage looper; leaves wet, greenish-brown excrement deep among leaves

B. Small (less than 4 mm long) piercing-sucking insects that extract sap and create discolored areas on foliage

1. **Aphids** – Soft-bodied, pear-shaped insects with a pair of dark cornicles and a cauda protruding from the abdomen; may be winged or wingless - wingless forms most common; feed in colonies; cause discoloration or mottling of foliage; often transmit virus diseases; excrete honeydew on which sooty mold grows.
    a. **Bean aphid** – Dark green to black body with white appendages; adult up to 2.6 mm long; cornicles about same length as cauda (Figure 5A); nymph green, last instar with 5 to 7 pairs of white spots on abdomen (Figure 5B)
    b. **Green peach aphid** – Pale yellow to green wingless adult up to 2.4 mm long; winged adult with dark dorsal blotch on yellowish-green abdomen; cornicles over twice as long as cauda and slightly swollen toward tip (Figure 6A); yellow-green nymphs with 3 dark lines on abdomen (Figure 6B)
    c. **Potato aphid** – Adult and nymph both solid pink, green and pink mottled, or light green with dark stripe; adult up to 3.5 mm long; long slender cornicles about twice as long as cauda (Figure 7)

d. **Turnip aphid** – Adult and nymph both dull green; adult up to 2.2 mm long; swollen cornicles slightly longer than cauda (Figure 8)

2. **Greenhouse whitefly** – White moth-like insect about 1.5 mm long; found in conjunction with tiny yellow crawlers and/or green, oval, flattened, immobile nymphs and pupae (Figure 9)
3. **Leafhopper** – Spindle-shaped pest up to 4 mm long; green body with yellowish to dark green to black spots (Figure 10); usually jumps instead of flies; extracts saps from underside of leaf causing leaf to crinkle and curl upward; can also cause yellowing of leaves.

Figure 1. Beet armyworm.

Figure 2. Cabbage looper.

Figure 3. Cutworm.

Figure 4. Imported cabbageworm.

Figure 5A. Bean aphid adult.

Figure 5B. Bean aphid nymph.

Figure 6A. Green peach aphid.

Figure 6B. Green peach aphid nymph.

Figure 7. Potato aphid.

Figure 8. Turnip aphid.

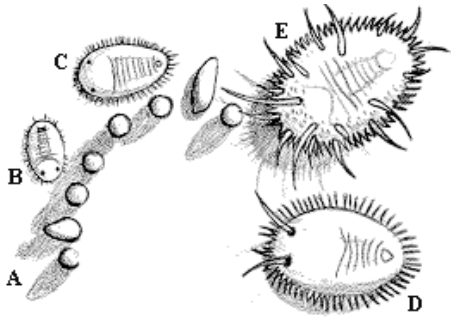


Figure 10. Leaffhopper.

Figure 9. Greenhouse whitefly nymphs.

Green Peach Aphid

Green peach aphid, *Myzus persicae* (Sulzer), Aphididae, HEMIPTERA

DESCRIPTION

Adult – This soft-bodied, pear shaped insect is usually wingless and ranges from 1.6 to 2.4 mm long. The wingless female is pale yellow to green. The winged midgrant form has a yellowish-green abdomen with a dark dorsal blotch. Both forms have a pair of tailpipe-like appendages known as cornicles.

Egg – No egg stage occurs in North Carolina.

Nymph – Slightly smaller than the adult but similar in shape, the nymph is pale yellow-green with three dark lines on the abdomen.

BIOLOGY

Distribution – The green peach aphid is a cosmopolitan species.

Host Plants – The green peach aphid infests a wide range of plants. Some important hosts include cabbage and related cole crops, dandelion, endive, mustard greens, parsley, turnip, tomato, tobacco, potato, spinach, pepper, beet, celery, lettuce, and chard.

Damage – Green peach aphids extract sap from plants and excrete a sweet sticky substance known as honeydew. Black sooty mold grows on honeydew and, though not directly harming the plants, may block out sufficient light to reduce yield. Weakened plants become susceptible to secondary disease and may be inoculated with viruses carried by aphids. Among the virus diseases transmitted by green peach aphids are potato leaf roll, potato virus Y, beet mosaic, beet yellows, and lettuce mosaic.

Life History – Adults pass the winter on greens and wild hosts such as cabbage, collards, turnip, wild mustard, and dock. Winged forms migrate to other hosts in late spring. During these migratory flights, aphids may spread virus diseases from infected volunteer plants and weeds to healthy crop plants. Movement between host plants continues through summer and fall.

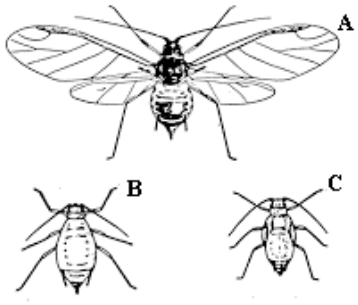
In southern states, the aphids are nearly all females. Successive generations of females, mainly wingless, are produced throughout the year. Winged migrants develop whenever overcrowding occurs or food becomes scarce. This type of development (all females, no males or eggs) occur as far north as Tennessee and Maryland. Many generations are produced each year.

CONTROL

Lady beetles and their larvae, lacewing larvae, syrphid fly larvae, and stilt bugs all feed on aphids. Fungus diseases, high temperatures, damp weather, and hard rains also reduce aphid populations.

Cultural practices are helpful in avoiding aphid infestations. Winter host plants (collards, mustard, dock, turnip) in the vicinity of seed beds should be destroyed before plants begin to come up. The purchase of certified seed from areas free of virus is also a good preventative measure.

A number of insecticides are available to control aphids on a wide variety of crops. However, repeated applications of certain carbamate insecticides within intervals of a week or less are frequently conducive to aphid buildups. For specific chemical recommendations, consult the current *North Carolina Agricultural Chemicals Manual*.



Green peach aphid. A, Winged adult. B, Wingless adult. C, Nymph.

Green peach aphid. A. Winged adult. B. Wingless adult. C. Nymph.

Potato Aphid

Potato aphid, *Macrosiphum euphorbiae* (Thomas), Aphididae, HEMIPTERA

DESCRIPTION

Adult – This soft-bodied, pear-shaped insect may be solid pink, green and pink mottled, or light green with a dark stripe. Usually wingless, it is about 2.5 to 3.5 mm long and has a pair of long, slender tailpipe-like appendages known as cornicles.

Egg – The egg stage does not occur in North Carolina.

Nymph – Although slightly smaller than the adult, the nymph is similar in color and shape.

BIOLOGY

Distribution – Potato aphids occur throughout North America.

Host Plants – Potato aphids infest a wide range of host plants. Some important cultivated hosts include potato, tomato, eggplant, sunflower, pepper, pea, bean, apple, turnip, corn, sweet potato, asparagus, clover, and rose. Weeds such as ragweed, lambsquarters, jimsonweed, pigweed, shepherdspurse, and wild lettuce are also common food plants.

Damage – Sporadic in occurrence, potato aphid infestations are rarely severe enough to kill plants. Aphids pierce veins, stems, growing tips, and blossoms with their needle-like mouthparts. As a result, blossoms are shed and yield is reduced. New growth becomes stunted and curled. Heavily infested plants turn brown and die from the top down. Aphids tend to spread rapidly from field to field transmitting a number of viral diseases. These include various mosaics, leaf roll, spindle tuber, and unmottled curly dwarf.

Life History – In North Carolina, female potato aphids feed and reproduce year round. No eggs or males are produced. Without mating, wingless females give birth to about 50 live nymphs. During warm weather, each of these nymphs matures in 2 or 3 weeks. The life cycle continues in this manner until overcrowding occurs or food becomes scarce. At these times nymphs develop into winged adults and migrate to new host plants. Once settled down, these aphids begin reproducing and the life cycle continues as before. During winter, however, feeding and reproduction occur at a much slower rate. Many generations are produced each year.

CONTROL

Lady beetles and their larvae, lacewing larvae, syrphid larvae, and stilt bugs all feed on aphids. Fungus diseases, high temperatures, damp weather, and hard rains also limit aphid populations.

Cultural practices are helpful in avoiding aphid populations. Crops should be planted in well-prepared, fertile seedbeds to promote vigorous growth. When possible, avoid planting sites near infested fields or from which an aphid-infested crop has been removed.

A number of insecticides are available to control aphids on a wide variety of crops. However, repeated applications of certain carbamate insecticides within intervals of a week or less are frequently conducive to aphid buildups. For specific chemical recommendations, consult the current *North Carolina Agricultural Chemical Manual*.

Potato aphid.

Potato aphid.

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Other Publications in Insect and Related Pests of Vegetables

Pests of Asparagus
Pests of Eggplant
Pests of Beans and Peas
Pests of Carrots
Pests of Crucifers
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Pests of Okra
Pests of Peppers
Pests of Potato
Pests of Sweet Corn
Pests of Sweetpotato
Pests of Tomato

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Pests of Crucifers

NC STATE EXTENSION

Key to Crucifer Pests

Crucifers, plants of the mustard family, have a unique set of pests. With the exception of cutworms, the cabbage looper, and the vegetable weevil, these insects pose little or no threat to most other vegetable crops. A group of three caterpillars, known as the "cabbageworm complex," causes most damage to crucifiers. These include the cabbage looper, diamondback moth larva, and the imported cabbageworm. The cabbage maggot is the most important pest of crucifers in western North Carolina.

