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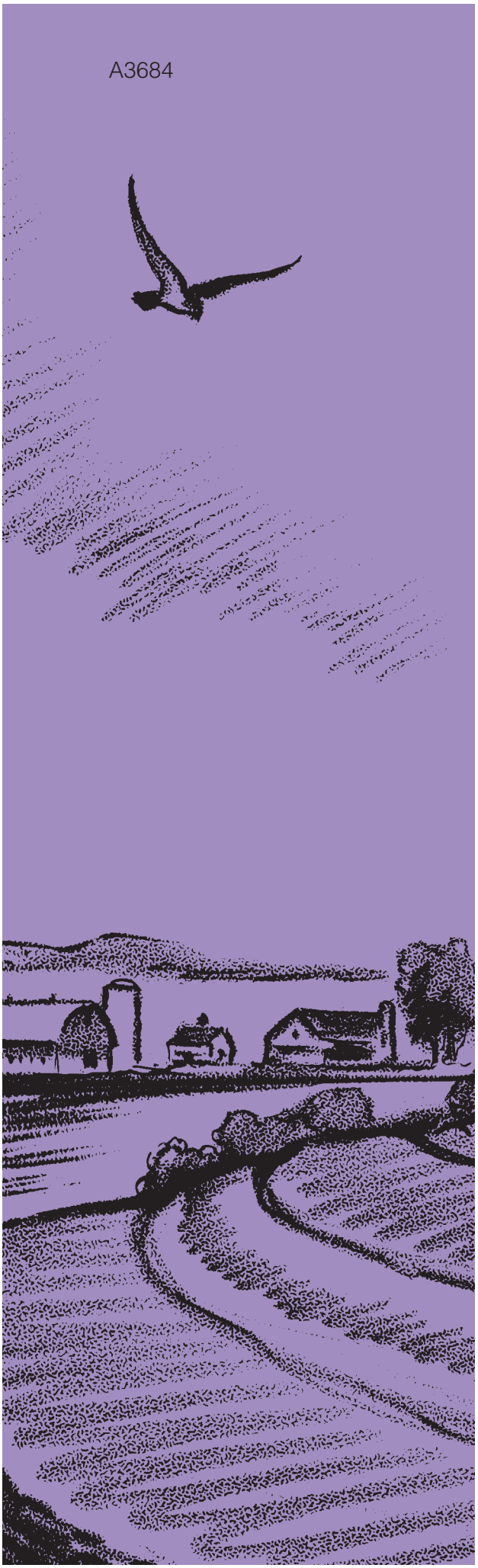

Growing broccoli, cauliflower, cabbage, and other cole crops in Wisconsin

A guide for fresh-market growers

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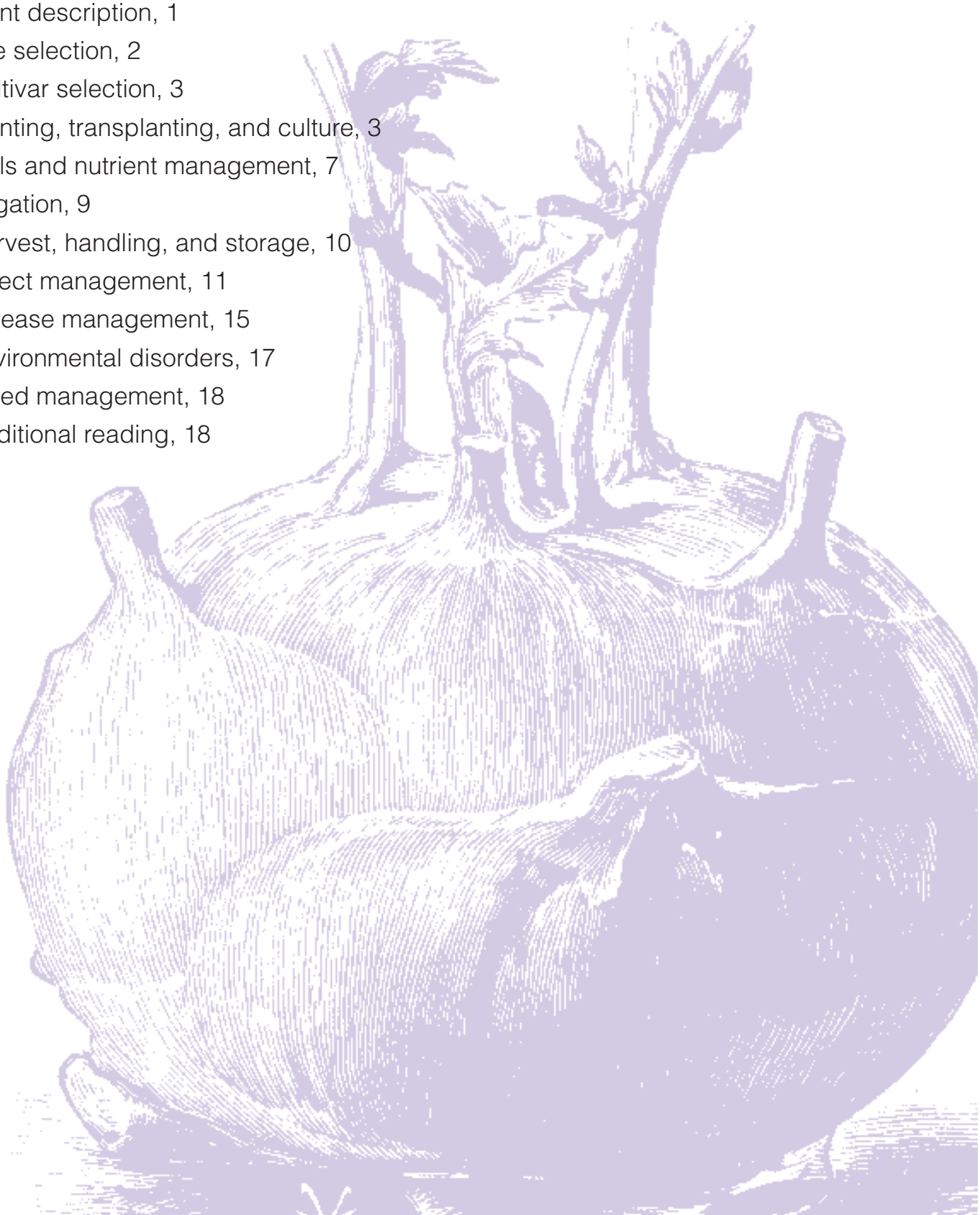


Successful fresh-market gardening involves more than just a talent for growing high-quality vegetables. You also need to find a market for them. Before you start, visit other growers, develop a marketing plan, and evaluate the feasibility of your proposed business. Think about what is unique about your 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).

