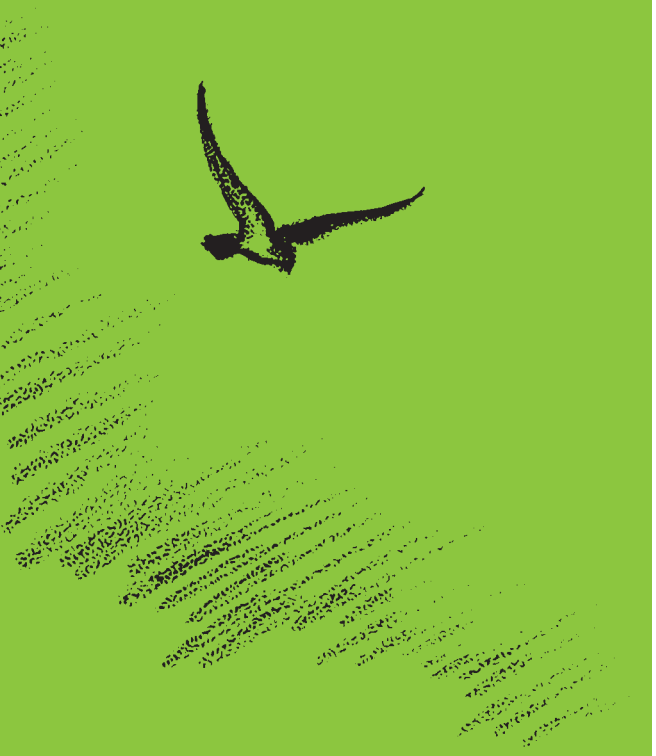
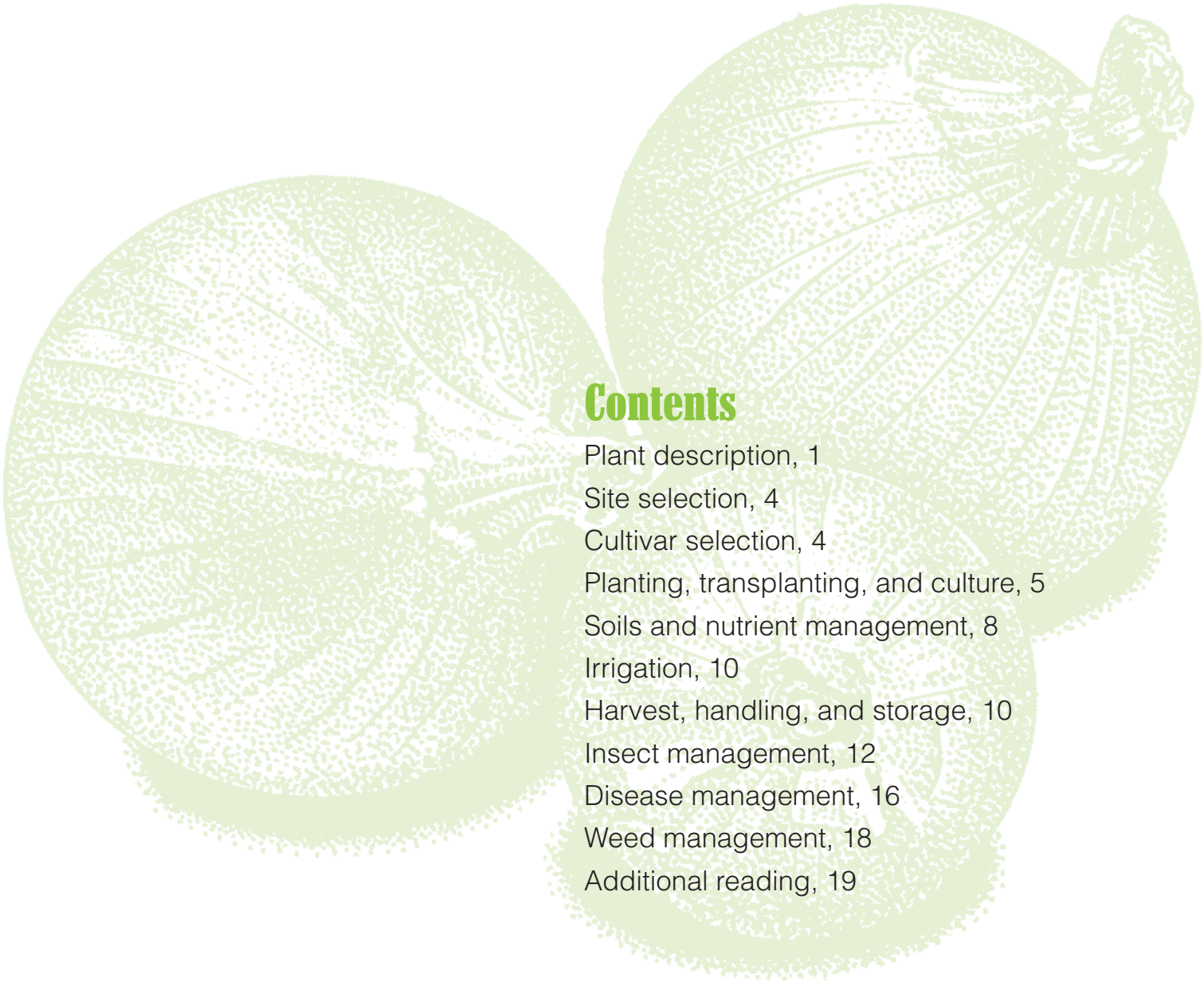
A3785



Growing onions, garlic, leeks, and other alliums in Wisconsin

A guide for fresh-market growers

K.A. Delahaut
A.C. Newenhouse



Contents

Successful fresh-market gardening involves more than just a talent for growing high-quality vegetables. You also need to find a market for them. Before you start, visit other growers, develop a marketing plan, and evaluate the feasibility of your proposed business. Think about what is unique about your product. Are you promoting the product for taste, freshness, health benefits, value-added, or time of availability? For assistance determining your market, consult with your county Extension agent or refer to Extension publication *Direct Marketing of Farm Produce and Home Goods* (A3602).

Onions and garlic offer plenty of marketing opportunities since these crops can be sold at different stages of growth, their harvest dates are flexible, they can be stored, and value-added products such as onion and garlic braids can bring more sales. Onions and garlic are staple ingredients in cooking and their health benefits have been touted for centuries. If you grow different types of alliums (members of the onion family) such as sweet onions, storage onions, green onions, or scallions, you can extend your harvest season from early spring through late fall. For example, you can plant onion or scallion seeds in late summer for a green onion crop in the fall, or to transplant the sweet bulbing onions the following April for harvest when mature in June.

Vidalia onions

Onions grown on soils low in sulfur have low pungency. In Vidalia, Georgia, soils are naturally leached of sulfur and therefore the sweet types of onions grown there (Granex types) have low pungency. By federal law, only Granex types of onions grown in Vidalia, Georgia can be called "Vidalia onions." Sweet Spanish onions grown in the north can be just as sweet.

Plant description

Onions, garlic, leeks, chives, shallots, and other members of the onion family are commonly grown in fresh market gardens. Plants in the family Alliaceae (previously Amaryllidaceae) are native to central Asia and derive their characteristic flavor from the enzyme alliinase that acts on sulfur compounds. Onions and other alliums contain simple sugars such as glucose, fructose, and sucrose.

Onions have been used for thousands of years. They have been identified in drawings on Egyptian tombs dating back to 2800 B.C. Onions continue to be prized for their medicinal value derived from sulfur compounds which have antimicrobial and antifungal properties, and for their high anti-platelet activity which thins the blood if onions are eaten raw. Historically, onions have also been used to control dysentery. Garlic has been used in middle Asia, Egypt, and the Mediterranean as far back as 2000 B.C. Leeks are thought to have originated in the eastern Mediterranean and records of leek cultivation date back to biblical times.

All plants in the Allium family are herbaceous, cool-season, biennial vegetables that are grown as annuals. Root systems are fibrous and shallow with all roots arising from a basal plate, including a few lateral roots. Members of this plant group have fleshy basal leaves that can be tubular or slightly flattened.