A. Chewing insects that leave holes in foliage or bore into stems and leaf veins

1. Caterpillars with three pairs of legs and three to five pairs of prolegs
    a. **Beet armyworm** – Soft-bodied green or black caterpillar up to 30 mm long; three lightly colored stripes running length of body; black spot on each side of body on second segment behind head; five pairs of prolegs (Figure 1); damages bud and young leaves.
    b. **Cabbage looper** – Green caterpillar with longitudinal white stripes; body up to 30 mm long and tapering toward the head; three pairs of fleshy prolegs (Figure 2); young larva on underside of leaf; mature larva deep within head; consumes tender leaf tissue leaving most veins intact.
    c. **Cabbage webworm** – Yellowish gray caterpillar up to 15 mm long; black head with well defined V-shaped mark; mature larva bearing five dark longitudinal stripes and moderately long yellow or light brown hairs; five pairs of prolegs (Figure 3); bores in plant often destroying bud or causing plant to be deformed; sometimes found in protective web along vein on underside of leaf; usually a problem only in fall.
    d. **Corn earworm** – Early instars: cream colored or yellowish green with few markings; later instars: green, reddish or brown with pale longitudinal stripes and scattered black spots; moderately hairy; up to 44 mm long; five pairs of prolegs. (Figure 4)
    e. **Cross-striped cabbageworm** – Early instars: gray with dark tubercles, large head, and sparse body hairs; mature larva: bluish gray with black transverse stripes and two stripes (one yellow, one black) down each side of the back; larva up to 15 mm long; five pairs of prolegs (Figure 5); feeds on buds and tender leaves.
    f. **Cutworms** – Fat, basically gray, brown, or black caterpillars 40 to 50 mm long when fully grown; five pairs of fleshy prolegs (Figure 6); active at night-young caterpillars climbing on leaves, older caterpillars severing stalks of leaves; hide during the day in soil burrows at base of plants.
    g. **Diamondback moth larva** – Pale green caterpillar up to 7 mm long with black head and scattered black hairs; five pairs of prolegs; tapers slightly at both ends and wiggles rapidly when disturbed (Figure 7); prefers to feed on underside of older leaves, between loose leaves, or on young buds; bud damage prevents proper development of heads.
    h. **Imported cabbageworm** – Velvety green caterpillar up to 32 mm long; yellow stripe down back; row of yellow spots down each side; five pairs of prolegs (Figure 8); feeds

deeper in plant and more likely to eat small veins than the cabbage looper; leaves wet; greenish brown excrement deep among leaves.

2. Beetles or beetle larvae

    a. **Striped flea beetle** – Black oval beetle about 2 mm long with a wavy yellow line down each wing cover; enlarged hind legs for jumping (Figure 9); makes small pits in leaves; remaining tissue drops out leaving small "shot holes"; transmits some plant diseases.

    b. **Vegetable weevil adult and larva** – Dull grayish brown weevil, about 6.4 mm long, with short, stout snout and light V-shaped mark on wing covers (Figure 10A); larva pale green, legless, up to 10 mm long with dark mottled head (Figure 10B); adult and larva feed primarily at night on buds and foliage.

B. Insects with needlelike or rasping mouthparts that cause foliage to be yellowed or distorted

1. **Aphids** – Pale green, soft-bodied, pear-shaped insects with a pair of dark cornicles and a cauda protruding from the abdomen; body up to 2.5 mm long; may be winged or wingless-wingless form most common (Figure 11); feed in colonies; cause discoloration or mottling of foliage; often transmit virus diseases; excrete honeydew on which sooty mold grows.
2. **Harlequin bug** – Black, shield-shaped bug up to 10 mm long, brightly colored with orange, red, and yellow markings (Figure 12); injured stems and leaves with irregular cloudy spots around puncture wound; young plants wilt, brown, die; old plants stunted.
3. **Onion thrips** – Foliage-rasping pest; pale yellow to dark brown body 2 mm or less in length; adult with two pairs narrow, fringed wings (Figure 13); causes silvery blotches or scratchlike markings on leaves; some infested leaves distorted, curling upward.

C. Insects that attack plants below ground

1. **Cabbage maggot** – White legless maggot up to 6 mm long with a pointed head (Figure 14); occurs only in a few mountain counties of North Carolina; devours small roots; tunnels in stems and fleshy roots making them brown and slimy; above ground, plants stunted and of unusually pale color; infested cabbage has sickly bluish gray leaves.
2. **Cutworms** – (See above for description). Soil insects that usually eat foliage; also sever stems near base of plants.
3. **Vegetable weevil and larva** – (See above for description). Feed at night on foliage or underground on large-rooted crucifers like turnips.

Figure 1. The beet armyworm is a soft-bodied green or black caterpillar up to 30 mm long; three lightly colored stripes running length of body; black spot on each side of body on second segment behind head; five pairs of prolegs.

Figure 2. The cabbage looper is a green caterpillar with longitudinal white stripes, a body up to 30 mm long and tapering toward the head and three pairs of fleshy prolegs.

Figure 3. The cabbage webworm is a yellowish gray caterpillar up to 15 mm long, a black head with well defined V-shaped mark. Mature larva bear five dark longitudinal stripes and moderately long yellow or light brown hairs with five pairs of prolegs.

Figure 4. The corn earworm is cream colored or yellowish green with few markings; later instars are green, reddish or brown with pale longitudinal stripes and scattered black spots; moderately hairy; up to 44 mm long; five pairs of prolegs.

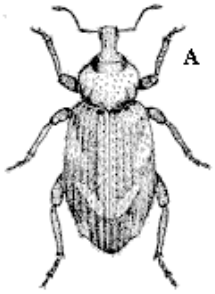
Figure 5. Cross-striped cabbageworm larva are larva up to 15 mm long with five pairs of prolegs.

Figure 6. Cutworms are fat, basically gray, brown, or black caterpillars, 40 to 50 mm long when fully grown with five pairs of fleshy prolegs.

Figure 7. Diamondback moth larva are pale green caterpillars up to 7 mm long with black head and scattered black hairs, five pairs of prolegs, tapers slightly at both ends and wiggles rapidly when disturbed.

Figure 8. The imported cabbageworm is a velvety green caterpillar up to 32 mm long, a yellow stripe down back, a row of yellow spots down each side and five pairs of prolegs.

Figure 9. Striped flea beetles are black oval beetles about 2 mm long



black oval beetles about 2 mm long with a wavy yellow line down each wing cover with enlarged hind legs for jumping.

Figure 10A. Vegetable weevil are dull grayish brown weevils, about 6.4 mm long, with short, stout snout and light V-shaped mark on wing covers.

Figure 10B. Vegetable weevil larva are pale green, legless, up to 10 mm long with dark mottled head.

Figure 11. Aphids are pale green, soft-bodied, pear-shaped insects with a pair of dark cornicles and a cauda protruding from the abdomen and a body up to 2.5 mm long.

Figure 12. Harlequin bugs are black, shield-shaped bugs up to 10 mm long, brightly colored with orange, red, and yellow markings.

Figure 13. Onion thrips are pale yellow to dark brown with a body 2 mm or less in length. Adults have two pairs of narrow, fringed wings.

Figure 14. Cabbage maggots are white legless maggots up to 6 mm long with a pointed head.

Cabbage and Turnip Aphids

Cabbage aphid, *Brevicoryne brassicae* (Linnaeus), Aphididae, HEMIPTERA
Turnip aphid, *Lipaphis erysimi* (Kaltenbach), Aphididae, HEMIPTERA

DESCRIPTION

Adult – Very similar in appearance, these two aphid species are pale green and, most commonly, wingless (Figure M). Both species have a pair of short swollen cornicles (tailpipe-like appendages) on their abdomens. The cornicles of the cabbage aphid are shorter than the turnip aphids. The cabbage aphid is 2.0 to 2.5 mm long and covered with grayish waxy coat. The turnip aphid has no such covering and is 1.6 to 2.2 mm long.

Egg – Virtually nonexistent in the south, the eggs of these aphids are minute, ovate, and black and are laid only in the fall.

Nymph – The wingless nymphs resemble the adults in color and shape but are smaller.

BIOLOGY

Distribution – Widely distributed throughout the United States, cabbage and turnip aphids are most troublesome in the southern states.

Host Plants – The cabbage aphid feeds primarily on broccoli, Brussels sprout, cabbage, cauliflower, collards, kale, and radish. Mustard is rarely infested. The turnip aphid typically infests mustard, radish, shepherdspurse, turnip, and watercress. It also injures other crucifers, particularly in their seedling stage.

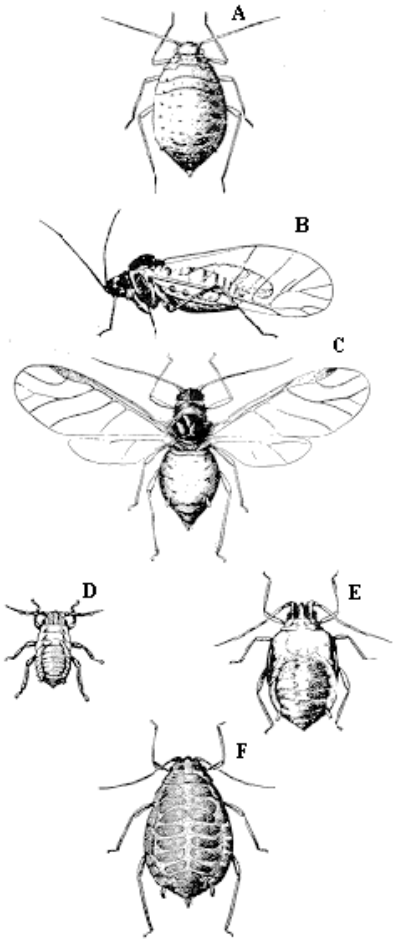
Damage – Aphids cluster on the underside of leaves and suck sap causing infested foliage to curl, wilt, or become distorted. Some infested plants are soon killed; others grow slowly, are stunted, and produce small unmarketable heads.