Cole crops are a group of related vegetables belonging to the mustard family, Brassicaceae (formerly Cruciferae). All cole crops are natural varieties of the species *Brassica oleracea*. They include broccoli, cauliflower, cabbage, Brussels sprouts, kale, collards, and kohlrabi. These vegetables are a common staple in market gardens in Wisconsin. Cole crops such as kale and kohlrabi provide growers with an early season product because they grow well in cool weather. In fall, cole crops such as Brussels sprouts can extend the fresh market vegetable season past the first frost. Although cabbage doesn't necessarily provide a high economic return, other members of this group of vegetables can be quite profitable. Fresh broccoli and cauliflower, in particular, have become popular for use in salads and for dipping.

This publication describes how to grow and harvest cole crops to help fresh market growers maximize yields while minimizing production costs. It covers cultivar selection, soil fertility and irrigation needs, harvest and handling recommendations, and potential insect and disease problems.

Plant description

All varieties of the species *Brassica oleracea* originated in Europe and Asia and are descendants of wild cabbage. They are hardy, cool-season vegetables which may be herbaceous annuals, biennials, or perennials. All cole crops contain mustard oil, a compound that gives these vegetables their distinctive flavor and odor. Some members of the mustard family produce progressively shorter petioles, or leaf stems, on new growth until the uppermost leaves entirely lack petioles. This characteristic is referred to as sessile growth and is one of the reasons cabbage plants form heads.

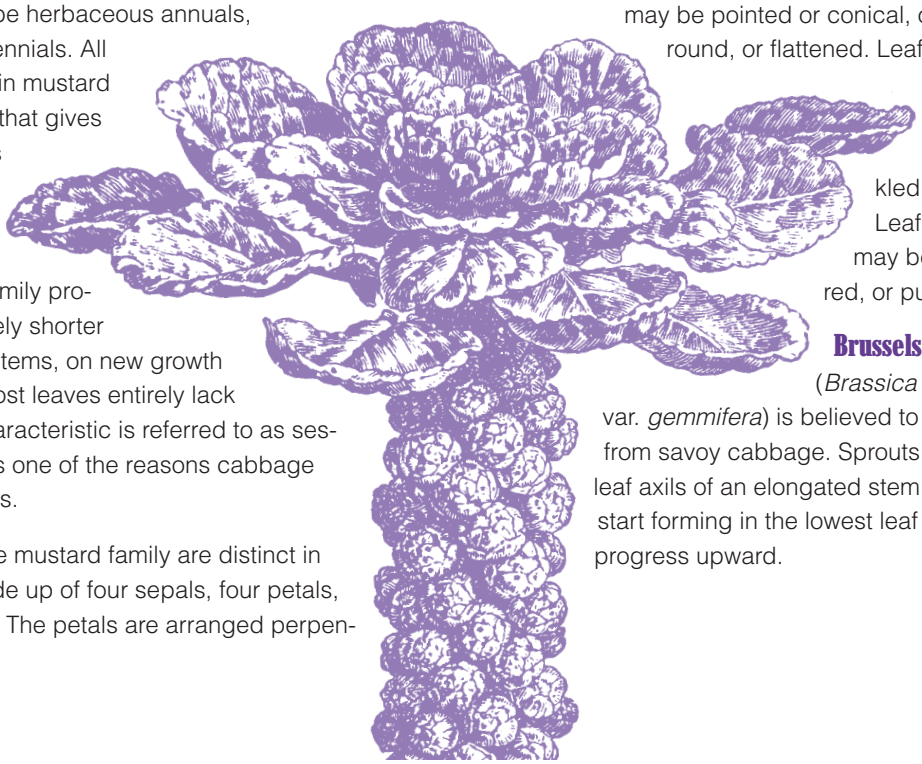
The flowers of the mustard family are distinct in that they are made up of four sepals, four petals, and six stamens. The petals are arranged perpendicular to each other, forming a cross—hence, the former Latin name "Cruciferae." Many flowers are self-incompatible, meaning they require pollen from another plant of the same species. Insects are the primary pollinators.

Broccoli (*Brassica oleracea* var. *italica*) is believed to be the first of the cole crops to evolve from wild cabbage. The head is comprised of functional flower buds. There are two types of broccoli: sprouting and heading. Sprouting broccoli forms small shoots in the leaf axils over a long time, while heading broccoli is a relatively recent introduction that produces one large central head.

Cauliflower (*Brassica oleracea* var. *botrytis*) is of unknown origin. Cauliflower leaves are more elongated than those of cabbage and broccoli. Leaf color is often lighter green. Winter or late-season types have curds that consist of functional flower buds, similar to broccoli.

Purple cauliflower is a winter variety of broccoli. If harvested before frost, the heads taste like broccoli; after frost, the heads taste like cauliflower. Purple cauliflower turns green when cooked.

Cabbage (*Brassica oleracea* var. *capitata, tuba,* and *sabauda*) is thought to be an early ancestor of the wild *Brassica* species. After the rosette stage, new cabbage leaves develop with shorter petioles and the leaves begin to cup inward to form heads. Heads may be pointed or conical, oblong, round, or flattened. Leaf texture may be smooth or crinkled (savoy). Leaf color may be green, red, or purple.