Bulbs form from enlarged leaf bases called scales. A combination of day length and temperature triggers bulb formation. High temperatures favor bulbing once a critical day length has been reached. Since yield is determined by the number of leaves present at bulb initiation, early planting ensures the maximum number of leaves and the largest bulbs.

When temperatures fall below 50°F, stems begin to elongate and flowering will occur. Long days alone will not induce flowering, but will speed up stem elongation. Flowers are radially symmetrical and are perfect (have both male and female flower parts). Individual flowers are borne in spherical umbels comprised of as many as 1000 flowers. Allium flowers are pollinated by insects.

2

Onions

Onions (*Allium cepa* var. *cepa*) are classified as either short-day, intermediate, or long-day cultivars according to the number of hours of light required to initiate bulb formation. Long-day onions grown under short-day conditions form leaves but not bulbs. Short-day onions grown under long-day conditions form small bulbs early. Long-day onions are grown in Wisconsin, requiring daylengths of 14 hours or longer to initiate bulbs. Long-day onions can be grown for immediate consumption or long-term storage. Typically, onions described as sweet should be eaten soon after harvest and onions described as dry can withstand prolonged storage. Short-day onions such as Bermuda onions cannot be grown in Wisconsin or areas at more than 30° latitude. Long-day onions are usually more pungent than their short-day relatives. Other factors affecting pungency include characteristics of the specific cultivar along with environmental conditions such as temperature, soil pH, and moisture extremes. Environmental conditions can also affect foliage size and color, bulb formation and size, bulb splitting, scale color and thickness, seed stalk formation, and storage quality. Onions may be spherical, flattened, or conical in shape and have skin colors ranging from white to yellow or brown, and red to purple. Bulb shape and size may also be related to the length of the growing period with rapid growth resulting in elongated bulbs while long growing periods produce larger bulbs. Multiple bulbs occur when lateral buds sprout in the leaf axils.

Green onions are actually immature true onions. They are harvested before bulbing has begun.

Scallions (sometimes called bunching onions) never form a bulb despite environmental triggers that will initiate bulb formation in other cultivars.

Japanese bunching onions (*Allium fistulosum*) are similar to scallions in that they do not form bulbs. They are very hardy and can be seeded in late summer to be overwintered and harvested in spring.

Multiplier onions belong to the *Allium cepa* var. *aggregatum* group and form 4–5 bulbs enclosed within a single leaf sheath. The bulbs of multiplier onions have a similar use in cooking as shallots while the green tops can be eaten like green onions.

Shallots (*Allium cepa* var. *ascalonicum*) resemble small true onions but develop a small cluster of bulbs rather than a single bulb. They are harvested when the bulbs are about 2 inches in diameter and are prized for their delicate, subtle flavor.

Pearl onions are not true onions but a member of the species *Allium ampeloprasum* which contains the leeks. They are short-day onions grown under long-day conditions so they only form a single storage leaf.

Summer mini onions or **cipollini** (*Allium cepa*) are mild and sweet small early onions that are planted in early spring. They're harvested when approximately golf ball sized, 60 days later.

Table 1. Nutritional information for onion, garlic, and leeks

Nutrition facts	Onions	Garlic	Leeks
Serving size	1 cup, cooked	3 cloves, raw	¼ cup, cooked
Calories	92	13	8
Protein	2.8 gm	0.5 gm	0.2 gm
Carbohydrates	21 gm	3 gm	2 gm
Fat	0.4 gm	0 gm	0 gm
Vitamins and minerals	Vitamin C—11 mg Folate—31mg Potassium—348 mg	Potassium—36 mg Phytochemical—allicin	Potassium—23 mg Anticarcinogen—diallyl sulfide

Garlic

Garlic (*Allium sativum* var. *sativum*) is a cool-season, hardy perennial made up of multiple cloves. Of all alliums, garlic prefers warmer conditions for optimum growth. Each clove is comprised of one papery leaf and a second, thickened storage leaf which makes up most of the clove. Individual cloves arise from axillary bulbs. Unlike the hollow, tubular leaves of onion, garlic leaves are solid, flattened, and folded. The leaves of garlic also do not serve as storage organs as do onion leaves. Garlic rarely produces flowers, but it forms bulbils or small bulbs at the top of a flower stem called a scape.

There are two types of garlic cultivars: hardneck and softneck. Hardneck cultivars are more cold hardy and have a milder flavor than softneck and are the most sought-after gourmet varieties. They are derived from wild garlic and will, under the right conditions, produce a flower stalk with fertile flowers. The flower stalk hardens to make a stiff "neck." Softneck garlic produces higher yields, has better storage qualities, and a stronger flavor than hardnecked garlic but doesn't do as well in Wisconsin's climate. Cold winters and heavy rains before harvest lower the quality of softneck garlic. Softneck garlic does not produce flowers and must be propagated vegetatively. The stems of softneck garlic can be braided.

Elephant garlic

Elephant garlic (*Allium ampeloprasum* var. *holmense*) is a form of leek that produces a mild-flavored bulb resembling a giant garlic.

Leeks

Leeks (*Allium ampeloprasum* var. *porrum*) are robust, winter-hardy biennials that do not form a hard bulb like onions or garlic. Instead, they are grown for their long, thick white stem. Leaves are solid, flat, and folded like the leaves of garlic. The leaves arise from the basal stem and are borne opposite each other with new leaves arising above the previous one. Leeks are sweeter than onions and have a creamy texture when cooked. They are used to flavor soups and stews.

Chives

Chives (*Allium schoenoprasum*) are a perennial grown primarily as an herb. The plant forms an herbaceous mound that produces flowers annually. Chives never develop usable bulbs.

Wild leek or ramp

Wild leeks, or ramps, (*Allium tricoccum*) are found in Wisconsin's rich, moist woods, in the eastern mountains of North America, as far west as Minnesota, and north to Canada. Ramps are perennial plants with two to three lily-like leaves 6–18 inches tall. The leaves are scented like onion or leek and the bulb has a sweet flavor that is similar to but less potent than garlic. Flowers are white to creamy yellow and bloom from June to July after leaves wither. Native Americans used ramps in cooking, and their sweet flavor continues to be prized by consumers and restaurant cooks.

Site selection

Onions and their relatives require full sun and grow best on muck soils (containing at least 20% organic matter), and irrigated sandy soils. They tend to perform poorly on heavy clay soils. Soil pH should be 6.0–6.8. Some vegetables, such as beets or cole crops, reduce soil pH and should not be planted immediately before alliums in a rotation unless you adjust the soil pH prior to planting. Alliums are shallow rooted so they tend to dry out quickly and are also sensitive to waterlogged conditions. Choose well-drained soils with a good moisture-holding capacity unless you plan to irrigate during dry weather.

Prepare new sites at least one season before planting alliums. Green manure worked into the soil increases the amount of organic matter thereby improving the quality of the crop grown. As with all root crops, the soil should be free of weeds and rocks before planting.

Grow leeks on deep soils to allow for the trenches necessary to blanch them.

Cultivar selection

Refer to table 2 for a list of some suggested cultivars for Wisconsin.

Onions

Onions are bred for flavor, sugar content, storage quality, size, shape, color, adaptability to different growing conditions, and early maturity. Breeders also select for disease resistance and yield.

Garlic

Garlic is bred for winter hardiness, productivity, flavor, disease resistance, and nutraceutical qualities such as blood thinners and other beneficial health effects.

Leeks

Leek breeders select for size and shape of the stalk, hardiness, disease resistance, and early maturity.

Table 2. Recommended cultivars

Onion	Garlic	Leek
White	**Softneck**	American Flag
Evergreen White Bunching	California White	Giant Musselburg
Super Star (Spanish)	Inchelium Red	King Richard
Sweet Spanish	New York White	Otina
Walla Walla (sweet)	Polish White	Pancho
Yellow	Silver Rose	
Candy (sweet)	**Hardneck**	
Copra (storage)	Chesnok Red	
First Edition (storage)	German Extra Hardy	
Yellow Sweet Spanish	Killarney Red	
Red	Music	
Mars (storage)	Russian Red	
Mercury (storage)	Siberian	
	Spanish Roja	

Note: Choose cultivars according to your own situation and needs. Consider what your market demands, the length of your growing season, your soil, pests, diseases, irrigation, cultivars other growers like, and cultivars you personally like. When trying a new cultivar, do not use it exclusively. Grow new trials next to old standbys so you may compare the characteristics objectively.