Life History – In North Carolina, cabbage and turnip aphids continue to feed and breed at reduced rates throughout the winter. Collards are an important overwintering host plant. As warm weather returns, aphid activity increases. Wingless female adults produce large numbers of live progeny (50 to 100) without mating, which all develop into females. Periodically, winged females develop and fly to new host plants. Favored by moderate temperatures and dry weather, reproduction continues in this manner throughout summer. As many as 30 to 45 annual generations occur along the Gulf Coast though not quite so many are produced in North Carolina.

CONTROL

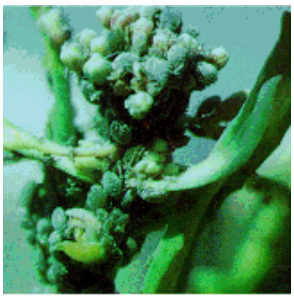
Cultural practices are helpful in avoiding aphid infestations. Plant the crop in a well-prepared, fertile seedbed to promote vigorous growth. Avoid planting near an aphid-infested crop or on land from which such a crop has been recently removed.

Chemical control of aphid infestations is often necessary. For up-to-date recommendations, consult the current *North Carolina Agricultural Chemicals Manual*.



Aphids. A-C, Cabbage aphids. D-F, Turnip aphids.

Aphids. A-C. Cabbage aphids. D-F. Turnip aphids.



M. Cabbage aphids.

Figure M. Cabbage aphids.

Cabbage Looper

Cabbage looper, *Trichoplusia ni* (Hubner), Noctuidae, LEPIDOPTERA

DESCRIPTION

Adult – The cabbage looper moth has a wingspan of about 38 mm. Near the center of each brownish-gray forewing is a silver figure-eight design; the lighter colored hind wings have dark margins.

Egg – The round, greenish-white egg is slightly smaller than a pinhead.

Larva – This green larva has three pairs of prolegs and several white stripes which run the length of the body. When fully grown, the caterpillar is less noticeably striped and measures 30 mm long. It moves in a characteristic "looping" motion (Figure P).

Pupa – The green or brown pupa is approximately 19 mm long and encased in a loosely woven cocoon.

BIOLOGY

Distribution – Native to North America, the cabbage looper is common from southern Canada into Mexico. In the United States, this caterpillar is primarily a problem in the south.

Host Plants – The cabbage looper infests a large range of plants. Some cultivated hosts include: cabbage and related plants, cotton, potato, spinach, lettuce, celery, parsley, tomato, and soybean. Collards and cotton are preferred over broccoli, cauliflower, or cabbage for oviposition.

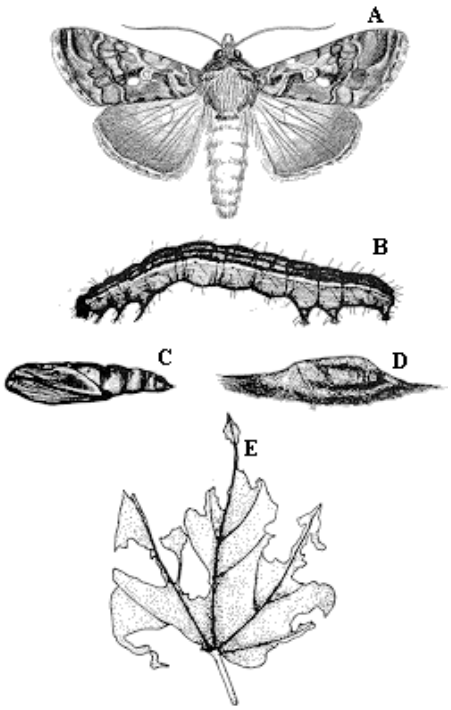
Damage – Cabbage looper feeding injury closely resembles that of the imported cabbageworm. The young caterpillars feed on the undersides of leaves. As the larvae mature, they move to more protected areas deeper within cabbage heads. These larger larvae feed between leaf veins as they progress from the outer to the inner leaves.

Life History – Cabbage loopers overwinter as pupae in Florida and adjacent states. The inconspicuous night-flying moths emerge in spring, and females soon begin depositing 275 to 350 eggs, singly, on the upper surface of leaves. Several days later, young loopers hatch from the eggs and begin feeding. The caterpillars consume foliage voraciously for 2 to 4 weeks before spinning cocoons on the host plant foliage and pupating. Within 2 weeks the next generation of moths emerge. There are three or more generations each year in North Carolina.

CONTROL

The use of resistant cabbage varieties such as Mammoth Red Rock, Chieftan Savoy, and Savoy Perfection Drumhead helps reduce cabbage looper damage. On most crucifers, however, chemical control of this pest becomes necessary.

Insecticides for control of the cabbage looper are most effective on young and exposed larvae. A 7-day spray schedule is usually recommended for caterpillar control on crucifers. For recommended chemicals and rates, consult the current *North Carolina Agricultural Chemicals Manual*.



Cabbage looper. A, Adult. B, Larva. C, Pupa. D, Cocoon. E, Damaged leaf.

Cabbage looper. A. Adult. B. Larva. C. Pupa. D. Cocoon. E. Damaged leaf.

P. Cabbage looper (top) and cabbage maggot.

Figure P. Cabbage looper (top) and cabbage magnet.

Cabbage Maggot

Cabbage maggot, *Hylemya brassicae* (Weidemann), Anthomyiidae, DIPTERA

DESCRIPTION

Adult – This fly resembles a common house fly although it is somewhat smaller. It is gray with three distinct black stripes on the thorax, a dark stripe along the top of the abdomen, and is 5 to 6 mm long. The eyes are reddish-purple.

Egg – The white, finely ridged egg is about 1 mm long.

Larva – The white, legless maggot has a pointed head and grows to a length of 6 mm.

Pupa – About the size of the adult, the pupa is enclosed in a hard brown puparium.

BIOLOGY

Distribution – Introduced from Europe, the cabbage maggot is most injurious in Canada and the northern United States. It has been a problem in Illinois and western North Carolina but is rarely serious any further south. In North Carolina cabbage maggots have been reported from practically all mountain counties west of a line from Polk County to Surry County and usually do not occur below 914 meters (3,000 feet) elevation.

Host Plants – The cabbage maggot feeds primarily on crucifers such as cabbage, cauliflower, broccoli, Brussels sprouts, collards, kohlrabi, radish, and turnip. Beet, cress, and celery have also been infested.

Damage – Cabbage maggots eat small fibrous roots and tunnel in stems and large fleshy roots. Tunnels where maggots have fed become brown and slimy, and organisms are likely to be introduced at these points. Plants attacked in the plant bed or soon after setting in the field fail to develop normally. Cabbage first takes on a sickly gray-blue color. Other infested crucifers may appear stunted or pale in color. If severe damage has been done, plants may wilt and die during the heat of the day. Infestations are difficult to detect in radishes and turnips because the tunneling of maggots in these large-rooted crops does not cause the foliage to wilt. Damage to these crops can be determined only by pulling some plants early and inspecting them. Cabbage maggots are usually most severe when the weather is cool and wet for a long period of time.

Life History – Cabbage maggots overwinter as pupae 2 to 13 cm deep in the soil. As the soil warms in spring, adult flies emerge from cocoons, feed on the nectar of flowers, and mate. Appearing as early as April, females soon begin depositing eggs in the soil at or near the base of host plants. Three to 7 days later, young maggots emerge from the eggs and move into the soil searching for roots upon which they feed for 3 to 4 weeks before pupating. Pupation may take place within root burrows or out in the soil and usually lasts 2 or 3 weeks. The second generation of adults appears in late June or early July. At least three generations occur annually in North Carolina.

CONTROL

Cultural practices such as late planting, careful selection of seedbed location, and elimination of weedy hosts can help prevent severe infestations. If planting is delayed until the last week of May or first week of June, few flies will be present to deposit eggs. Seedbeds located as far as possible from growing areas and protected from egg-laying flies with a gauze cloth will less likely be infested. The use of transplants grown in North Carolina at elevations below 3,000 feet will eliminate the danger of introducing the maggots on infested transplants. The fall destruction of turnip and cabbage stumps and weeds such as wild mustards will eliminate many larvae or pupae associated with these plants. Proper fertilization, irrigation, and good soil practices also lessen maggot damage by improving plant tolerance.

Cabbage maggots often require chemical control. An insecticide can be broadcast and incorporated just prior to planting seed or setting transplants. The application of a drench after setting transplants may also be effective. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.

Cabbage Webworm

Cabbage webworm, *Hellula rogatalis* (Hulst), Pyralidae, LEPIDOPTERA

DESCRIPTION

Adult – The moth has brownish-yellow forewings mottled with darker brown and pale gray hind wings. The wingspan is only slightly more than 13 mm. Resting on the ground where it is well camouflaged, the moth takes short, erratic flights when disturbed.

Egg – Oval and about 1 mm long, the egg is grayish-white at first, later acquiring a pinkish hue.

Larva – The first instar larva has a pale yellowish-gray body about 1 mm long with a dark, wide head. The mature larva is also yellowish-gray but has five dark longitudinal stripes with moderately long yellow and light brown hairs and is 13 to 15 mm long. The black head has a well-defined V-shaped mark.

Pupa – The yellowish-brown pupa is 6 to 7.5 mm long, 2 mm wide and occurs within a cocoon about 9 mm long made of silk and soil particles.

BIOLOGY

Distribution – Primarily a problem in southern states, the cabbage webworm occurs from North Carolina south to Florida and westward into California.