Brussels sprouts (*Brassica oleracea* var. *gemmifera*) is believed to derive from savoy cabbage. Sprouts form in leaf axils of an elongated stem. Sprouts start forming in the lowest leaf axil and progress upward.

Kale and collards belong to the group *Brassica oleracea* var. *acephala*. Both are thought to be a form of non-heading cabbage. The smooth leaves of collards form a rosette at the top of the stem while the savoy (crinkly) leaves of kale are borne along the length of the stem.

Kohlrabi (*Brassica oleracea* var. *gongyloides*) develops a thickened stem just above the soil line. Although this vegetable is often called a "turnip-rooted cabbage," the edible portion is an enlarged stem rather than root tissue. Kohlrabi originated in northern Europe in the 16th century.

Site selection

Cole crops use large amounts of nutrients and water. They may be planted in sunny locations on sandy, clay, muck, or loamy soils. Cole crops do well on light, sandy soils which warm up quickly in the spring. However, they will need frequent irrigation and supplemental nitrogen during the summer. The ideal location for mid- to late-season plantings is on heavier soils which have a better water-holding capacity and require less frequent irrigation. Avoid planting cole crops in the same site each year to prevent the build-up of soil pathogens. Soil pH should be 6.0–6.8, or 5.6 on muck soils.

Table 1. Recommended cole crop cultivars for Wisconsin

Broccoli

Arcadia
Emperor (F_1)
Green Belt (F_1)
Green Comet (F_1)
Green Valiant
Packman (F_1)
Raab
Romanesco Minaret
Saga

Cauliflower

Alverda (green)
Candid Charm (F_1)
Early Glacier (F_1)
Polar Express (F_1)
Snow Crown (F_1)
Snow King (F_1)
Snow Queen
Snowball Y
Silver Cup 45 (F_1)
Violet Queen (F_1, purple)

Cabbage

Fresh market
(earliest to latest)

Jersey Wakefield
Wisconsin Golden Acre
Gourmet (F_1)
Green Acre
Sanibel (F_1)
Wisconsin All Seasons

Specialty
Red Acre
Red Danish
Savoy
Savoy Ace (F_1)
Sombrero

Brussels sprouts

Captain Marvel (F_1)
Jade Cross (F_1)
Oliver
Prince Marvel (F_1)

Kale

Dwarf Blue Curled Vates
Konserva
Lacinto
Red Russian
Squire
Vates
Winter Bor

Kohlrabi

Gigante
Grand Duke (F_1)
Purple Vienna
White Vienna

F1 hybrids Many cultivars have the designation "F_1 hybrid." An F_1 hybrid is created when two purebred strains of plants are crossed, producing identical offspring. F_1 stands for "filial 1," the first generation of hybrids after the cross was made. Seeds of F_1 hybrids will not produce true to form—the cross between the original parents must be made each time.

Cultivar selection

Table 1 lists some of the recommended cole crop cultivars for Wisconsin. When trying a new cultivar, do not use it exclusively. Grow new trials next to old standbys so you may compare the characteristics objectively.

Broccoli. Broccoli grown in Wisconsin is typically the calabrese or Italian green type. Most of the cultivars available today are F_1 hybrids which produce one large, early head with two or three smaller harvests thereafter. Green Comet is a good selection for gardeners who want a substantial second cutting once the primary head has been harvested. Romanesco broccoli forms a spiral-shaped, chartreuse head which is unlike any of the other cultivars. Cultivars with rounded, or convex, heads shed water, reducing the likelihood of bacterial soft rot developing from excess moisture accumulation.

Cauliflower. Snowball types are the most common cauliflower cultivars available today. Cauliflower cultivars selected for early season harvest mature in 50–55 days from the time of transplant while late season cultivars mature in 75–80 days. Cauliflower cultivars that are resistant to one or more of the following disorders are the most desirable: bolting, black rot, drought, downy mildew, frost, hollow stem, internal black spot, and purple tinge.

Cabbage. Cabbage cultivars are selected based upon their use. Savoy, red, green, and pointed varieties are grown for fresh market sale. In addition to physical characteristics, the number of days to harvest is an important factor when selecting a cultivar. Early season varieties usually have relatively small heads of 1–2 pounds and mature 50–60 days after transplant, while full season, storage or processing cultivars produce 10–12 pound heads that require 130 days or more to mature. Most of the cabbage cultivars available today are hybrids. Disease resistance is also an important consideration when selecting a cabbage cultivar. Cultivars resistant to black rot, downy mildew, Fusarium yellows, and tipburn are desirable.

Brussels sprouts. The hybrids listed in table 1 have good uniformity, vigor, and disease resistance.

Kale. Kale cultivars can have red, blue, or green leaves which are smooth, curled, or wide.

Planting, transplanting, and culture

Soil preparation

For early season crops on sites where erosion is negligible, prepare the planting site the previous fall. Preparing the soil in the fall will prevent any planting delays caused by cold, wet soils and will help reduce soil compaction associated with working wet soils. Compacted soils restrict root growth, reduce the amount of oxygen available to roots and limit water penetration, all of which can hurt yield potential. Work beds 6–7 inches deep to promote good rooting.

Raised beds. 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.

Starting seeds

Broccoli, cauliflower, cabbage, and Brussels sprouts should be started in the greenhouse in mid-March in southern Wisconsin, 6–8 weeks before the frost-free date (figure 1). This allows sufficient time for growth and hardening off before transplanting to the field.

Shortly before planting, treat seeds in a hot water bath (see sidebar) to kill the seed-borne bacteria and

Hot water treatment for seeds

To prevent black rot, black leg, and damping off, 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 the pathogen to remain viable. Place the seed in a mesh bag and dip the bag into water heated to 122°F. Treat cauliflower and broccoli seed for 20 minutes; treat cabbage and Brussels sprouts seed 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.

fungi that can decimate young plants. Sterilize empty transplant trays in a 10% bleach solution.