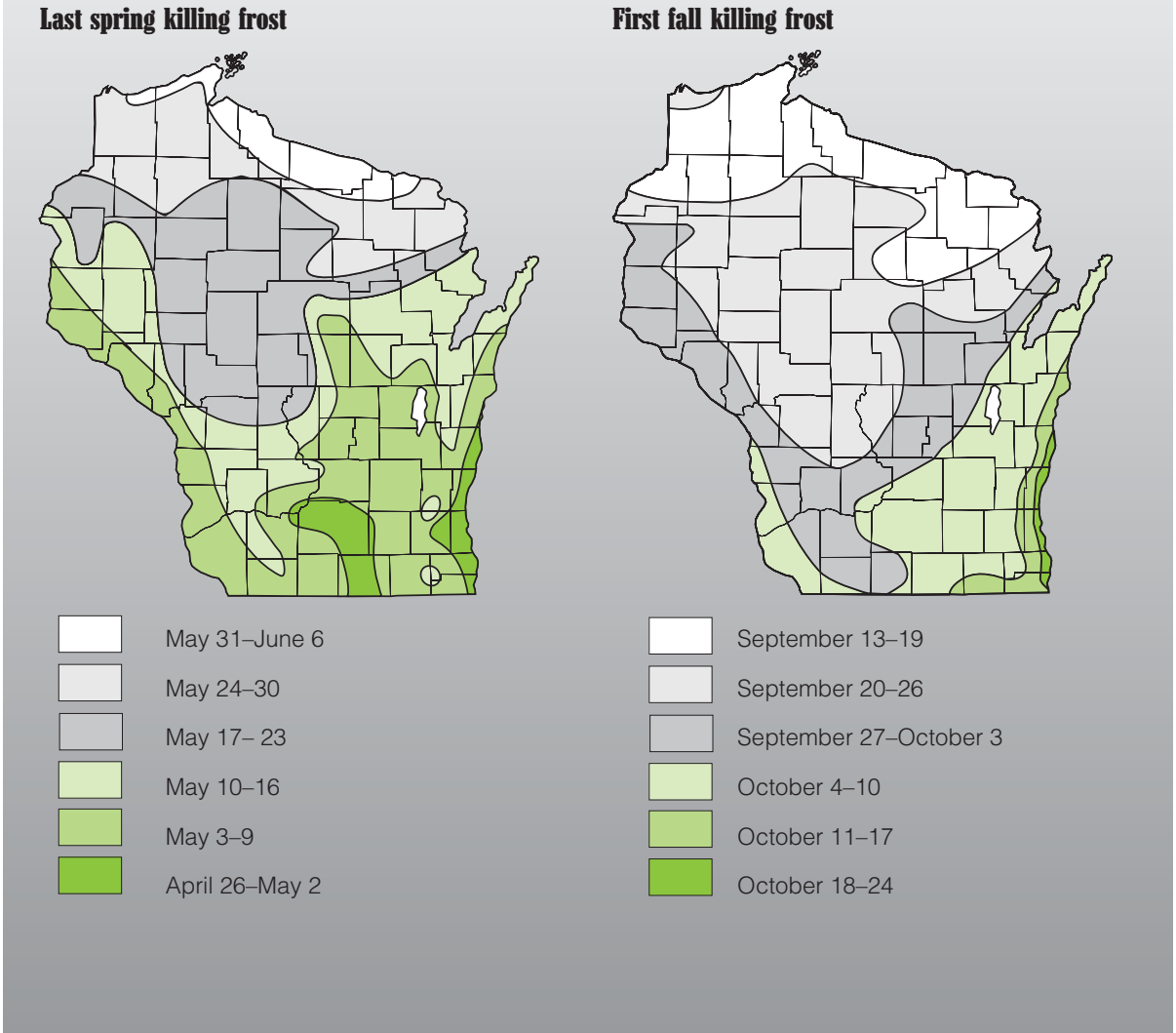
Planting, transplanting, and culture

Onions may be grown from seed, sets, or transplants. Precision seeding has made controlled plant spacing easier and has improved the survival rate of pre-germinated seed. Since most onions require a long growing season, growers usually raise onions from transplants rather than direct seeding. You can start your own seedlings or purchase them from a dealer. Planting onion sets is not recommended for market-quality onions. Sets are the second year's growth of storage varieties or multiplier onions and therefore tend to be less sweet than other onions. In addition, they may bolt or go to seed early.

Starting seeds

Plant onion seeds in a greenhouse or under lights indoors in late January or February, 10–12 weeks before the last frost date in your area (see figure 1). Use a sterile potting mix that contains compost, peat, or sphagnum to retain moisture; vermiculite or perlite for aeration; and mineral and nutrient sources to encourage growth after the first roots form. Prevent bacterial and fungal infections by sterilizing transplant trays in a 10% bleach solution before you plant. Fill flats or cell trays with media or make individual soil blocks with a soil blocker. Plant seeds ¼-inch deep either in rows in flats, or with 3–5 seeds per cell or soil block. Label trays with cultivar and planting date. Keep media moist but not wet. Maintain soil temperature at 70–72˚F using a heating mat or cable until seedlings emerge, in 6–12 days. Keep temperatures in the greenhouse at 60–65˚F during the day,

Figure 1. Approximate dates for first and last killing frosts



and 55–60˚F at night. If you are starting onion seedlings indoors under fluorescent lights, provide at least 10 hours of light a day. Ideally, the seedlings should be ¼-inch thick at transplanting. You may need to experiment with seed spacing and planting dates to find the best scheme for your situation.

A week before transplanting to the field, move plants into a cold frame where lower temperatures will harden them off. Reduce water and withhold fertilizer while the plants are in the cold frame to help acclimate them to field conditions.

Soil preparation

Alliums, with their shallow root systems, grow best in well-prepared soil. The seedbed or transplant bed should have loose, crumbly soil that is free of stones, clods, or debris. In soils with a naturally low organic matter content, add composts and other organic materials. Alliums compete poorly with weeds, so it is important to control weeds before planting. Work beds 7–8 inches deep, being sure to bury surface organic matter to prevent attracting the onion maggot. Raised beds are an alternative to the conventional field planting method. They improve soil drainage and allow access to the crop without causing soil compaction. Raised beds are typically 4–5 feet wide and 100 feet long. The width is determined by the type of equipment used and by the crop. Leave a 1-foot aisle on either side of each bed to accommodate foot traffic.

Direct seeding

To direct seed onions or leeks, sow seeds ¼–¾ inches deep, 8–12 seeds per row foot. Thin onions to 3–4 inches between plants and leeks to 4–6 inches. (Garlic is planted as cloves, not seeds.) Onion seed is often graded and pelleted to make germination more uniform. You can also seed onions in the field for transplanting later. Plant seeds at four to five times the rate for direct seeding and transplant seedlings when they are ¼-inch in diameter. Given good conditions, seeds germinate 6–12 days after planting. The optimum temperature range for germination is between 70–85˚F. As allium seeds germinate the embryonic root and shoot are pushed out of the seed coat but the tip of the cotyledon remains in the seed producing a bent seedling. This unusual-looking seedling is referred to as the knee stage.

Transplanting

Transplant onions in mid-April, once frost is out of the ground and approximately 4 weeks before the last frost date. If you are growing onions from purchased transplants, place roots in a shallow pan of water immediately upon arrival, and plant them within a day or two. Plant transplants 1 inch deep and 4 inches apart. At transplanting, clip off tops to 5 inches to prevent drying out while the transplant's root system becomes established. Water onion transplants immediately after planting. Even though onions appear to push up out of the ground as they grow, they do not need soil hilled up around them.

Table 3. Planting guide

Vegetable	Planting time in southern WI[a]		Plants or seeds needed for 100 ft of row	Seed depth (inches)	Spacing (inches)[b]		Days to first harvest[c]	Estimated yield (lb/ft of row)[d]
	Indoors	Outdoors			Between rows	Between plants		
Onion	Feb. 15	April 15	½ oz	¼–¾	16–24	3–4	110–120	200 lb
Garlic	—	Oct. 15	400–600 cloves	2–3	18–30	4–6	60–90	40–70 lb
Leek	Feb. 15	April 15	¼–½ oz	¼–¾	16–24	4–6	120–150	150 stalks

[a]Plant about 1 week later along the lower lake shore and in the central part of state and about 2 weeks later in northern counties.