Host Plants – Most crucifers and some closely related weedy plants are attacked by cabbage webworms. Hosts include cabbage, turnip, beet, collard, cauliflower, kale, rutabaga, radish, kohlrabi, mustard, rape, horseradish, shepherdspurse, and purslane.

Damage – In North Carolina cabbage webworms do no damage to spring cole crops. In late summer or early fall, however, young plants of the fall crop are subject to attack. By boring into buds, stems, and stalks, webworms destroy or disfigure buds and sometimes kill entire plants. Plants with destroyed buds will produce secondary buds but these are not likely to mature into marketable heads by harvest.

Webworms feeding on the outer leaves of older plants are harmless. Webworms are enclosed by protective silken webs, often hiding along leaf veins on the underside of leaves. They feed during the day, but are fairly inactive during cold weather.

Life History – Little information is available concerning the life history of the cabbage webworm in the southern United States. Closely related species overwinter as larva or pupae in silk-lined cells in soil. Cabbage webworm moths deposit approximately 300 to 350 eggs on host plant buds. About 3 days later, larvae emerge and feed in the buds, eventually moving to the outer leaves where they spin webs and continue to feed along large leaf veins. They pupate among shed leaves or other refuse on the ground. The number of annual generations in North Carolina has not been determined.

CONTROL

Cabbage webworm control is not necessary on spring-planted crucifers. On fall-planted crucifers, control is primarily preventive. Plants should be sprayed or dusted as soon as they come up or are set out. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.

Cross-Striped Cabbageworm

Cross-striped cabbageworm, *Evergestis rimosalis* (Guenee), Pyralidae, LEPIDOPTERA

DESCRIPTION

Adult – The yellowish-brown moth has a body about 10 mm long and a wingspan of about 25 mm. The mottled forewings are marked with dark brown zig-zag lines; the pale hind wings have 5 or 6 small dusky spots between the middle of the wing and its inner border.

Egg – The egg mass, laid on the foliage, consists of thin, oval, flattened eggs which overlap like fish scales. Each individual yellow egg is about 1.2 mm long and 1 mm wide.

Larva – Only a few millimeters long when newly hatched, the first instar larva has a large head and uniformly gray body sparsely covered with hairs. A mature larva has a bluish-gray body up to 20 mm long with tiny black transverse stripes. A black stripe with a yellow stripe underneath it runs along each side of the body. The underside of the larva is green mottled with yellow (Figure J).

Pupa – The yellowish-brown to dark brown, 11- to 12-mm-long pupa can be found in a light gray cocoon with particles of sand enmeshed. The cocoon itself is about 16 mm long and 10 mm wide.

BIOLOGY

Distribution – Cross-striped cabbageworms have been reported in many states from Delaware and Nebraska southward. Moths have been taken farther north, but this insect is believed to be primarily southern in distribution.

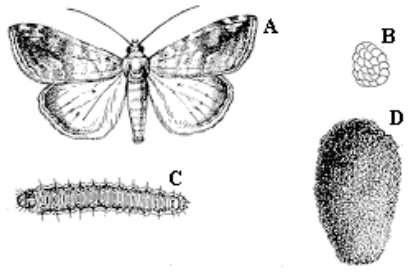
Host Plants – Cabbage, turnip, and related plants are the only known hosts of this pest.

Damage – Because eggs are deposited in masses, individual plants may be infested with large numbers of cross-striped cabbageworms. These caterpillars feed on all tender plant parts but prefer terminal buds. Young leaves and buds are often riddled with holes (Figure K).

Life History – No biological studies of this pest have been conducted in North Carolina, but in Washington, DC, the cross-striped cabbageworm is reported to produce four generations per year. They probably overwinter as larvae and pupate in spring. Pupation occurs just below the soil surface and lasts about 6 days. Moths emerge from pupae and soon deposit eggs in masses of 20 to 30 on the underside of leaves. Under warm, favorable conditions, eggs hatch in about 6 days. Larvae develop in about 2 to 3 weeks in summer, but require longer to develop during cooler periods of weather.

CONTROL

For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.



Cross-striped cabbageworm. A, Adult. B, Eggs. C, Larva. D, Cocoon.

Cross-striped cabbageworm. A. Adult. B. Eggs. C. Larva. D. Cocoon.

J. Cross-striped cabbage-worm.

Figure J. Cross-striped cabbageworm.

K. Cross-striped cabbage-worm damage.

Figure K. Cross-striped cabbageworm damage.

Diamond Moth

Diamond moth, *Plutella xylostella* (Linnaeus), Yponomeutidae, LEPIDOPTERA

DESCRIPTION

Adult – This grayish-brown moth has narrow forewings, conspicuously fringed hind wings, and an 18 mm wingspan. When at rest, the wings of the male come together to form a line of white or pale yellow diamonds down the middle of the back (Figure R).

Egg – The minute round egg is pale yellow.

Larva – Tapering slightly at both ends, this pale green larva with a black head and scattered black hairs reaches a length of 7 mm when mature (Figure R). It wriggles rapidly when disturbed, often dropping from the plant and hanging by a silk-like thread.

Pupa – The yellowish pupa is enclosed within a loosely spun, gauze-like cocoon measuring about 7.5 mm in length.

BIOLOGY

Distribution – A native of Europe, the diamondback moth can be found throughout the United States and in all areas of the world where cole crops are grown. It can be a problem in greenhouses also.

Host Plants – The diamondback moth is a pest of practically all crucifers, including cabbage, broccoli, cauliflower, collards, kale, brussels sprouts, kohlrabi, turnip, radish, mustard, and watercress.

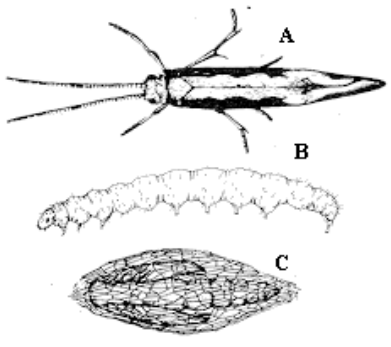
Damage – Diamondback moth larvae feed on all plant parts, but prefer the undersides of older leaves, crevices between loose leaves, and young buds. They eat small holes in leaves and buds, or feed superficially leaving slight perforations instead of holes. When populations remain low, these small caterpillars cause little damage; however, in large numbers they are particularly injurious to young plants. Heavy feeding on buds may cause the marketable portion of the plant to fail to develop properly.

Life History – Diamondback moths overwinter as adults among field debris of crucifer crops. In spring, eggs are laid, singly or in groups of two or three on foliage. Larvae, which hatch from eggs a few days later, feed for about 10 days during warm weather and a month during cool seasons. Larvae first feed as leafminers but soon emerge and infest the undersides of leaves. Once mature, larvae spin loose cocoons which remain attached to lower leaf surfaces. After a 2-week pupal period, a new generation of moths emerge. In temperate regions, the diamondback moth has 2 to 6 or more generations each year. Five or 6 generations per year are common in North Carolina.

CONTROL

Since these moths overwinter in the field, destroying or plowing under crop debris is a recommended cultural practice. Planting resistant varieties also reduces infestation. The following crucifer varieties are less attractive to diamondback moth larvae: Michihli Chinese and Mammoth Red Rock (cabbage); Southern Giant Curled (mustard); Seven Top and Purple Top White Globe (turnip); Vates (kale); and Cherry Belle, White Icicle, Globemaster, and Champion (radish).

Diamondback moth caterpillars are controlled by the same insecticides used against other caterpillars on crucifers. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemical Manual*.



Diamondback moth. A, Adult. B, Larva. C, Cocoon.

Diamond moth. A. Adult. B. Larva. C. Cocoon.

R. Diamondback moth (top) and larva.

Figure R. Diamonback moth (top) and larva.

Harlequin Bug

Harlequin bug, *Murgantia histrionica* (Hahn), Pentatomidae, HEMIPTERA

DESCRIPTION

Adult – This black, shield-shaped bug is brightly colored with orange, red, and yellow markings (Figure N). It varies from 7 to 10 mm in length.

Egg – The barrel-shaped egg, about 1 mm long, is light gray or pale yellow. It has two black bands -- one at the top, the other near the bottom -- and a black spot just above the lower band. Eggs are laid in clusters on crucifer foliage.

Nymph – The oval nymph is similar to the adult in coloration, but is slightly smaller and lacks wings.

BIOLOGY

Distribution – Native to Central America and Mexico, the harlequin bug is now found from coast to coast in North America as far north as the Great Lakes and New England. It is most injurious, however, in the southern states and rarely causes damage north of latitude 40°N.

Host Plants – Harlequin bugs attack nearly all crucifers, including common weeds of the mustard family such as wild mustard, shepherdspurse, peppergrass, bittercress, and watercress. If infestations are heavy and food becomes scarce, harlequin bugs will also feed on squash, corn, bean, asparagus, okra, and tomato.

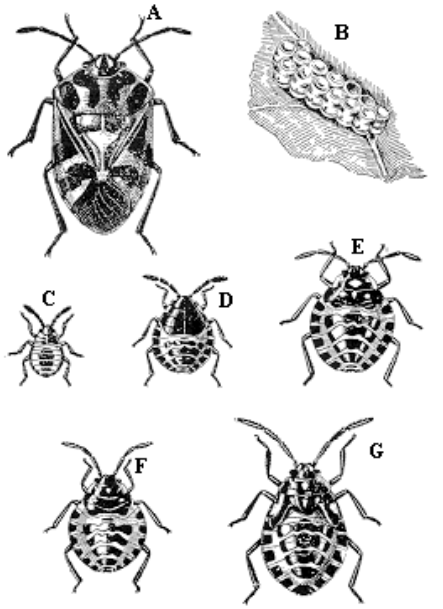
Damage – Adults and nymphs pierce stalks, leaves, and veins with their needle-like mouthparts and extract plant juices (Figure O). Stems and leaves injured in this manner develop irregular cloudy spots around the puncture wound. Young plants are likely to wilt, turn brown, and eventually die; while older plants are only stunted.