You can buy or mix your own sterile potting mix for starting transplants. The mix should include peat, sphagnum, or compost to retain moisture; vermiculite or perlite for aeration; and mineral and nutrient sources to encourage growth after the first roots form.

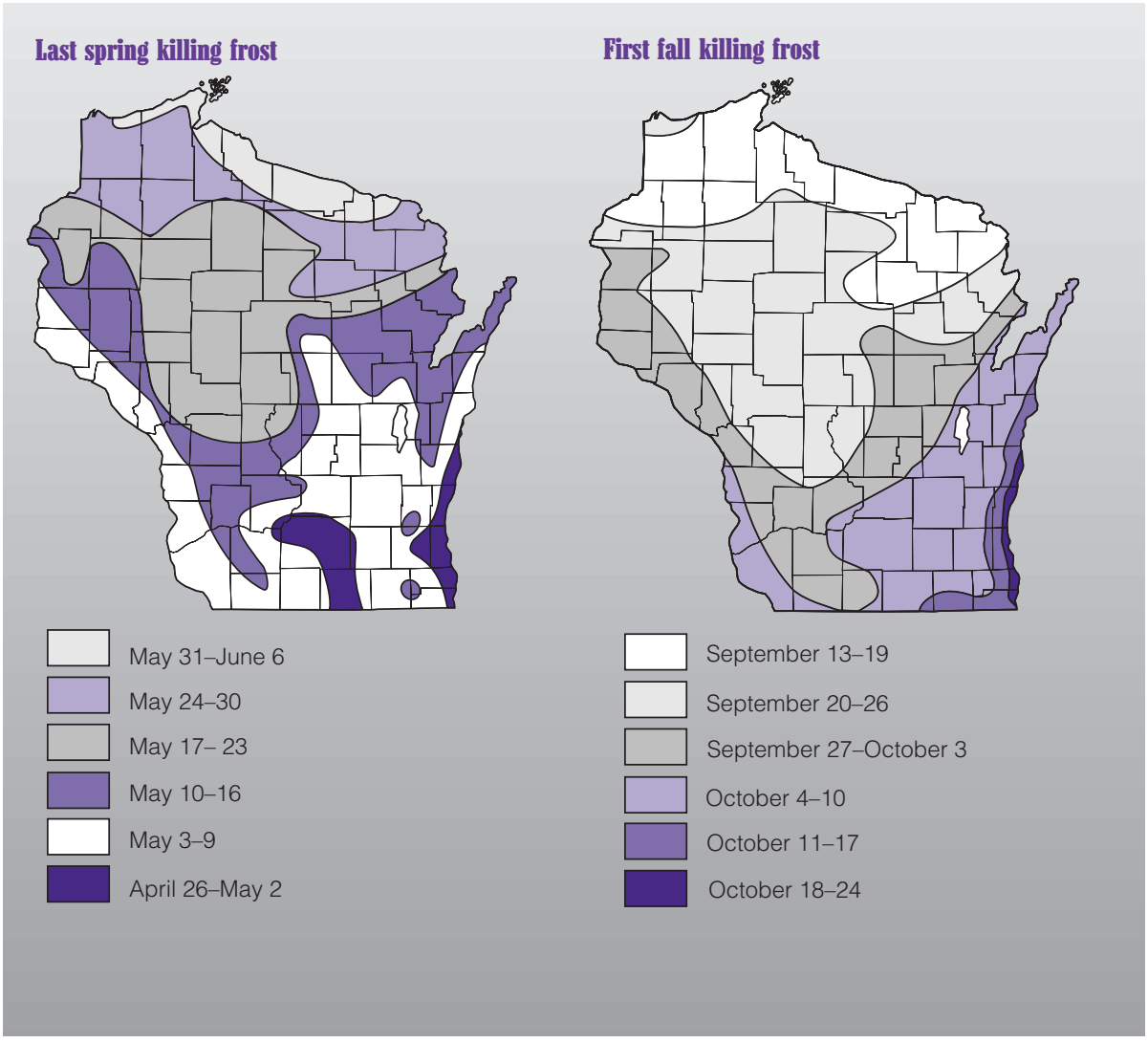
Fill plastic or polystyrene cell trays with media, or make individual blocks with a soil blocker. Cells 1–2 inches in diameter work well. Plant seeds and cover with a fine layer of media. Label transplant trays with cultivar and planting date. Keep media moist but not wet. The optimum germination temperature is between 70° and 75°F. Once seedlings emerge, daytime temperatures should be kept between 65° and 70°F while nighttime temperatures should range from 50° to 60°F. Thin seedlings to one plant per cell or plug, or one plant every 2 inches if grown in undivided flats.

Transplanting

Spring crops should be transplanted May 1 in southern Wisconsin and 2 weeks later in northern counties. Ten days before transplanting to the field, move plants into a cold frame to harden them off. Once cole crop plants have been sufficiently hardened off they will be able to withstand temperatures as low as 28°F. Refer to table 2 for recommended row and plant spacing for each crop.

You can also purchase transplants commercially. Transplants grown in the southern United States are

Figure 1. Approximate dates for first and last killing frosts.



often sturdier than those grown in northern greenhouses. However, transplants arriving from southern states should be inspected immediately upon arrival for caterpillar pests, particularly diamondback moths (see the Insect Pest Management section). Harden off purchased transplants in a cold frame as described above.

Although cole crops are adapted to cool temperatures, prolonged periods below 50°F may induce bolting (flowering), particularly after broccoli and cauliflower have reached the five-leaf stage.

Direct seeding

Brussels sprouts, kale, collards, and kohlrabi as well as mid- to late-season broccoli, cauliflower, and cabbage can be direct-seeded into the garden. For spring crops, sow the seed 3 weeks before the average date of the last frost (figure 1). For fall crops, sow the seed 10–12 weeks before the first killing frost. One ounce of seed will yield approximately 5,000 transplants. When direct-seeding, use size-graded seed and select the size to fit your planter. Plant single seed 3–4 inches apart. After emergence, remove excess plants by thinning. If planting in clusters, plant three seeds per cluster and space seed 2 inches apart within each cluster. Once the seed has germinated, thin to remove all but one plant per cluster.