[b]If using a plate-type seeder, spacing between plants will be determined by plate configuration.

[c]Cultivars vary greatly in time needed to reach harvest stage; extend the harvest season by planting cultivars of different maturity dates or by making successive plantings of the same cultivar.

[d]Estimated yields under less than ideal growing conditions; actual yields will vary widely with weather, soil fertility and cultural practices.

If you are growing onions from sets, plant the sets 1–2 inches deep and 3–4 inches apart in the row. To reduce the likelihood of bolting, use sets that are ¼ inch or smaller in diameter.

Onion culture

Each onion cultivar has a specific day length requirement that triggers the plant to form a bulb. The rate of growth and ultimate size of the bulb are influenced by temperature, nutrition, soil moisture, and competition. Until the plant receives the critical amount of day length, it grows new leaves without forming a bulb. These can be harvested as green bunching onions.

Onions and other alliums bolt when plants are subject to temperatures between 40–50°F for 1–2 months. Onions grown from sets are prone to bolting if exposed to prolonged cool temperatures in the spring.

Garlic culture

Since cultivated garlic rarely produces fertile flowers, garlic is propagated vegetatively by planting cloves saved from the previous crop. Larger cloves produce larger bulbs. Bulbils form at the top of a stem called a scape, but plants propagated from these bulbils will be too small to be marketable.

The best time to plant garlic cloves is in the fall, 6–8 weeks before the ground freezes. This allows the cloves time to grow roots under cool conditions and become established before winter. Garlic should not be planted in the spring since warm temperatures and increasing day length will stimulate premature bulb formation. You will need 100 pounds of garlic for 1000 square feet if you plant the cloves 4 inches apart in the bed. To prevent disease, wait to divide the bulbs until just before planting. Plant cloves with their points up, 2–3 inches deep and 4–6 inches apart. Garlic is commonly planted in double or triple rows in beds that are 2–3 feet apart. If planted too shallow, shoots may start to grow in fall. These tender shoots detract from root production and will be killed in the winter. Once the soil has frozen, mulch the plants with a layer of 4–6 inches of weed-free straw to prevent soil heaving. By spring the mulch will have compacted to about 1 inch. Remove the mulch in early spring to help warm up the soil and speed growth, or leave it in place to add organic matter to the soil. Garlic requires a moderate amount of nitrogen for optimum growth. On soils with more than 20% organic matter, apply 35 lb nitrogen/acre. On sandy soils with less than 2% organic matter, apply 60 lb nitrogen/acre. Garlic is best able to use the nitrogen when it's applied in two or three smaller amounts. If applying twice, make the first at planting and the second about 2 weeks after emergence in spring. For three applications, apply a third of the nitrogen at planting, at emergence in spring, and again 1 month later. Avoid applying nitrogen within 60 days before harvest to help the plants die back properly.

In early summer, when the scape on hardneck garlic has formed a circle, remove it and its bulbils (or topsets) so the bulb grows to an adequate size of 8–10 cloves. The bulbils and scapes have a mild flavor and can be marketed for cooking.

You can also grow green garlic, which is garlic that is harvested before it forms bulbs. Green garlic can be produced from small cloves, dense plant populations, or thinnings. It has a milder flavor than bulb garlic and can be eaten raw like green onions or chopped and cooked to add flavor to meat or vegetable dishes.

Leek culture

Leeks are more cold tolerant than onions and garlic with the best temperatures for leek development between 68° and 78°F. Leeks have site requirements similar to those of onions and garlic but prefer wetter conditions. Leeks are usually propagated by seed grown indoors and then transplanted into the field when weather conditions permit. Direct seeding is not practical for leeks because of the slow rate of seed germination. Plant leek seeds in flats ¼ inch apart and ¼ inch deep in February–March. Transplant to 1 inch apart when the plants are big enough to handle. You can also seed directly into a coldframe. In mid- to late April, transplants should be planted 4–6 inches apart within the row and 18 inches between rows, in a furrow or individual holes 5–6 inches deep, letting at least 1–2 inches of leaves

extend above the soil surface. Instead of firming up the soil near the base of the transplants, let rain and irrigation help fill in the hole over time. Systematically burying the lower portion of the plant creates the characteristic blanched or whitened leek stem. The longer the blanched stem, the higher the quality. To blanch stems, wait until leeks put out new strong growth. Then start gradually filling in the furrow with soil to blanch 5–6 inches of the stem. You can use a cultivator or hoe to hill up soil around the base of the plant two or three times during the growing season. Do not bury the place where the leaf attaches to the stem. Leeks grow slowly and can require 120–150 days before reaching maturity.

Elephant garlic culture

Elephant garlic is slightly less hardy than regular garlic. Plant and mulch elephant garlic in the fall as you would regular garlic, but plant cloves 2–3 inches deep and 6–8 inches apart. Hill up the plants with 2–3 inches of soil. Elephant garlic will produce leaves before the ground freezes. The next spring, break off any flower buds. Elephant garlic requires approximately three times more nitrogen than regular garlic.

Wild leek or ramp culture

Collecting ramps from the wild may decimate local native populations. If you harvest from the wild, remove no more than 5–10% of the plants in each plot to maintain the patch. When growing your own ramps, plant enough so that you harvest only 1⁄7 to 1⁄5 of the plot each year. Choose a shady, moist site that is well drained. The soil should have a high level of organic matter. The site could be under natural shade from trees such as sugar maple, birch, beech, linden, hickory, and oak, or from a shade structure. Ramps are perennial plants that grow new leaves in March through April. These leaves die back in June, the plant produces a flower stalk, and the flower blooms in early summer. Seeds develop in late summer and need a warm, moist period followed by a cold period to break dormancy. If they don't receive these conditions, it may take 18 months for them to germinate. Growing ramps from seed takes 5–7 years to get the stand to maturity.

You can also grow ramps from transplants or bulbs. Plant bulbs in March and transplants in March–April. Plant bulbs 4–6 inches apart and 3 inches deep, leaving the tip of the bulb above the soil surface. Plant transplants to the same depth they were growing. Cover ramp seeds, bulbs, or transplants with 2–3 inches of hardwood leaf mulch.

Soils and nutrient management

Compared to other vegetables, onions and other alliums are shallow, heavy feeders. Obtain a soil test for available nutrients before planting a field for the first time. You'll need to test the soil again at least once every 3 years to keep your fertility management program current. For information on how to collect good samples and where to get them analyzed, see Extension publication *Sampling Soils for Testing* (A2100).

Table 4. Nutrient composition of various organic fertilizers

Material	N	P_2O_5	K_2O
	%		
Alfalfa hay	2.0–3.0	0.2–0.6	2.0–3.2
Bone meal	0.2–1.0	12.0–14.0	—
Compost[a]	0.5–3.5	0.5–1.0	1.0–2.0
Fish meal	9.0–11.0	5.0–8.0	0.0–3.0
Greensand	—	—	7.0
Manure, cow	0.5–0.7	0.2–0.4	0.5–0.8
Manure, sheep	1.0–2.0	0.7–1.0	0.5–2.0
Manure, poultry	1.1–1.7	1.0–1.3	0.5–1.0
Rock phosphate	—	20.0–30.0	—
Soybean meal	7.0	0.5	2.3

[a]Nutrient analysis of compost will vary based on the source.

Routine soil tests include pH, organic matter content, phosphorus, and potassium. Special tests are available on request for nitrate-nitrogen, calcium, magnesium, sulfur, boron, manganese, and zinc. You will receive the results of your soil test along with fertilizer recommendations based on your cropping history and planned use of the field. If you plan to apply supplemental fertilizer to alliums, band the application rather than broadcasting it since the roots don't extend far from the plant. Two or three small nitrogen applications are more effective than one large application.

Soil pH

Soil pH for onions should be between 6.5 and 8.0 on mineral soils or 5.8 on peat. For garlic, the soil pH should be between 6.0 and 7.0. The soil pH for leeks should be 6.0–8.0.