Life History – Harlequin bugs overwinter as adults throughout most of their range. They remain active throughout the mild winters of the Gulf States, but hibernate among plant debris during the harsh winters of northern states. Adults emerge early in spring. Approximately 2 weeks after resuming activity, females begin depositing eggs on the undersides of leaves. Eggs are laid in double-row clusters of 10 to 13 until each female has deposited approximately 155 eggs. In early spring, eggs hatch in about 20 days. Eggs hatch in 4 to 5 days as the weather becomes warmer. Nymphs feed for 6 to 8 weeks and develop through 5 instars before becoming adults. Two to four generations occur each year in North Carolina.

CONTROL

Populations of overwintering adults can be reduced by plowing under field debris after the onset of cold weather. Destruction of weeds within fields and along fence rows also limits overwintering sites. In addition to cultural practices, resistant varieties should be planted when possible. The following varieties are recommended: Copenhagen Market 86, Headstart, Savoy Perfection Drumhead, Stein's Flat Dutch, and Early Jersey Wakefield (cabbage); Green Glaze (collards); Early Snowball X and Snowball Y (cauliflower); Red Devil, White Icicle, Globemaster, Cherry Belle, Champion, and Red Prince (radish).

For chemical control of harlequin bug infestations, insecticides should be applied when bugs first appear and applications repeated as necessary. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.

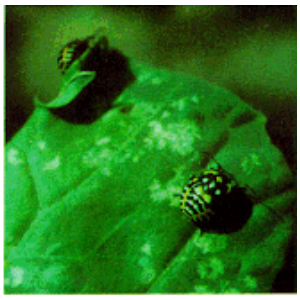


Harlequin bug, A, Adult.. B, Eggs. C-G, Nymphs.

Harlequin bug. A. Adult. B. Eggs. C-G. Nymphs.

N. Harlequin bug.

Figure N. Harlequin bug.



O. Harlequin bug nymphs and damage.

Figure O. Harlequin bug nymphs and damage.

Imported Cabbageworm

Imported cabbageworm, *Pieris rapae* (Linnaeus), Pieridae, LEPIDOPTERA

DESCRIPTION

Adult – Both sexes of this white butterfly have a black area near the tip of each forewing and a small black spot on the front edge of each hind wing. The female has two black spots on each forewing while the male has only one. The female has a wingspan of about 50 mm; the male is slightly smaller.

Egg – The pale yellow, bullet-shaped egg, about 1 mm long, is ribbed lengthwise and crosswise and is attached endwise to the leaf surface.

Larva – The velvet-like green larva has a faint yellow stripe down its back, a row of faint yellow spots on each side, and five pairs of prolegs (Figure L). When fully grown, it measures about 32 mm long.

Pupa – The sharply-angled pupa, or chrysalis, is gray, green, or brown and about 20 mm long. It is attached to the lower leaf surface by a silken loop.

BIOLOGY

Distribution – The imported cabbageworm has spread throughout the United States from coast to coast after introduction into Canada from Europe. In the Western Hemisphere, this butterfly is most common between latitudes 30°N and 60°N. It is equally destructive in the northern and southern areas of its range.

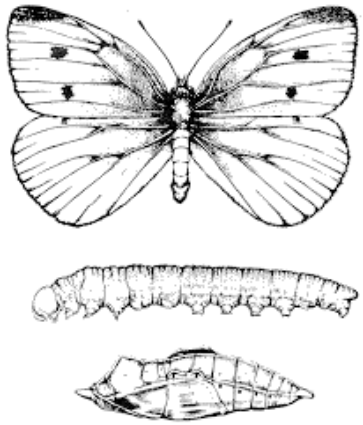
Damage – Imported cabbageworms are commonly found on the undersides of leaves. Like cabbage loopers, young caterpillars feed superficially, leaving the upper surface intact. Larger larvae leave holes in the leaves and are more likely to eat through small veins than are loopers. In contrast to cabbage loopers, imported cabbageworms bore into the center of the head thereby doing more damage to the edible portion of the plant. The presence of masses of wet, greenish-brown excrement deep among leaves is indicative of this pest.

Life History – Imported cabbageworms overwinter as pupae attached to host plant debris. Adults emerge early in spring, as early as March even in the northern states. Soon after mating, females begin depositing eggs singly on cultivated host plants, if available . Often, however, the first generation of cabbageworms is raised on wild hosts. After hatching 4 to 8 days post egg-deposition, larvae feed and develop through five instars in 10 to 14 days. When mature, larvae fasten themselves to lower leaf surfaces by silk bands. During spring and summer, the pupal stage lasts 7 to 12 days before a new generation of butterflies emerges. There are usually 3 or 4 generations each year.

CONTROL

Although cabbageworms are subject to attack by a number of disease organisms and parasites, a combination of cultural and / or chemical control practices are necessary. The use of resistant cabbage varieties, such as Mammoth Red Rock, Chieftan Savoy, and Savoy Perfection Drumhead, provides some protection but not complete control. New plantings should be as far as possible from those of the previous season. At the end of the season, crops should be harvested without delay. Plowing under or destroying plant residues at this time eliminates an important food source for the overwintering generation of cabbageworms.

Insecticide applications should begin when the cabbageworm population reaches a threshold of one worm per plant. Sprays then should be repeated every 5 to 7 days, as needed. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.



Imported cabbageworm. A, Adult. B, Larva. C, Chrysalis.

Imported cabbageworm. A. Adults. B. Larva. C. Chrysalis.

L. Imported cabbageworm.

Figure L. Imported cabbageworm.

Striped Flea Beetle

Striped flea beetle, *Phyllotreta striolata* (Fabricius), Chrysolmelidae, COLEOPTERA

DESCRIPTION

Adult – This small black beetle, 1.5 to 2.5 mm long, has a wavy yellow line running the length of each wing. The hind legs are thickened, enabling the beetle to jump.

Egg – The minute, oval to elongate egg is white.

Larva – When fully grown, the white, brown-headed larva is 3.2 to 5.0 mm long. It has 3 pairs of tiny legs near its head.

Pupa – The tiny white pupa is approximately the same size and shape as the adult.

BIOLOGY

Distribution – The striped flea beetle is common throughout the eastern and Pacific areas of the United States and is Eurasian in origin. It is not common in much of the Rocky Mountain regions.

Host Plants – Striped flea beetles infest many crucifers but prefer mustard, turnip, radish, and related weeds.

Damage – Although larvae feed on the roots of host plants, the primary damage is caused by adult beetles feeding on foliage. Beetles make small pits in leaves (Figure Q). The remaining thin layers of tissue eventually dry up and fall away leaving small "shot holes" in the foliage. This type of injury is capable of killing young plants. In addition, beetles may act as vectors of plant disease.

Life History – Striped flea beetles overwinter among debris in and around fields. Emerging early in spring, they attack seedlings and young plants. Eggs are deposited in tiny crevices gnawed out of the base of host plant stems. About 10 days later, grubs hatch from the eggs and move into the soil

to attack roots. After feeding for 3 or 4 weeks, the larvae pupate for 7 to 10 days. A new generation of beetles then emerges. There are at least two generations each year in North Carolina.

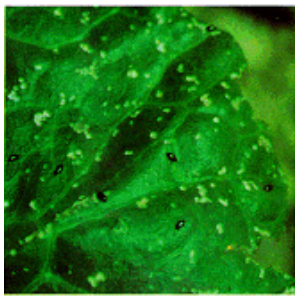
CONTROL

Cultural practices and the use of resistant varieties help prevent severe flea beetle infestations. Stripes of gauze physically protect seedbeds from flea beetles. Good weed control and the destruction of crop residue reduce overwintering populations. The use of resistant varieties may reduce injury by existing beetles. Such varieties include: Stein's Early Flat Dutch, Mammoth Red Rock, Savoy Perfection Drumhead, Early Jersey Wakefield, Copenhagen Market 86, and Ferry's Round Dutch (cabbage); Vates and Georgia (collards); Florida Broadleaf (mustard); American Purple Top (Rutabaga); Snowball A and Early Snowball X (cauliflower); DeCicco, Coastal, Italian Green Sprouting, and Atlantic (broccoli); Vates, Dwarf Siberian, Dwarf Green Curled Scotch, and Early Siberian (kale).

Chemical treatments for control of flea beetles should be applied as needed. For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.

Striped flea beetle.

Striped flea beetle.



Q. Flea beetles and damage.

Figure Q. Flea beetles and damage.

Variegated Cutworm

Variegated cutworm, *Peridroma saucia* (Hubner), Noctuidae, LEPIDOPTERA

DESCRIPTION

Adult – The forewings of this moth are yellow or brown with pale mottled designs, while the hind wings are white with brown veins and margins. The wingspan varies from 3.8 to 5.0 cm.

Egg – The spherical white or pale yellow eggs are ribbed and slightly less than 1 mm in diameter. They are laid in irregular elongate patches and turn brown before hatching.

Larva – The smooth-skinned larva is pale gray or light brown mottled with dark brown. The first three abdominal segments bear two yellow or orange dots while the eighth segment is marked with a dark "W." The mature larva may be as long as 40 mm and curls into a C-shaped ball when disturbed.

Pupa – The reddish-brown pupa is 15 to 20 mm long.

BIOLOGY

Distribution – The range of the variegated cutworm spans most of North America including Canada and Alaska and extends into South America. It is also found in Europe and the Mediterranean area. Although it is of most importance in the Pacific Northwest and some northeastern states, this cutworm is an occasional pest in North Carolina, especially in areas with sandy or sandy loam soils.