Culture

Broccoli. Broccoli requires cool weather, but temperatures below 40°F will cause chilling injury and will initiate early flower development.

Cauliflower. Cauliflower is very sensitive to temperature. Cool, humid weather (68°–78°F) is ideal; hot summer temperatures result in poor curd quality. Avoid planting in hot southern or western exposures. If planting purple cauliflower, which is actually a type of winter broccoli, use the plant spacing listed for broccoli. Tie cauliflower leaves together to blanch the curds as soon as you notice curd development. Even self-blanching cultivars may need to be tied to adequately eliminate exposure to sun. Use color-coded bands when tying leaves to keep track of when each plant was tied. In warm weather, heads may develop 3–5 days after tying. Under cooler conditions, it may take up to 2 weeks for heads to mature. Check plants every other day to monitor maturity of the heads.

Table 4. 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		
Broccoli	March 15	May 1 (plants)	40–50 plants	¼	18–36	12–24	60–70	0.80
Brussels sprouts	March 15	June 1 (plants)	40–50 plants	¼	24–30	12–18	90–100	1.00
		April 15 (seeds)	⅛ oz seeds	½	24–30	12–18	90–100	1.00
Cabbage, early	March 15	May 1 (plants)	50–70 plants	¼	18–24	12–18	60–70	2.00
Cabbage, late		May 15 (seeds)	⅛ oz seeds	½	24–30	18–24	90–100	2.50
Cauliflower	March 15	May 1 (plants)	50–70 plants	¼	18–36	12–24	50–60	0.80
Collards		June 20 (seeds)	⅓ oz seeds	½	24–36	12–24	60–85	1.90
Kale		April 15 (seeds)	⅓ oz seeds	½	24–30	8–10	50–70	0.75
Kohlrabi		April 15 (seeds)	8 oz seeds	¾	15–18	3–4	50–60	1.50

[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.

Cabbage. The optimum temperatures for growing cabbage are 60°–75°F. Cabbage plants that are exposed to temperatures of 50°–55°F for prolonged periods will produce premature seed stalks instead of heads.

Brussels sprouts. Brussels sprouts are one of the most tolerant cole crops when it comes to environmental conditions and cultural requirements. Cool temperatures (58°–66°F) are ideal, therefore, late-season harvests are best. Brussels sprouts are planted later in the season than most other cole crops since frost improves the flavor. Sprouts harvested before frost tend to be loose and bitter.

Kale and collards. These two crops are the hardiest of the cole crops and can tolerate both high and low temperatures. In Wisconsin they are grown primarily as a summer or early fall crop.

Kohlrabi. Kohlrabi has specific temperature requirements. It grows best at temperatures of 60°–65°F. When kohlrabi is exposed to temperatures of 50°F or less, it forms flowers instead of an enlarged stem (the part that you eat).

Season extenders

You can lengthen the growing season by protecting plants from late spring frosts and early fall frosts. There are a variety of ways to prolong the growing season, including planting on a southern slope, creating a warmer microclimate using floating row covers, dark plastic mulch to warm the soil, clear plastic tunnels, cold frames, or using windbreaks to shield plants.

Floating row covers. Floating row covers of spunbonded polypropylene allow sunlight and water to pass through the fabric but prevent insects from reaching the plants. Row covers can be used to cover low-growing crops and protect them from frost. They also serve as windbreaks and protect crops against insect pests. Depending on the fabric weight, row covers can provide 4–8° of frost protection. Row covers allow you to plant cool-season crops 3–4 weeks earlier in the spring and extend the season 3–4 weeks later in the fall. Cole crops respond well to this method of season extension. Row covers can be reused two to three seasons.

Row covers may be draped over the crop or supported by wire hoops. If you gather the edges in a loose accordion-type fold and loosely bury them in soil along the crop row, then as the crop grows, it will push up enough fabric to maintain a "floating" cover. With tender crops or late fall crops which will grow to market maturity under row covers, consider supporting the row cover fabric to prevent abrasion damage to plants. Use 9-gauge wire hoops spaced 6 feet apart and buried 1 foot deep on each side of the row.

Row covers can be held in place by burying the edges or by weights such as reebar. Completely seal all four edges to the ground if you use row covers as an insect barrier. If not using row covers as an insect barrier, remove covers when the average daily temperature is warm enough for crop growth. Be sure to vent the beds on hot days and to let plants harden off for a few days to prevent burning before completely removing the row covers. Harden plants by removing covers on overcast days or for a few hours on sunny days.

Plastic mulch. Plastic mulch raises the soil temperature early in the season and can boost crop maturity by 1–3 weeks. Lay wide strips of 1.25–1.5 mil black polyethylene plastic over the beds before planting using a plastic mulch layer or by hand. Place soil along all the edges of the plastic to anchor it from winds. Cut or burn holes (with a propane torch) into the plastic where you want to plant. Remove loose plastic flaps which might rub against tender stems and cause abrasion. Before laying plastic, consider placing drip irrigation tape along plant rows, under the plastic. Clear plastic raises the soil temperature more than dark plastic, but it doesn't shade out weeds. If puddles form on top of the plastic, poke tiny drain holes to prevent a wet environment suitable for fungi.

Tunnels and cold frames. Tunnels are large, unheated plastic hoop-frames that can also be used to extend the growing season. Slitted clear poly tunnels increase daytime temperatures by 10°–30°F, and provide 1°–4°F of frost protection. Cold frames can be used to grow crops to maturity earlier in the spring and later in the fall than would normally be possible. Consult the references listed on page 19 for more information on cold frames and tunnels.