Fertilizer needs

Plants take up nitrogen as nitrate (NO_3^-) or ammonium (NH_4^+), phosphorus as phosphate (P_2O_5), and potassium as potash (K_2O). These nutrients can come from organic or inorganic sources. Soil microbes break down organic matter freeing up chemical nutrients needed by plants. Organic fertilizers can also improve soil tilth and health. Inorganic fertilizers can be used to quickly supply nutrients to plants.

Organic fertilizers can come from a variety of sources such as manures, compost, fish meal, and bone meal. Each material contains varying amounts of specific nutrients. Table 4 lists organic fertilizers and the amounts of nutrients in each. For more information on this subject, refer to Extension publication *Organic Soil Conditioners* (A2305).

Alliums require relatively high levels of phosphorus and potassium compared to other vegetables. (See table 5 for recommended annual amounts.) They also have a high requirement for copper, manganese, zinc, and (on muck soils) for molybdenum.

Manganese deficiency results in a gradual, interveinal chlorosis, stunting, and twisting of the top growth on onions and other alliums. Plants also exhibit delayed bulbing and thick necks. Manganese deficiency is most common on muck soils with a high pH.

Zinc deficiency is commonly encountered in both sands and muck soils because of the naturally low levels of this micronutrient in the soil. Symptoms of zinc deficiency include overall stunting of the plant, a twisting and outward bending of the leaves, and a faint yellowing of the tissue between the leaf veins on the younger leaves.

Table 5. Annual nitrogen, phosphate (P_2O_5), and potash (K_2O) recommendations

	Nitrogen			Phosphate and potash				
	Organic matter	Amount to apply		Yield goal	Amount to apply[a]			
					P_2O_5		K_2O	
Vegetable	%	lb/a	oz/100 sq ft	cwt	lb/a	oz/100 sq ft	lb/a	oz/100 sq ft
Onions	<2.0	150	5.5	400–600	60	2.2	130	4.78
	2.0–9.9	140	5.25					
	10–20	130	4.78					
	>20	120	4.5					

[a]Amounts of P_2O_5 and K_2O are for optimum soil test levels. Apply half the given rate if the soil test is high and omit if the soil test is excessively high. If soil test is low or very low, increase rates according to the soil test recommendations.

Irrigation

Onions with their shallow root systems need frequent watering to keep the top 3–4 inches of soil moist. Roots grow from a flat “stem plate” on the bottom of the bulb, and until the onions form bulbs, this stem plate should not be allowed to dry out. On sandy soils, you may need to water daily. Once the plants start to bulb, they’ll need an inch of water a week. A thorough soaking once a week will produce a stronger root system than frequent, light waterings. Cut back on irrigation 1–2 weeks before harvest.

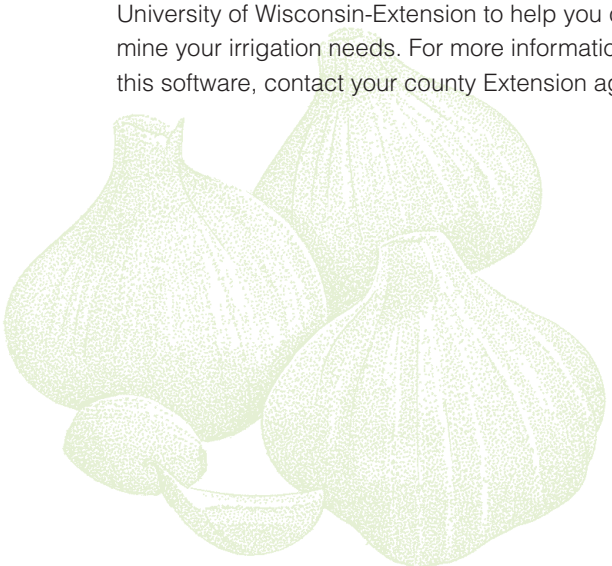
Garlic requires consistent soil moisture during the bulbing period (April – June). Cut back on irrigation 3–4 weeks before harvest (mid-July to mid-August) to prevent bulb rot.

Leeks require less water than onions. After establishment they should only be irrigated during prolonged drought conditions.

If leaves begin to wilt mid-day, plants are moisture stressed. Plants that wilt intermittently produce smaller yields. Plants that wilt frequently or that have been allowed to wilt too long will often die due to permanent cell damage.

Both drip and overhead sprinkler irrigation systems are effective. These systems include trickle tape, solid set, and traveler hose wheel.

Irrigation scheduling software is available from the University of Wisconsin-Extension to help you determine your irrigation needs. For more information on this software, contact your county Extension agent.



Harvest, handling, and storage

Onions

Harvest fresh onions when 15–25% of the tops have fallen over. Storage onions should be harvested when 50–80% of the tops have fallen over. If storage onions are harvested earlier, they are more likely to rot during storage. Onions harvested after more than 80% of the tops have dried down will be more susceptible to scale infection during storage. Undercut the roots with a blade or in small quantities by hand with a spade or spading fork. Even though onions feel solid, they bruise easily and should be handled carefully to avoid damaging the bulb which can lead to storage rots.

USDA size categories for U.S. No. 1 onions

Description: Onions must be mature, firm, well-shaped, free from decay and damage, and at least 40% must be greater than 11/2 inches in diameter.

Sizes (diameter):

Small = 1–2¼ inches

Medium = 2–3¼ inches

Large or jumbo = >3 inches

Colossal = >3¾ inches

Green onions can be pulled any time the tops are at least 6 inches tall and ½–1 inches in diameter. Two to three weeks before harvest, hill up approximately 2 inches of soil around the base of the stems to blanch them. At harvest, remove the discolored outer skin, trim the leaves, and bunch with a rubber band according to the size bunch common in your market (usually 5–7 onions). Wearing a supply of rubber bands around your wrist speeds bunching. Keep green onions cool to maintain quality.

After harvest, storage onions should be cured at temperatures of 85–90˚F under low humidity for several days to one week. Curing and drying promotes dormancy, enhances the development of well-colored scales and prevents inoculation by disease organisms. Leave the dry, outer scales on the bulbs throughout the curing process. If curing onions outdoors, protect them from moisture and direct sun. You can put onions on screens on warm, dry days with an adequate breeze for good air circulation. Place them in a shady location away from rainfall and heavy dews. Properly cured onions have dry outer scales and a dry neck. Onions can be stored for up to 6 months at temperatures of 32˚F and humidity levels of 60–70%. Onions may sprout in storage if temperatures exceed 40˚F.

Garlic

Harvest garlic when two-thirds of the tops are dry and the leaves collapse. Pull a few bulbs near harvest to determine exactly when to harvest the crop. Later harvest gives bigger bulbs, but the skin might split and lower bulb quality. Bulbs can rot and individual cloves may split off if garlic is left in the field after it matures. Harvest garlic on a warm dry day to prevent soil from adhering to the bulbs, making them difficult to clean. Garlic can be dug with a spading fork in small plantings or with the same harvesting equipment used for onions in larger plantings. The roots are then undercut with a lifter before being pulled. Never pull garlic bulbs without first loosening the soil with a shovel or spading fork. Remove excess soil from the bulbs in the field. If you intend to market garlic braids, leave the tops on and braid the garlic immediately after harvest. Then cure the braids as you would bulbs.

To cure garlic, either windrow bulbs in the field for several days, crate them in standard plastic ventilated containers and keep them in the field with good air circulation, or lay them out in a shady spot with good air flow. Garlic should be cured for 30 days after harvest. During this period, the bulbs will lose up to half their weight and will improve in flavor. Before storing or marketing garlic, peel off the outer one or two layers of skin, trim roots to 1 inch, and trim the tops to 1½–2 inches (unless braided). Garlic may be stored with the dried tops removed, trimmed, intact, or braided.

Harvesting & packing tips

When harvesting onions, garlic, and leeks, change your position often to minimize stress and fatigue to your body. You might wear kneepads, or sit on a small cart. Use garden carts and wagons as much as possible to minimize lifting and hand carrying heavy produce. Standardized vented plastic containers that stack are easy to load and unload, and clean.