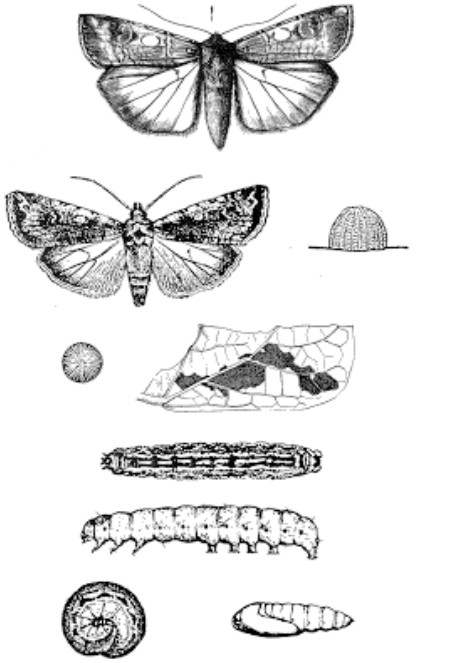
Host Plants – The variegated cutworm feeds on a variety of garden crops, trees, vines, grasses, field crops, ornamentals, and greenhouse plants.

Damage – Beginning in early spring and continuing throughout summer, variegated cutworms climb host plants and devour foliage, buds, and fruit. Damaging infestations, however, are sporadic. Because the variegated cutworm is one of the few cutworm species that climb plants to feed, its presence is usually more noticeable than that of subterranean cutworms. Late larval instars, however, burrow in the soil and cut off plants at or near the soil surface.

Life History – Variegated cutworms overwinter as pupae with a high percent mortality occurring during this life stage. Female moths emerging from surviving pupae compensate by laying over 2,000 eggs during their short life span. Clusters of 60 or more eggs are deposited on stems or leaves of low-growing plants as well as on fences and buildings. During summer, eggs usually hatch in 5 days. The active larvae feed at night and on cloudy days for about 3½ weeks before burrowing into soil to pupate. The pupal stage lasts two weeks to a month before second generation moths emerge. Requiring 48 days to complete a life cycle, variegated cutworms produce two to four generations each year. The exact number of annual generations produced in North Carolina is not known.

CONTROL

For recommended insecticides and rates, consult the current *North Carolina Agricultural Chemicals Manual*.



Variegated cutworm. A-B, Adults. C-E, Eggs and egg mass. F-H, Larvae. I, Pupa.

Variegated cutworm. A-B. Adults. C-E. Eggs and egg mass. F-H. Larva. I. Pupa.

Vegetable Weevil

Vegetable weevil, *Listroderes costirostris obliquus* (Klug), Curculionidae, COLEOPTERA

DESCRIPTION

Adult – The female adult weevil is about 6.4 mm long with a short, stout snout. It is dull grayish-brown with a light V-shaped mark on the wing covers.

Egg – The egg is elliptical, 0.5 mm in diameter, and creamy white when first laid. It becomes black before hatching.

Larva – The pale green, legless larva has a dark mottled head and is about 1 cm long when fully grown.

Pupa – The pupa is pale yellow at first and later turns brown. It is similar in shape to the adult, with snout, legs and wing pads folded vertically along the body. It is about 7.9 mm long.

BIOLOGY

Distribution – The vegetable weevil, originally from South America, was first reported in this country in 1922. It now occurs in the Gulf and southern states and in Oklahoma, Arizona, and California. In North Carolina the vegetable weevil occurs throughout the state but is generally more common in the southern Coastal Plain.

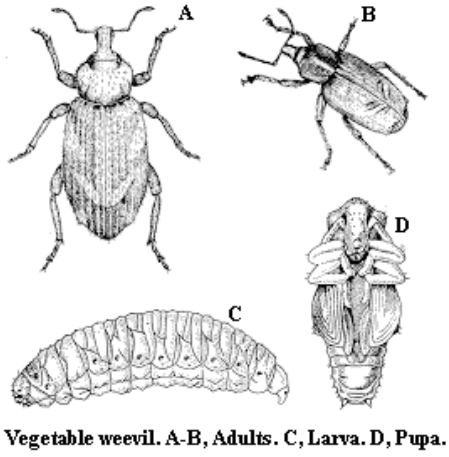
Host Plants – The vegetable weevil feeds on a wide range of cultivated crops: turnip, carrot, collards, mustard, tomato, potato, tobacco, clary sage, and also a number of weeds.

Damage – Larval and adult vegetable weevils attack foliage and roots of a number of vegetable crops, often injuring seedlings or newly set plants. Plants attacked underground are usually large-rooted crops like carrot and turnip. When larvae feed on buds, growth may be stunted. Irregularly shaped holes in the leaves are indicative of this pest.

Life History – The adult vegetable weevil is active during fall, winter, and spring and aestivates (enters dormancy) during the summer in trash, leaves or grass at the edge of fields. Reproduction is parthenogenetic (no males, females lay eggs which develop into females) and some individuals may live 2 years. After coming out of aestivation, adults feed for several days to a month before depositing eggs on turnips or collards. Oviposition begins in fall and may continue into spring of the next year. Hatch occurs after an incubation period of 2 or more weeks depending on the temperature. Larvae feed on various crops and become full grown in 23 to 45 days. They then excavate earthen cells in the soil and pupate. Pupation, which may occur in spring or in fall and late winter, lasts from a few days to 2 weeks depending on temperature. Adults emerge from January to June. The length of time from egg hatch to adult emergence may vary from 1 to 4 months. There is one generation per year.

CONTROL

Cultivation in fall and winter is important in reducing populations. Insecticides are also available for control of the vegetable weevil. For specific recommendations, consult the current *North Carolina Agricultural Chemicals Manual*.



Vegetable weevil. A-B, Adults. C, Larva. D, Pupa.

Vegetable weevil. A-B. Adults. C. Larva. D. Pupa.

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Other Publications in Insect and Related Pests of Vegetables

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Postharvest Cooling and Handling of Cabbage and Leafy Greens

NC STATE EXTENSION

Postharvest Cooling and Handling of North Carolina Fresh Produce

Freshness Facts

Preferred cooling method:	Room cooling, hydrocooling, and icing (Icing is suitable for leafy greens only)
Optimum temperature:	32°F
Freezing temperature:	30°F
Optimum humidity:	95%
Storage life:	Cabbage – 2 to 3 months; Leafy greens – 1 to 2 weeks

Cabbage and leafy greens (collards, kale, mustard greens, and turnip greens) are important commercial vegetable crops in North Carolina. Although growers in the state supply only about 4 percent of United States cabbage production, during the month of June they produce one-fourth of the domestic supply. Leafy greens are shipped from the state year-round, but the bulk of the crop is shipped in late spring and early summer. Mishandling can easily damage these crops, but most serious postharvest losses can be prevented. Careful attention to proper postharvest handling can ensure buyer satisfaction and marketing success. This publication has been prepared to acquaint growers, packers, and shippers of cabbage and leafy greens with proper postharvest handling procedures.

Harvesting

Cabbage

Although there have been occasional attempts to harvest cabbage mechanically, almost all North Carolina fresh-market cabbage is harvested by hand. Machine harvesting is much faster than hand harvesting, but unless extreme care is taken, machine harvesting can result in significant damage to the cabbage. For this reason, mechanically harvested cabbage may be better suited for processing than for the fresh market. Machine-harvested cabbage intended for the fresh market must be unusually uniform in size and maturity.

A mature head of cabbage generally weighs from 3 to 5 pounds, depending upon variety. Cabbage should be harvested promptly when the heads are firm and mature. Delaying harvest even a few days beyond maturity can result in split heads and increased incidence of field disease. Unharvested cabbage may develop significant infestations of alternaria leaf spot and downy mildew, particularly during wet weather. These diseases can be spread through normal harvesting and handling. Harvesting immature heads, however, reduces yield, and the heads are too soft to resist handling damage. Immature heads also have a shorter shelf life than mature heads.

Field workers have a major influence on quality. They should be made aware of the importance of good sanitation practices, be properly instructed in selecting for maturity, and be cautioned against handling cabbages roughly. An experienced picker should be able to determine the level of maturity quickly and consistently by feel and by the size of the head. The head is harvested by bending it to one side and cutting it with either a Russel knife or a common butcher knife. Harvesting knives should be sharpened frequently to reduce effort and lessen picker fatigue. The head should not be removed by snapping or twisting it since this practice damages the head and results in inconsistent stalk length and trim. Broken stalks are also more susceptible to decay.

The stalk should be cut flat and as close to the head as possible, yet long enough to retain two to four wrapper leaves. Extra leaves act as cushions during handling and may be desired in certain markets. Yellowed, damaged, or diseased wrapper leaves should be removed, however. Heads with insect damage and other defects should be discarded. It is essential that heads not harvested be left undamaged because fields may be harvested as many as three times for maximum yield. Harvested cabbage can be placed in bags, boxes, wagons, or pallet bins, depending on the harvesting method employed.

Harvesting aids can significantly reduce harvest labor costs, improve harvest efficiency and cabbage quality, and speed the harvest operation dramatically. Aids may be as simple as a modified farm trailer for transporting cabbage and boxes or as sophisticated as a self-propelled unit costing thousands of dollars. The more complex machines conveniently integrate and automate most of the harvesting and packing functions into a single unit. An effective but simple harvesting aid employs a simple belt conveyor attached to a tractor that slowly passes through the field alongside the pickers. Workers place harvested heads on the conveyer belt, which carries the heads to a bulk bin, wagon, or even a mobile packing station. The conveyer can be a homemade conversion of a grain conveyer or a factory-built model especially designed for cabbage harvesting. When equipped with a canopy and high-flotation tires, a harvesting aid can be operated during rainy weather.