Windbreaks. A grove of trees to block the prevailing winds can serve as a windbreak. Windbreak effects typically extend to 2½ times the height of the windbreak. For example, a 10-foot-tall windbreak will reduce air flow up to 25 feet away on the lee side. Less-permanent windbreaks include planting a tall cover crop such as grain rye upwind to the crop or between rows to reduce wind gusts or placing a semipermeable fabric fence on the upwind edge of the field.

Soils and nutrient management

Obtain a soil test for available nutrients before planting a field for the first time and routinely thereafter at least once every 3 years. After 3 years, soil conditions can change enough to make your current fertility management program obsolete. For information on how to collect good samples and where to send them for analysis, see Extension publication *Sampling Soils for Testing* (A2100).

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.

Soil pH

The best soil pH for cole crops is 6.0–6.8 on mineral soils and 5.6 on organic soils. Acid soils will predispose the crop to clubroot, an economically important disease of cole crops.

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 chemicals, as fertilizers, can come from organic or inorganic sources. With adequate environmental conditions, soil microbes break down organic matter and supply the chemicals that plants need to their roots. 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 3 lists organic fertilizers and the amounts of nutrients in each. For more information on this subject, refer to Extension publication *Organic Soil Conditioners* (A2305).

Table 3. 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.

Nitrogen. Cole crops are heavy nitrogen feeders; refer to table 4 for the amount of nitrogen to apply annually. On long-season crops like cabbage being grown for storage and Brussels sprouts, split the nitrogen applications. Apply half at planting and sidedress the remainder midseason. The other cole crops have relatively short growing seasons and should receive all of the nitrogen at planting.

Potassium and phosphorus. Potassium is sufficient if test results fall between 100 and 200 ppm. Optimum levels of soil phosphorus range from 26 to 50 ppm. The amounts of each nutrient to apply will be specified on your soil test report. Apply phosphorus and potassium at planting. For years when no soil test is performed, refer to the recommendations in table 4.

Micronutrients. Some cole crops have high requirements of certain micronutrients. Broccoli and cauliflower require high amounts of molybdenum; broccoli, cauliflower, and cabbage have high boron requirements.

Molybdenum deficiency is very rare in Wisconsin. In early season cauliflower and broccoli, molybdenum-deficient plants have strap-like leaf blades, an effect known as whiptailing. This micronutrient becomes unavailable in acidic soils. If there is a sufficient level of molybdenum present in the soil, raise the soil pH to 6.5 or higher to prevent the molybdenum deficiency symptoms.

Cabbage grown on soils that are deficient in boron produce water-soaked, brown heads. In severe cases, the pith may be hollow with a dark lining. Broccoli grown on soils with insufficient boron will develop brown hearts or hollow stems. On cauliflower, early symptoms of boron deficiency include browning of the leaf tips and spots on the curd. As the condition worsens, the spots enlarge to cover the entire head. The core also becomes water-soaked and small cracks develop inside the stem. If your soil test for boron indicates low or very low levels, include boron with your fertilizer application prior to planting. For cauliflower, add 2–3 lb/acre of boron; for broccoli or cabbage add 1–2 lb/acre.

Table 4. Annual nitrogen, phosphate (P_2O_5), and potash (K_2O) recommendations

Crop	Nitrogen			Phosphate and potash				
	Organic matter	Amount to apply		Yield goal	Amount to apply[a] P_2O_5		K_2O	
	(%)	lb/a	oz/100sq.ft.	tons/a	lb/a	oz/100sq.ft.	lb/a	oz/100sq.ft
Broccoli	<2	100	3.75	4–6	10	0.4	20	0.75
	2.0–4.9	80	3.0					
	5–10	60	2.2					
	>10	40	1.5					
Cauliflower	<2	120	4.5	6–8	20	0.75	50	1.9
	2.0–4.9	100	3.75					
	5–10	80	3.0					
	>10	60	2.2					
Cabbage	<2	180	6.75	8–12	15	0.6	70	2.6
	2.0–4.9	140	5.25	12.1–20	25	0.9	120	4.5
	5–10	100	3.75	20.1–30	40	1.5	180	6.75
	>10	80	3.0					
Brussels sprouts	<2	100	3.75	4–6	30	1.1	120	4.5
	2.0–4.9	80	3.0					
	5–10	60	2.2					
	>10	40	1.5					

[a] Amounts are for optimum soil test levels. Apply 50% of 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

Cole crops require regular irrigation, particularly on sandy soils. If leaves begin to wilt mid-day, plants are moisture stressed. Plants that wilt intermittently produce smaller yields while plants that wilt frequently or that have been allowed to wilt too long will often die due to irreversible cell damage.

Both drip and overhead sprinkler irrigation systems are effective, such as trickle tape, solid set, and traveler hose wheel. Drip irrigation works particularly well with colored plastic mulch that is used as a season extender. Be careful to avoid overwatering as this may cause cabbage heads to split, particularly if excess soil moisture is followed by drought. To prevent splitting, lift the cabbage plants to break some of the roots once the head becomes firm.

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

Cole crops retain their fresh crisp taste if they are hydrocooled and kept under high humidity. Hydrocool them by submerging the crop in a cool water bath for a few minutes immediately after harvest. Dry the crop on screen tables and pack into waxed cardboard boxes. Maintain high humidity and provide evaporative cooling by lining the box with a clean, damp cloth.

Broccoli is harvested when the heads are firm and the individual florets have not yet begun to open. The average head size should be 4–6 inches in diameter. Harvest heads leaving 4 inches of stem attached. Sprouting broccoli should be cut just below the floret to stimulate the plant to form new shoots. Because of its high rate of respiration, broccoli must be rapidly cooled after harvest to prevent deterioration. Under high humidity in a cooler, broccoli will keep in top condition for 4–5 days.

Cauliflower is hand harvested with a knife when the curds are still compact and surrounded by leaves. Harvest heads with enough wrapper leaves to hold the head intact. Blemish-free, white heads are the ideal. Black specks on the curds or broken leaves indicate bruising and rough handling during harvest. Under high humidity in a cooler, cauliflower will keep in top condition for 4–5 days.