With a smooth level floor in the packing area, a palletized packing and storage system can be designed to fit small-scale operations (small pallets moved with a hand-pulled pallet jack) or large operations (pallets moved by forklift). Heavy boxes of produce can be moved from one area to another on roller tables.

Lay out your washing and packing area to minimize stooping, lifting, and carrying. Set up screen tables so you can work at table height. Ideally, tables could be adjusted to match each worker, so that work is performed at a height between wrist and elbow. For more information on tools and methods to improve work efficiency visit the University of Wisconsin Healthy Farmers, Healthy Profits website at bse.wisc.edu/hfhp/.

Garlic can be stored for up to 6 months at 32˚F and humidity levels of 60–70%. Storage temperatures above 40˚F will cause garlic cloves to sprout and relative humidity levels over 70% initiates root development and mold.

Leeks

Unlike onions and garlic which are harvested when they're dormant, leeks are harvested while they're still actively growing. When mature, leeks are typically 1¼–3 inches thick, depending on the cultivar. If you heavily mulch leeks to keep the ground from freezing, you can extend your harvest season. Dig under the leeks to cut the extensive root system before pulling out plants. After harvest, trim roots and green leaves, and wash. You can harvest leek greens and immature stems all season. Leeks can be stored for up to 2 months at 32˚F and 95% relative humidity.

Elephant garlic

Dig elephant garlic bulbs when all the leaves show some yellowing, but before the entire top has dried. Elephant garlic bulbs are fragile. They bruise easily and their thin papery outer covering separates easily. Brush soil away from bulbs being careful not to knock them together as you dislodge soil. Braid or trim the leaves, cut off roots, and dry and cure the bulbs for about 6 weeks. Elephant garlic is often packed for sale as individual bulbs in net bags.

Wild leek or ramps

Harvest ramps when leaves are 12–18 inches tall. When harvesting, be careful not to damage the bulbs, and keep them cool and moist when digging. Trim rootlets, wash bulbs, pack them in waxed cardboard boxes and store them in a cooler.

Insect management

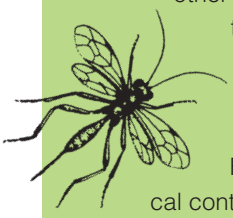
Aster leafhopper

Description: The aster leafhopper is a serious pest of onions because it transmits the aster yellows pathogen. Adult aster leafhoppers are olive-green, wedge-shaped, and about ⅕-inch long. Adults have six spots on the back of the head. Nymphs are similar in shape to the adults, but are cream colored and lack fully developed wings. Adults are extremely active and jump, crawl, or fly when disturbed. Nymphs are less active but crawl rapidly.

Life cycle: The first leafhoppers that appear each season migrate from the Gulf states. They are carried north on warm, southerly winds. Large influxes may occur in June and early July as local populations develop. Adult females lay eggs in the leaves of susceptible plants. Nymphs hatch 5–7 days later and mature in 20–30 days. There are normally two to five generations per year.

Damage, symptoms: Both nymphs and adults feed by inserting piercing-sucking mouthparts into the plant to extract sap. If a leafhopper feeds on a plant diseased with aster yellows, it ingests the pathogen. When the leafhopper moves to another plant to feed, it transmits the pathogen in its saliva. In onions, disease symptoms appear about one month later.

Conservation of natural enemies



Not all insects are pests. Beneficial insects prey on other insects, helping to keep populations in check. You can take advantage of this free natural resource by minimizing the use of broad-spectrum insecticides. For more information about biological controls, see Extension publication *Biological Control of Insects and Mites: An Introduction to Beneficial Natural Enemies and Their Use in Pest Management* (NCR481).

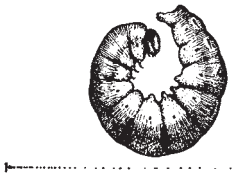
Bulbs infected with aster yellows show a general chlorosis, stunting, and twisting of the stems and leaves. Bulbs infected with aster yellows dry poorly.

Management: Aster leafhoppers may be effectively controlled by excluding them from the onion planting using floating row covers. Row covers should be in place from the time the onions emerge or are transplanted until 30 days before harvest. Drape the covers over the crop or support it using wire hoops. Hold the material in place by burying the edges or by using reebar or rough lumber to weigh it down. Completely seal all four edges to the ground.

If you're not using row covers, the only effective way to prevent the spread of aster yellows disease is through insecticidal control of aster leafhoppers. To control leafhoppers, you need to know both the size of the population and the percent of the population that's infective. Place sticky cards in the field when the onions are transplanted. Place the cards just above the crop a few rows in from the outer field edge. Begin scouting weekly when you find leafhoppers on the cards. Use a sweep net to take 25 sweeps per site, and sample two sites per acre. Each spring, the University of Wisconsin-Extension collects samples of migrating leafhoppers and determines the percentage that are infective. For current information, contact your county Extension office. If the percent of infectivity is not known, use 2.5% for the following calculations. To decide whether treatment is necessary, multiply the number of leafhoppers per 100 sweeps by the percent infectivity of the migrant populations. Treat when an index of 200 is reached. Continue treating until 30 days before harvest.

Remove weeds from field edges as these may be a reservoir for the pathogen. Avoid planting susceptible crops near untreated crops or weeds that the leafhopper uses for refuge. If not using insecticides or row covers, consider planting an additional 30% to offset losses due to aster yellows.

Black cutworm



Description: Cutworms are the larvae of nocturnal grey moths. Cutworms are active feeders on young foliage and stems and will cut off many young seedlings in an evening. The large (1½–2 inches), fleshy larvae curl up into a tight C-shape when disturbed.

Life cycle: Few cutworms overwinter in Wisconsin. Beginning in late May, moths migrate into the state. Female moths lay hundreds of eggs either singly or in clusters. Most eggs are laid on low-growing, grassy vegetation or plant residue from the previous year's crop. Once the eggs hatch, the young larvae feed above ground on the tips of plants. Larger larvae feed at or just below the soil surface at night or on cloudy days. During the day they hide in the soil or beneath foliage. There are three to four generations per year in Wisconsin, but the first generation is the most damaging because it coincides with seedling plants.

Damage, symptoms: One large larva may destroy several plants in one evening. The larvae often pull the stem of the severed plant into their subterranean burrows.

Management: Since female moths prefer to lay eggs in grassy areas, controlling grassy weeds lessens the possibility of problems. Avoid planting in low, wet areas or in areas where grassy plants or weeds existed the previous year. Insecticides may be used in areas where cutworms historically have been a problem. Fields should be scouted if feeding damage is observed. Shake every plant along a 5-foot length of row in two adjacent rows into the furrow and count the larvae on the soil surface. Spot treat if you find two or more larvae per foot of row.

Onion maggot

Description: Adult onion maggots are slender, gray, large-winged, bristly flies that resemble houseflies but are only ¼-inch long. While at rest, their wings overlap their bodies. The maggots are approximately 1-inch long, cream-colored, and legless with a sharply pointed head end.

Life cycle: Onion maggots overwinter as pupae in the soil or in onion cull piles. In mid-May, adults emerge from the soil and lay eggs on the soil surface at the base of onion, garlic, leek, chive, or shallot plants. When the larvae emerge, they crawl beneath the leaf sheath and enter the bulb. The onion maggot pupates in the soil and the next generation appears 3–4 weeks later.

There are three generations of onion maggots per year. The first is often the largest and most damaging. The third generation attacks onions in mid-August shortly before harvest. Damage at this time can lead to storage rot as onion maggots introduce bacteria into wounds caused by their feeding.

Damage, symptoms: Onion maggot larvae feed on the hypocotyl (below ground) tissue of seedlings, resulting in various types of damage. Larval feeding may kill seedlings; therefore, poor plant stands may indicate an onion maggot problem. In larger plants, larvae may tunnel into bulbs, causing plants to become limp and yellow. Onion maggot feeding can introduce soft rot bacteria into the plant.

Management: Once damage has been detected, it is too late to attempt control. Therefore, action thresholds for foliar insecticide applications are based on the emergence of adults. Peak emergence of each generation can be forecasted using degree-day accumulations (for a discussion of degree days, see sidebar). Begin degree day calculations when the ground thaws in the spring. Use a base temperature of 40°F. The three generations of adults emerge when degree day totals reach $680DD_{40}$ (spring), $1950DD_{40}$ (summer), and $3230DD_{40}$ (fall), respectively.