Collards and Other Greens

Collards can be harvested as leaf-collards, in which case only leaves of the proper size and maturity are harvested, or as head-collards, in which case the entire plant is taken. Leaf-collards can be packed loose or gathered into bunches of 8 to 12 leaves and secured with a rubber band. Head-collards are seldom bunched. Head-collards are usually harvested when plants have 16 to 20 mature leaves. Leaves that show cold injury, yellowing, mechanical injury, or insect damage should be discarded. It is essential that all leaves be of high quality and uniform in color. Collards intended for machine harvesting are normally planted very close together (much closer than when head-collards are desired) and harvested at the four- to eight-leaf stage.

Turnip greens, mustard greens, and kale may also be harvested as single leaves or as whole plants. Leafy greens are still predominantly harvested by hand in North Carolina. However, machines are available that cut and gather greens into bulk containers. Fields are usually harvested several times,

but care must be exercised to prevent damage to the plants. At the packing shed, the greens are removed from the bulk containers onto a grading belt for cleaning, sorting, and packing.

Postharvest Handling

Harvested produce should always be removed from direct sunlight and transported to the packing shed as soon as possible. Cabbage and leafy greens are particularly susceptible to wilting and other damage from high temperatures. When there is a delay of more than an hour or two between harvest and packing, a water drench or spray arrangement can help prevent dehydration and overheating.

Cabbage

Cabbages are generally packed in 50-pound fiberboard cartons, 50- to 60-pound wire-bound crates, or mesh bags. The industry has been slowly abandoning the mesh bag in favor of cartons or crates because bags offer only minimal protection from rough handling. Cartons and crates are also easier to palletize. A recent market innovation is the shipping of cabbage in heavy fiberboard bulk pallet bins holding 500, 750, or 1,000 pounds, as shown in Figure 1. Some specialty cabbage (such as red, savoy, and Chinese types) are packed in 25-, 30-, or 40-pound cartons, depending upon market preference. Uniformity and the proper count per carton are important; 18 to 22 heads per 50-pound carton is customary.

Proper packing and cooling are essential to maintaining the freshness of cabbage. Freshness can be tested by rubbing two heads together; if they are fresh, they will make a squeaking sound. Cabbage should be cooled immediately after packing. A refrigerated room controlled to 32°F and 95 percent relative humidity is ideal. In this environment, the center of a medium-sized cabbage should take about 18 hours to cool from 80 to 36°F. It is usually not necessary to cool cabbage by more rapid means, although some packers use forced-air cooling fans to greatly decrease cooling time. For more information on forced-air cooling, refer to Extension publication AG 414-3, *Maintaining the Quality of North Carolina Fresh Produce: Forced-Air Cooling*.

Greens

Greens that have been harvested during rainy weather or harvested by machine often are contaminated with soil. They are normally washed in fresh water or in water chlorinated at 75 ppm before they are graded and packed. (For more information on chlorination, refer to the current *North Carolina Agricultural Chemicals Manual* and Extension publication AG 414-4, *Maintaining the Quality of North Carolina Fresh Produce: Hydrocooling)*.

Mustard greens, turnip greens, and kale are banded into 1-pound bunches or packed loose into 21- or 24- pound cartons or wire-bound crates. Leaf-collards can be treated similarly. Head-collards are usually packed with 8 to 16 bunches per container. Leaves that have yellowed, show signs of disease, or have other obvious defects should be discarded.

Rapid cooling either by hydrocooling alone or in combination with package icing is essential to maintaining the quality of leafy greens. For more information on icing, refer to Extension publication AG 414-5, *Maintaining the Quality of North Carolina Fresh Produce: Crushed and Liquid Icing*. Greens may be held in refrigerated storage under ideal conditions for as long as two weeks. Southern-grown cabbage has been held in common cold storage for two to three months. The use of controlled atmosphere storage has been shown to extend this period somewhat. Cabbage and all

types of leafy greens freeze at about 30°F and are sensitive to ethylene gas. These items should not be stored or shipped in proximity to fruits and vegetables that are known to produce ethylene, such as apples, pears, peaches, or tomatoes.

Figure 1. Bulk pallet bin of cabbage in the packing house.

Marketing

To market a crop successfully, producers must always be aware of the supply and demand, which vary with season and locality. Although per capita consumption of vegetables in the United States increased nearly 30 percent between 1980 and 1990, cabbage consumption apparently declined somewhat. In 1990, cabbage farm cash receipts were 18 percent lower than 1980 levels, and interstate shipments of cabbage to selected major markets were about 20 percent below 1980 levels. It is estimated that North Carolina cabbage production decreased 10 percent during that decade. California, Florida, and Texas remain the dominant cabbage supply areas, providing nearly 60 percent of the nation's supply.

United States production and consumption of leafy greens have increased somewhat in recent years, and import competition has intensified. North Carolina collard and leafy greens production increased 40 percent between 1980 and 1990, with most production occurring in the eastern part of the state. Peak supply availability for greens usually occurs during the winter season, with California, Georgia, and Texas leading in production. To gain and retain a market for their crops, cabbage and greens producers need to reduce cost per unit and offer buyers improved quality by using proper postharvest practices, such as cooling and strict quality control. A market window may exist for summer marketing of cabbage grown in the mountains. Supply is smallest and grower prices are highest for cabbage and leafy greens during the summer months. A prudent grower always makes marketing and postharvest handling arrangements before planting.

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Crushed and Liquid Ice Cooling

NC STATE EXTENSION

Postharvest Technology Series

In a competitive market, produce buyers demand the highest quality products. For many fresh fruits and vegetables, rapid and thorough cooling immediately after harvest is essential to preserving quality.

Ice has been used since early times to remove heat rapidly from food and to extend its shelf life. It is the preferred cooling method for many types of extremely perishable produce items. Ice not only removes heat rapidly when first applied to produce but, unlike other cooling methods, continues to absorb heat as it melts. Crushed and liquid ice cooling methods can be used effectively by growers with both small and large operations.

This publication is intended to help growers, packers, and shippers of fresh produce make informed decisions concerning the application of crushed and liquid ice cooling. Included are discussions of icemaking equipment and ways to purchase ice, types of produce that may be suitably iced, various produce-icing methods, how to calculate the amount of ice required to cool a given amount of produce, and the economic considerations of cooling with ice.

Choosing the Best Cooling Method

Crushed or liquid icing may be used on a variety of fresh produce. Icing is particularly effective for perishable items that cannot be readily cooled by other methods. Top icing a truck loaded with already cooled produce is a good way to provide additional assurance that the load will arrive properly cooled. However, icing in any form is not recommended for all types of fresh fruits and vegetables. Some items like strawberries, blueberries, and brambles cannot tolerate wetting. Other items, such as squash and tomatoes, can be injured by chilling to near freezing. Some produce items that can be successfully iced: asparagus, cauliflower, broccoli, green onions, cantaloupes, leafy greens, carrots, sweet corn.

For a complete list of produce items commonly grown in North Carolina and their recommended cooling methods, refer to Extension publication AG 414-1, *Proper Postharvest Cooling and Handling Methods*.

Block Ice

Until about 50 years ago, all commercially produced ice was made in rectangular blocks weighing about 300 pounds each. Block ice is still widely available during most of the year. However, occasionally during the peak of harvest season in North Carolina the demand for block ice may exceed the supply. During periods of shortage, block ice may be trucked into North Carolina at a much higher price reflecting, in part, the increased transportation cost.

Block ice is produced by much the same method used when refrigeration was introduced early in the twentieth century. Rectangular metal cans approximately 11 inches wide, 22 inches long, and 42 inches deep are filled with water and spaced in regular rows about 4 inches apart on the floor of a

shallow pool. This pool is filled with brine, which is chilled to approximately 15°F and circulated past the cans. It often takes as long as four days to completely freeze the water in the cans. The technology for producing block ice is relatively inefficient in energy use and costly in terms of both equipment and labor. Block ice plants have been gradually replaced by the more efficient chip or flake ice plants. Because of its large volume-to-surface-area ratio, however, block ice can be trucked long distances or held for a considerable time without refrigeration and without appreciable loss from melting.

Availability of Ice on the Farm

Modern chip or flake ice makers are several times more energy efficient than block ice-making equipment and require much less labor. Unfortunately, chipped or crushed ice cannot be stored or transported in the large bulk lots required for produce cooling because it refreezes into a solid mass, making it difficult to use. However, when on-site ice making is not economically justified, as is the case for some short-season agricultural operations or small-volume growers, the purchase of ice in block form may be the only economical alternative.

When faced with an uncertain supply of expensive block ice, some moderate- and large-scale growers have opted to install their own ice-making equipment. The decision to purchase ice-making equipment should be made only after thoughtful consideration of both the benefits and costs. (See the section on Economics of Ice Cooling.) On-farm ice makers are often situated over or near an insulated enclosure or bunker that has sufficient storage capacity to hold one or two days' production of ice. Chipped ice stored for more than a day or so will freeze together into a solid mass. Therefore, both the ice maker and the ice bunker must be correctly sized to maximize utilization and minimize cost. A number of equipment manufacturers are now marketing ice makers and ice storage bunkers as modular units designed specifically for on-farm postharvest icing operations.

Containers

Many types and sizes of fresh produce containers can be used successfully with iced produce. Popular types include waxed fiberboard cartons; wooden wire-bound crates, baskets, and hampers; and perforated plastic liners. Any container that will retain its strength after wetting can be used satisfactorily with ice. Waxed fiberboard cartons are particularly well suited for icing operations. They have minimal openings, they offer some insulation to help reduce the rate of melting, and their strength is unaffected by wetting.