Cabbage grown for fresh market or storage is hand-harvested with each field being picked over two to three times. Cabbage is ready for harvest when heads are firm. When harvesting, cut the heads just above the root crown. With hydrocooling but no refrigeration, cabbage will keep for 1 day. Under high humidity in a cooler, quality can be maintained for 4–5 days.

Harvesting & packing tips

When you harvest tomatoes, peppers, and eggplants, 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.

Layout your washing and packing area to minimize stooping, lifting, and carrying. Set up screen tables or water baths at table height. Ideally, tables could be adjusted to match each worker, so that work is performed at a height between wrist and elbow.

Brussels sprouts are ready for harvest when they are 1–1¾ inches in diameter. The flavor should be sweet, the color should be bright green, and the texture firm. Brussels sprouts become sweeter and more flavorful if harvested after frost. Cut off the top 3 inches of the plants 3 weeks before harvest. If you want to prolong the harvest, don't cut back plants. Prolonged storage or excessive handling causes yellowing of the wrapper leaves and poor quality. If a once-over, destructive harvest is planned, plants may be cut at the base and transferred to a shed where the sprouts are removed. Multiple harvests will require more hand labor and leaves are usually removed at the same time as the sprouts to improve visibility. Some farmers' market customers enjoy the novelty of buying Brussels sprouts by the stalk. Since Brussels sprouts are usually harvested in cool weather, hydrocooling is not necessary. They will keep in top condition for 1–2 days. Quality can be prolonged by storage in a cooler.

Kale and collards should be harvested with a knife while young and tender. These crops can be harvested one leaf at a time or as a once-over harvest, taking the entire plant. Frost brings out both the flavor and color of kale. Make bunches of kale or collards in the field by wearing a supply of rubber bands on one wrist and forming the bunch with the other hand as you go. Kale and collards may be damaged if handled roughly during harvest. Leaves have a high respiration rate and benefit from hydrocooling and refrigeration soon after harvest. Collards are much more heat tolerant than kale, so immediate refrigeration is less critical. Kale and collards stay in top condition 1 day. They are usually sold in bunches tied with a twist tie or rubber band.

Kohlrabi should be harvested when the stems are 1½–2 inches in diameter with bright green or purple color. Cut the stem just below the bulb. The lower leaves should be healthy and remain on the tuber after harvest. Without refrigeration, kohlrabi keeps in top condition for 1 day. Good quality can be prolonged by storage in a cooler.

Storing cole crops. To preserve the characteristics of fresh market or stored cole crops, the vegetables should be refrigerated at 40°F and a relative humidity of 95–100% as soon as possible after harvest. For prolonged storage, drop the cooler temperature to 32°–34°F. Cabbage can be stored at these conditions for up to 6 months. Savoy cabbage however, can only be stored successfully for 3 months. High quality cauliflower may be stored for 4–6 weeks and broccoli for 2 weeks under optimal conditions.

Insect management

There are three key insect pests of cole crops in Wisconsin: cabbage looper, imported cabbageworm, and diamondback moth. These three pests are the larvae (caterpillars) of butterflies and moths. If left uncontrolled, they will cause economic damage to cole crops. Consumers will reject produce if it shows signs of insect damage. Because they cause similar damage to the plants and because combined damage has a cumulative effect, these three insects are considered a pest complex and managed together.

Imported cabbageworm

Description: The imported cabbageworm adult is the white butterfly commonly seen flying in great numbers on warm summer days. Larvae are velvety green worms up to 1 inch long with a faint yellow stripe running down the back. This insect is the most important insect pest of cole crops grown in Wisconsin.

Life cycle: Imported cabbageworms overwinter on plant debris as pupae. Butterflies emerge in early May and begin laying small yellow-orange eggs singly on any aboveground plant part. The larvae develop on cruciferous weeds and early-planted cole crops. The second-generation butterflies emerge in mid-July and larval development occurs almost entirely on cultivated cole crops. This generation causes the most damage. There are usually three generations per season.

Damage/Symptoms: The larvae feed upon the leaves of cole crops between the large veins and midribs. Feeding occurs primarily on the upper leaf surface near the midrib, producing large, irregular holes. As older larvae move toward the center of the plant, they may devour all but the main leaf veins. Severe feeding damage will stunt cabbage and cauliflower heads. The copious quantity of greenish-brown fecal

material produced by the larvae is also a problem as it contaminates heads and foliage.

Management: See Management Practices for Caterpillars.

Cabbage looper

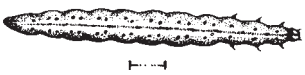
Description: The cabbage looper got its name from the way it arches its body while moving. When fully grown, its greenish body is 1½ inches long and tapers near the head. There is a thin white line along each side and two white lines along the back. The cabbage looper adult is a grayish-brown, night-flying moth. The mottled brown forewings are marked near the middle with a characteristic small, silver-white figure 8 or letter Y.

Life cycle: Adult cabbage loopers overwinter in the south and migrate into Wisconsin from mid-July through September. The female moths lay white eggs singly on the lower leaf surfaces in July. Four to five weeks after hatching, the larvae pupate. Moths emerge 10–14 days later, mate, and lay eggs which give rise to the second generation. This generation causes the most damage to cole crops in Wisconsin.

Damage/Symptoms: Feeding damage caused by the cabbage looper is similar to that of the imported cabbageworm. Most of the damage appears in late summer and is caused by the second generation larvae. Head boring is also common in early cabbage and can result in unmarketable heads.

Management: See Management Practices for Caterpillars.

Diamondback moth



Description: The diamondback moth is a small, grayish-brown, night-flying moth. It holds its wings together, roof-like over its back, when at rest. When in this position, a pattern of three diamond-shaped spots can be seen along the top of the moth's body. The small caterpillars (up to ⅜ inches long at maturity) are pointed at both ends and range in color from cabbage green to yellow. When disturbed, the larva rapidly wiggles its body back and forth, often causing it to fall off the plant.