Effective onion maggot control programs should include the following elements to reduce populations, avoid insecticide resistance and achieve control.

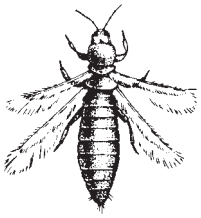
1) Rotate onion crops whenever possible to provide at least ¼ mile between new seedlings and previous crops or cull piles. This may not always be possible on smaller farms.

2) Destroy crop debris and remove culls from the field to reduce numbers of overwintering onion maggot populations.

3) Transplant onions 1 week before flies are expected to emerge.

If damage from the previous year's crop exceeded 5–10%, preventative soil insecticide applications are recommended to control the first-generation larvae.

Onion thrips



Description: Adult onion thrips are tiny pale yellow or brown insects about 1/12-inch long. Their wings have no veins and are fringed with long hairs. Nymphs resemble adults except that they are smaller and lack wings.

Life cycle: Adults and nymphs overwinter on plants, debris, and along weedy field edges. Females can reproduce without mating and lay eggs beneath the leaf's surface. Eggs hatch after 5–10 days and nymphs are fully grown within 15–30 days. One to two weeks after hatching, the nymphs move into the soil to complete development. During this period, they do not feed. After the fourth molt, adult female thrips return to the plant. Thrips produce about five to eight generations per year. Hot, dry weather favors thrips outbreaks.

Damage, symptoms: Onion thrips damage plants primarily by their rasping and feeding which produces whitish blotches on leaves and decreased pollen set. Both adults and larvae cause damage that appears as a silvery streaking on the leaves. As time passes, affected areas become dry and yellow. Heavy infestations can cause onion leaf tips to turn brown. Severe damage causes bulbs to become distorted or undersized.

Management: Thrips should be controlled early, before they become protected by plant tissue. Due to their small size and reclusive habits, onion thrips are difficult to monitor and control. No treatment thresholds have been established for onions. Yellow or white sticky traps may be used along field edges to monitor the initial migration of thrips into a field. Cleaning plant debris from the field and the surrounding area may aid in controlling thrips. In general, onion cultivars with an open type of growth, circular leaf structure, and glossy foliage suffer less damage than cultivars with leaf sheaths tight to the stem. Red onions are particularly susceptible to attack while sweet Spanish onions are more resistant.

Because of thrips' protected location in the plant, control through the use of insecticides is difficult. Foliar insecticides should be applied in sufficient water with a spray additive to achieve penetration into the plant.

Calculating degree days

Temperature affects the rate of development of plants and insects. Cold weather slows development while warm weather accelerates it. For this reason it is misleading to describe development in terms of time alone. To monitor crop development and predict pest behavior, professional pest managers often use a system that takes into account the accumulation of heat with passing time. This system is based on degree days (DD).

A degree day (DD) is a unit of measure that occurs for each degree above a base temperature during a 24-hour period. The base temperature is the temperature below which there is no plant or insect development. Specific insects have specific base temperatures. Most plants use a base temperature of 50°F. Cool-season plants, such as peas, grow in cooler temperatures and have a base temperature of 40°F. Begin recording degree day accumulations for Wisconsin on March 1.

To monitor plant and insect development using degree days, you will need a maximum/minimum thermometer to obtain the daily high and low temperatures. Calculate degree days using theequations below.

Example: Assume you have accumulated 200 degree days to date using a base temperature of 40°F. If yesterday's high temperature was 75°F and the low was 60°F, then the daily average temperature would be 67.5°F [(75 + 60) ÷ 2]. To calculate the degree day accumulation, subtract the daily average from the base temperature for a total of 27.5DD (67.5 – 40). Add this number to the total number of degree days to date (27.5 + 200) for a new total of 227.5.

(daily high[a] + daily low[b]) ÷ 2 = daily average temperature
daily average temperature − base temperature = degree day accumulation

[a]Use 86°F if the high temperature for the day is more than 86°F.
[b]If the daily low is less than the base temperature, use the base temperature.

Disease management

Botrytis leaf blight and neck rot

Hosts and severity: Botrytis leaf blight is a destructive disease that kills onion foliage so rapidly that it is often referred to as "blast." All cultivated onions are susceptible to botrytis leaf blight. Botrytis neck rot also originates in the field but symptoms don't appear until the onions are in storage. White onions are more susceptible than red or yellow varieties and leeks, shallots, and garlic are also susceptible to botrytis neck rot.

Disease cycle: The fungi that cause leaf blight and neck rot overwinter in the soil on onion crop residues or as sclerotia. In moist weather, the sclerotia germinate and produce conidia (airborne spores) which are disseminated by wind and splashing water. These spores lodge on wet foliage and enter the plant through wounds. Onions are highly susceptible to leaf blight during the early stages of bulbing and ozone injury may aggravate leaf blight damage. In the case of botrytis neck blight, the fungus generally enters after harvest through succulent tops that were not properly dried.

Symptoms: Symptoms of botrytis leaf blight first appear as tiny, oval, whitish or yellowish spots on the oldest leaves. If affected leaves are cut, you will notice that the lesions extend through the thickness of the leaf blade.

Infected plants show little or no evidence of botrytis neck rot prior to harvest, but the disease becomes obvious after onions are topped and have been stored for a few days. Scales around the neck begin to soften and this softening progresses toward the base of the bulb. Infected tissue takes on a sunken, brownish, water-soaked appearance with a definite margin between healthy and diseased tissue. On red and yellow onions the pigment of diseased tissue is destroyed.

Management: To prevent problems with botrytis leaf blight, plant healthy seeds or sets in well-drained soil in areas with good air circulation. Remove weeds and destroy infected plant debris after harvest. Practice a 2-year crop rotation to avoid other diseases that might predispose the plants to botrytis infection.

Onion varieties that mature readily so neck tissues dry before storage will help to reduce the incidence of botrytis neck rot. You can reduce plant susceptibility by not applying fertilizer late in the season or providing excessive irrigation when tops are drying. Harvest onions when fully mature after tops are dry. Cut tops close (½ inch from the top of the bulb) and dry stubs before storing.

Downy mildew

Hosts and severity: Downy mildew is a cool-weather problem that affects all types of onions, garlic, leeks, chives, and shallots. There are several strains of the fungus, each strain causing infection only on a specific crop with no cross infection occurring. Under cool, moist conditions, downy mildew can be quite destructive.

Disease cycle: The fungus overwinters as thick-walled resting spores in diseased plant residue. When conditions are favorable, spores are produced that are carried by air to healthy plants. Heavy fogs, persistent dews, and drizzling rains favor infection. Plants may be infected at any stage of development.

Symptoms: Downy mildew causes onion leaves to become blighted and die prematurely. Infected plants produce undersized, immature bulbs that are often attacked by other organisms after harvest. Downy mildew may produce local infections on onion leaves or the disease may become systemic within the plant with the older, outer leaves becoming infected first. Local infections produce lesions on the leaves and stalks that are pale green, oval to elongate, and slightly sunken. In moist weather, a fuzzy violet growth develops over the entire leaf surface. As the disease progresses, entire leaves become pale green and finally yellow. Plants that are infected systemically are stunted with pale green leaves.

Management: Prevention is best achieved by planting disease-free seed or sets in well-drained soil and spacing them far enough apart to promote good air circulation. Avoid overcrowding and excessive nitrogen fertilization. Practice a 3-year crop rotation out of onions.

To prevent downy mildew, seed is usually grown in arid, western states where risk of downy mildew is negligible. If saving your own seed however, seed should be treated in a hot water bath. The temperature of the water is critical—variation by as little as one degree will cause the seed to die or allow the pathogen to remain viable. Place the seed in a mesh bag and dip the bag into water heated to 122°F for 25 minutes. Transfer the bag to cold water immediately to cool the seed. There will be some reduction in the germination rate of treated seed; you may wish to sow additional seed to compensate.

Onion smut

Hosts and severity: Onion smut is a serious and widespread disease of onions, leeks, and shallots. Infected plants either die or remain vegetative for the entire growing season.