Ice Crushers

Block ice and some chip or flake ice must be crushed before it can be used for icing. Pieces of ice should be no larger than $\frac{3}{8}$ inch so that they will penetrate the voids in the produce package. Also, small pieces of ice are much less likely to cause mechanical damage to the produce than large pieces. Electrically powered ice crushers can crush large blocks of ice to a suitable fineness. Some ice crushers are equipped with a blower that allows the ice to be distributed onto or over a load of produce.

Ice crushers can be extremely dangerous when improperly used. Anyone using a crusher must be properly instructed in its safe use, and all guards and safety devices must be in place. All electrical equipment, including ice crushers, should be equipped with an approved electrical ground.

Icing Methods

Individual Package Icing

The simplest icing method is to add a measured amount of crushed ice manually to the top of each carton filled with produce. This method is sufficient in many instances but can result in uneven cooling because the ice generally remains where it was placed until it has melted. Because each carton must be opened, iced, and reclosed, the process is slow and labor intensive. Individual package icing has been automated to some extent by ice-dispensing devices and the use of package conveyors and roller benches. Individual package icing is usually not considered for high-volume production.

Liquid Icing

Sometimes known as slush icing, liquid icing is the preferred method when large amounts of produce must be iced in a relatively short period of time. The required equipment consists of an ice crusher, a slurry tank with mixer, a pump, and delivery hoses.

In the simplest form of liquid icing, a mixture of water and finely crushed ice is pumped into open containers traveling along a conveyor under an injection nozzle, as shown in Figure 1. This method is a significant improvement over hand icing because the water carries the ice into the voids throughout the package, thus bringing it into greater contact with the produce.

Liquid icing may be considered a hybrid of package icing and hydrocooling. The chilled water in the slurry has a pronounced cooling effect on the produce. In the liquid icing of broccoli, it has been estimated that as much as 40 percent of the total product cooling is accomplished by the water alone. The balance of the cooling is accomplished by the ice as it melts inside the carton.

If the produce has been packed and palletized in the field, the water and ice mixture can be alternatively pumped from a hose into the hand openings of each container, as shown in Figure 2. This method is fast and effective, and it does not require that the cartons be opened or removed from the pallet. With the proper equipment, two workers can liquid ice a pallet of 30 cartons in about 5 minutes.

An even faster and more automatic method for liquid icing of palleted produce has been developed, as shown in Figure 3. A pallet of filled cartons is placed inside a metal enclosure that is rapidly filled with a slurry of water and ice. The water and ice penetrate all the voids in the cartons. After the enclosure is entirely filled, the excess slurry is drained away, leaving the ice inside the cartons. An automatic pallet-icing operation can be controlled by the lift truck operator alone.

The equilibrium temperature of a mixture of melting ice and water is 32°F. Users of liquid icing have occasionally added salt (sodium chloride) to the slurry in an attempt to lower its temperature and effect faster cooling. Adding 40 pounds of salt per hundred gallons of slurry will lower the temperature to approximately 27°F. However, this 5°F reduction in temperature will not reduce cooling time significantly. Furthermore, the brine solution may cause the produce to lose more water (wilt more) than is acceptable. Therefore, many produce buyers strongly discourage this practice. The brine solution may also contribute to the corrosion of the icing equipment.

Liquid icing is an excellent cooling method, although it does wet the produce. The surface of warm, wet produce provides an excellent site for postharvest diseases to develop. Therefore, it is essential that, once iced, produce not be allowed to rewarm. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, or abrasions) is

particularly susceptible to postharvest diseases. To help reduce the spread of postharvest diseases, the *North Carolina Agricultural Chemicals Manual* recommends the use of chlorine as a disinfectant at a rate of 55 to 70 parts per million. Chlorine to be used in hydrocooling water can be purchased in the form of a sodium hypochlor-ite solution (for example, Clorox) or as dry, powdered calcium hypochlorite. For a thorough discussion of chlorination, refer to the Extension publication AG 414-6, *Chlorination and Postharvest Disease Control*.

Top Icing

Top icing is the placing of a 2- to 4-inch layer of crushed ice over the top of pallets of precooled produce. Trucks loaded with precooled fresh produce, such as hydrocooled sweet corn, are frequently top iced just before shipment. Top icing can add considerably to the shipping weight of the load. Top icing a 40-foot trailer can require 8,000 pounds of ice. It has been previously supposed that as the top ice melts, the chilled water would trickle down through the load to continue the cooling process. Tests have shown, however, that top icing affects only the uppermost layers of produce. Furthermore, the chilled water from the melting ice often passes through spaces between the cartons and pallets with little cooling effect. In general, top icing provides little additional cooling and is useful only in preventing an increase in temperature.

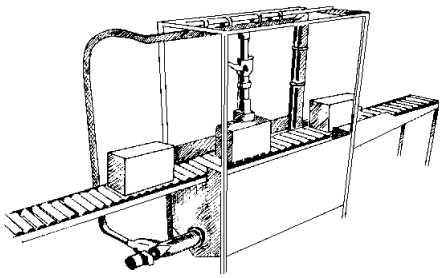

Figure 1. Liquid icing single cartons of produce.

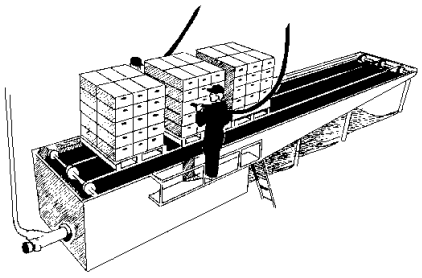

Figure 2. Injecting liquid ice into palletized broccoli cartons through the hand openings.

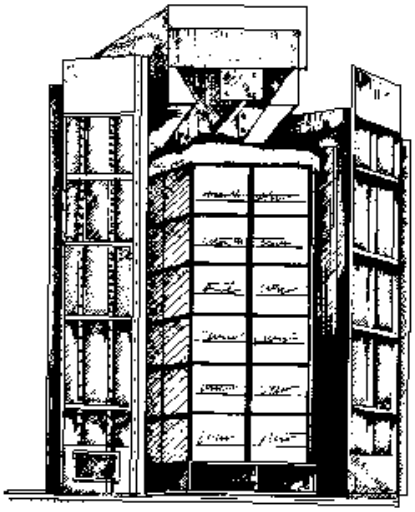

Figure 3. Automated pallet icing.

Calculating Ice Requirements

Ice may be considered a type of stored thermal energy. The melting of 1 pound of ice will absorb 144 Btu of heat. It has been shown that in most commercial icing applications, however, only about one-fourth to one-half of the ice is actually used to cool the produce. The rest is melted by the outside heat that passes through the sides of the container.

As an example of how to calculate the amount of ice needed to cool a given amount of produce, consider the icing of broccoli. Broccoli is an extremely perishable crop and is one of the most commonly iced fresh vegetables. Most buyers require broccoli to arrive with ice inside the container as proof of sufficient and continuous cooling. Broccoli is frequently packed in cartons containing approximately 20 pounds of product. Cooling 20 pounds of broccoli from 85°F to 45°F requires the removal of approximately 800 Btu of heat. Assuming that during shipping and handling another 1,000 Btu would enter the container from the outside, the total heat load per carton would be 1,800 Btu. Therefore, the minimum amount of ice required to provide proper cooling would be:

1,800 Btu/carton ÷ 144 Btu/pound of ice = 12.5 pounds of ice/carton

In actual practice, approximately 16 pounds of ice is required for each 20-pound carton of broccoli. The additional ice ensures proper cooling under extraordinary conditions. If the liquid icing method is used, another 10 pounds of ice per carton may be required to cool and maintain the water in the slurry at a low temperature. In this example, therefore, a total of approximately 26 pounds of ice would be required to properly cool each 20-pound carton of broccoli.

Economics of Ice Cooling

Most fruit and vegetable growers and handlers know that some postharvest losses will occur in the normal course of producing, packing, and marketing perishable products. A relevant question is, Can these losses be economically reduced? To answer that question, the extent of physical and economic losses, along with the cost of their remedy, must be precisely determined. For example, if the extent of postharvest loss from lack of proper cooling is large but the cost of installing and operating an icing facility is minimal, then precooling is likely justified. On the other hand, if postharvest losses are small, then even low-cost equipment might not be economically feasible.

A second question is whether the loss is directly related to lack of cooling or is due to other reasons, such as oversupply, improper harvesting, carelessness in grading, or poor marketing. Icing equipment can do little to control losses not related to cooling.

A third question is whether the initial investment costs and system operating costs of an icing system are less than the benefits expected from icing the produce. That is, does the sum of the market value of the produce saved or the price premium received for precooled product exceed the annualized cost of cooling? A final question is whether the volume of product handled matches the type of precooling system considered. For example, a high-volume grower or handler may discover that use of a hydrocooler is more cost effective than package icing.

Beyond economic considerations and the physical characteristics of the produce to be cooled, marketing traditions also influence the type of precooling method used. While either hydrocooling or package icing are recommended practices for cooling sweet corn, broccoli, and leafy greens, most wholesale buyers expect loads to arrive with ice visible inside the shipping carton. Similarly, while it is permissible to package ice or top ice cantaloupes, buyers seem to prefer hydrocooled cantaloupes over iced loads. (However, icing is preferred to no cooling.) When alternative precooling methods are possible, economic considerations and buyer traditions should both be considered.

For many small- to moderate-volume growers and for producers of short-season fruit and vegetable crops, icing provides a low-cost precooling option. Initial investment and operating costs can be obtained by requesting price quotes from the companies that supply icing equipment.

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