Disease cycle: The fungus survives in the soil for many years even without a susceptible host. When onions are planted in an infested field, the spores germinate and infect seedlings and new transplants.

Symptoms: Onions are only susceptible to smut while small; older plants become resistant. The first symptom of infection appears as a brown to black, elongated blister on the cotyledons and young leaves. A single lesion may cover an entire leaf and cause it to curl downward. Most infected seedlings die within 3–5 weeks after germination. Plants are usually stunted and may die slowly. If plants survive, the disease becomes systemic and infected plants remain vegetative throughout the growing season. If bulbs do form, they become covered with black lesions and are open to attack by secondary organisms.

Management: To prevent onion smut, plant disease-free transplants that have passed the susceptible period. Practice crop rotations to prevent inoculum buildup in the soil.

Purple blotch

Hosts and severity: Purple blotch causes onions to become blighted and die prematurely. This disease affects onions, garlic, and leeks.

Disease cycle: The purple blotch fungus overwinters on plant debris. With warm, wet weather in the spring, the fungus produces spores that infect leaves, stems and flowers of susceptible hosts. Rain or persistent moisture is necessary for infection.

Symptoms: Purple blotch first appears as small, brown, water-soaked areas on onion leaves, flower stalks, and flowers. The enlarging spots develop light and dark purple zones that become somewhat sunken. The border of the lesion is reddish or purple with a yellow halo. If conditions are favorable, affected leaves and stems may turn yellow, drop over, and die within several weeks after the first lesions appear. Onion bulbs may be attacked through the neck or through wounds in the bulb scales at harvest or later while in storage. Diseased bulb tissue gradually dries out and becomes papery.

Management: Practice a 4-year crop rotation in fields free of weeds and plant debris. Plant healthy seeds or sets in well-drained soil where air circulation is good. Avoid overcrowding plants and excessive nitrogen fertilization.

Soft rot

Hosts and severity: Bacterial soft rot is a disease that affects many vegetables. It can be a particularly serious post-harvest disease if alliums are stored improperly.

Disease cycle: The bacteria often enter susceptible plants that are already weakened by other disease-causing organisms or they may enter through fresh wounds. Onion maggots are particularly effective at spreading this disease. The gnawing action of the maggots keep the tissue freshly wounded and predisposed to soft rot. The maggots ingest the bacteria which remain in their bodies until they become adults. The adult flies carry the bacteria to new locations and lay contaminated eggs. The bacteria are also spread by tools, clothing, decayed plant tissue, rain, and running water.

Symptoms: Onion bulbs may be infected in the field, but the disease often goes unnoticed until after harvest. Bacterial soft rot usually starts at the neck of the bulb, and progresses downward along one or more scales. At first the tissue is water-soaked. Later it disintegrates into a soft, slimy mess. The decay does not spread easily from scale to scale. One or two scales may be completely rotted while the remainder are sound. Gently squeezing diseased bulbs releases a foul-smelling watery fluid.

Management: The first step in controlling soft rot is to control other diseases and avoid injury to the plants. This includes controllling insects such as the onion maggot that wound plants and transmit the bacteria.

Allow the crop to mature completely before harvesting. The tops should be dried out as much as possible after lifting and before topping. Mechanical toppers should be designed to minimize bruising. At all stages of harvest and storage, onions should be handled carefully to avoid bruising. Cure bulbs thoroughly before storage so that the outer scales and neck tissues are completely dry. And finally, remove bulbs that show any sign of disease or injury before storage.

Weed management

Weed management is essential for crops to produce maximum yields. Weeds compete with crop plants for sunlight, water, nutrients, and space. Before planting, reduce perennial weed populations by smothering them with a cover crop (such as buckwheat), by heating the soil with black plastic, by hand removal, or by using herbicide sprays. Cultivate or hoe regularly to control annual weeds. Preemergent herbicides may be used to clean up any annual weeds present in the field at the time of planting.

Non-chemical weed control in onions, garlic, and leeks is often difficult because of the relatively small canopy produced by these crops as compared with bean, tomatoes, or vine crops. Repeated cultivations are often necessary to reduce weed competition in root crop plantings. Sometimes hand cultivation or hand weeding is necessary.

Chemical weed control in onions is based on the type of soil on which the crop is grown—muck vs. mineral soil—because the species of key weeds will differ as will the selection of available herbicides.

Refer to Extension publication *Commercial Vegetable Production in Wisconsin* (A3422) for specific herbicide recommendations.

Additional reading

Culture

Direct Marketing of Farm Produce and Home Goods—Direct Marketing Alternatives and Strategies for Beginning and Established Producers (A3602). John Cottingham, James Hovland, et al. 1994. University of Wisconsin-Extension.

Growing for Market Newsletter. Fairplain Publications, P.O. Box 3747, Lawrence, Kansas 66046. A monthly newsletter with practical articles on all aspects of small-scale fresh market farming.

Harvesting Vegetables from the Home Garden (A2727). H.C. Harrison. 1996. University of Wisconsin-Extension.

Knotts Handbook for Vegetable Growers, Fourth Edition. Donald N. Maynard and George J. Hochmuth. 1997. Wiley.

The New Organic Grower. Second Edition. Eliot Coleman. 1995. Chelsea Green Publishing.

The New Seed Starters Handbook. Nancy Bubel. 1988. Rodale Press.

Soil Test Recommendations for Field, Vegetable, and Fruit Crops (A2809). K.A. Kelling, L.G. Bundy, S.M. Combs, and J.B. Peters. 1998. University of Wisconsin-Extension.

Storing Vegetables at Home (A1135). H.C. Harrison. 1996. University of Wisconsin-Extension.

Sustainable Vegetable Production From Start-up to Market. Vernon P. Grubinger. 1999. Natural Resource, Agriculture, and Engineering Service Cooperative Extension.

Rodale's All New Encyclopedia of Organic Gardening. Edited by Fern Marshall Bradley and Barbara W. Ellis. 1992. Rodale Press.

Work Efficiency Tip Sheets. Healthy Farmers, Healthy Profits Project. University of Wisconsin-Madison. www.bse.wisc.edu/hfhp/. Work efficiency tools for small-scale vegetable farmers.

World Vegetables: Principles, Production, and Nutritive Values. Second edition. Vincent E. Rubatzky and Mas Yamaguchi. 1997. Chapman and Hall.

Pests

Biological Control of Insects and Mites: An Introduction to Beneficial Natural Enemies and Their Use in Pest Management (NCR481). Daniel L. Mahr and Nino M. Ridgway. 1993. University of Wisconsin-Extension.

Commercial Vegetable Production in Wisconsin (A3422). C.M. Boerboom et al. Updated annually. University of Wisconsin-Extension.

Identifying Diseases of Vegetables. A.A. MacNab, A.F. Sherf, and J.K. Springer. 1983. Pennsylvania State University College of Agricultural Sciences.

Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide. Second edition. Mary Louise Flint. 1998. University of California Press.

Rodale's Color Handbook of Garden Insects. Anna Carr. 1979. Rodale Press.

Vegetable Insect Management with Emphasis on the Midwest. Rick Foster and Brian Flood, editors. 1995. Meister Publishing Company.

Weeds of the North Central States. North Central Regional Research Publication No. 281. 1981. University of Illinois at Urbana-Champaign, College of Agriculture.

Partial funding for the printing of this publication was through a grant from the U.S. Environmental Protection Agency—Region V as part of their Agricultural Stewardship Initiative.

Authors: K.A. Delahaut is horticulture outreach specialist for the Fresh Market Vegetable Program, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension. A.C. Newenhouse is assistant scientist for the Wisconsin Healthy Farmers, Healthy Profits Project of the department of Biological Systems Engineering, College of Agricultural and Life Sciences, University of Wisconsin-Madison. Produced by Cooperative Extension Publishing, University of Wisconsin-Extension.

This publication is available from your Wisconsin county Extension office or from Cooperative Extension Publishing. Call toll free 877-WIS-PUBS (947-7827) or order online at cecommerce.wisc.edu.

A3785 Growing Onions, Garlic, Leeks, and Other Alliums in Wisconsin: A Guide for Fresh-Market Growers

I-9-03-1.2M