Life cycle: The diamondback moth overwinters as an adult, and therefore is an early season pest. In the early spring, females lay eggs on weeds in the mustard family. The first instar larvae mine between the leaf surfaces. After completing four larval stages, they spin a white silk cocoon on the lower portion of the plant. There are typically three to five generations of diamondback moths each season in Wisconsin.

Damage/Symptoms: The caterpillars typically feed on the lower leaf surface, leaving the upper layer intact. This creates a "window" that later disintegrates. The most severe damage occurs when larvae disfigure the developing bud on young cabbage, causing the head to abort.

Management: See Management Practices for Caterpillars.

Flea beetles

Description: Flea beetles are a common pest of cole crops. The larvae are delicate and threadlike with white bodies and brown head capsules. All flea beetles have characteristically large hind legs, that give the adults the ability to jump. The adults are tiny; about 1/10 inch in length. Although several species of flea beetles feed on cole crops, the most common are the striped, the western black, and the crucifer flea beetles. The striped flea beetle is black, with two crooked yellow stripes on its back, while the crucifer flea beetle is solid bluish- or greenish-black.

Life cycle: Flea beetles overwinter as adults in leaf litter, hedgerows, windbreaks, and wooded areas. They emerge in late April, when temperatures reach 50°F and feed on cruciferous weeds and volunteer plants until new cole crops emerge. Adults begin laying eggs in the soil at the base of host plants in May. Eggs hatch in 7–14 days and larvae feed on various plant parts until full grown. They pupate in earthen cells for 11–13 days before emerging as adults.

Damage/Symptoms: Adults feed on both the upper and lower leaf surfaces but they favor the underside.

Management practices for caterpillars

Scout fields weekly throughout the season for imported cabbageworms, cabbage loopers, and diamondback moths. Check plants carefully—even if no feeding damage is apparent—to look for eggs that will hatch into small caterpillars several days to a week later. Examine the lower leaves of the plant for the larvae of each pest. Although feeding damage and fecal material are signs of activity, it's better to rely on larvae counts to determine the level of infestation. Caterpillars cause varying amounts of damage depending on the maturity of the plant, so the need for treatment changes as the crop grows. Table 5 lists the recommended treatment thresholds for each stage of plant development. Keep a record of which insect is present, the life stage, and the percent of plants infested. This information will be useful for monitoring whether the population is increasing or decreasing and whether pest management activities are successful.

There are several natural enemies of the three caterpillar pests of cole crops. If natural populations do not provide sufficient control, releases of parasitic wasps, *Trichogramma* and *Diadegma insulare,* may help to suppress the population. The bacterium *Bacillus thuringiensis* (Bt) is a microbial insecticide that can be very effective in controlling young larvae. Bt sprays will control caterpillars without harming the natural enemies that may also be providing control. There are many commercial formulations of Bt registered for use on cole crops. However, some populations of diamondback moth have already developed resistance to Bt. For detailed information about the natural enemies and commercially available biological controls of insect pests of cole crops, see Extension publication *Biological Control of Insect Pests of Cabbage and Other Crucifers* (NCR471).

Several chemical insecticides are labeled for the control of cabbage loopers, diamondback moths, and imported cabbageworms. Refer to Extension publication *Commercial Vegetable Production in Wisconsin* (A3422) for specific recommendations.

Table 5. Treatment thresholds for caterpillar complex

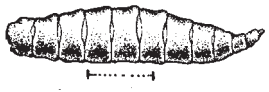
Crop	Growth stage	Threshold (% infestation)
Broccoli and cauliflower	Seedbed	10%
	Transplant to first flower or curd	50%
	First flower or curd to maturity	10%
Cabbage	Seedbed	10%
	Transplant to cupping	30%
	Cupping to early heading	20%
	Early heading to mature head	10%

Source: *Biological Control of Insect Pests of Cabbage and Other Crucifers* (NCR471), University of Wisconsin-Extension, 1993

They chew small, circular holes through the leaf to the upper surface which often remains intact for some time before drying and falling out. The circular holes give the plant a "shotgun" appearance. Heavy feeding on young plants may reduce yields or even kill plants. The larvae feed on the roots and tubers but don't cause economic damage. Flea beetles often spread plant diseases.

Management: Planting cole crops in April or later in June may help to avoid high populations of flea beetles while the plants are small and vulnerable. Enclosing seed beds with floating row covers will protect plants from egg-laying adults. Other effective cultural controls include removing cruciferous weeds, deep plowing crop residue in the spring, and crop rotation. Some varieties of broccoli, cabbage, collards, and kale have partial resistance to flea beetles but will not avoid damage completely. Foliar insecticides provide quick control of large populations of adult flea beetles.

Cabbage maggot



Description: The cabbage maggot is a serious pest of cole crops in Wisconsin. The larvae are typical fly maggots: legless and white with ⅓-inch long bodies that taper toward the head. Adult cabbage maggots are ash-gray, bristly flies that resemble houseflies but are only half as long and have black stripes on the thorax.

Life cycle: Cabbage maggots overwinter as pupae in the upper 1–5 inches of the soil. In early May adults emerge and lay eggs on the soil near the base of cole crops. The eggs hatch 3–7 days later and the larvae immediately begin feeding on the roots of the plant. Feeding continues for 3–4 weeks before the larvae pupate in the soil. The second generation adults emerge in late June and lay eggs. There are three generations per year in Wisconsin.

Damage/Symptoms: The larvae feed in and on the roots of all cole crops. Maggots are especially damaging to seedlings, injuring the growing point of the root and thereby stunting plant growth. Affected plants appear stunted and off color. Severely damaged plants may wilt during hot weather. Cabbage maggot feeding wounds may provide a point of entry for the fungus that causes soft rot or black leg.

Management: Prevention is the best method of cabbage maggot management. Late plantings (mid-June) are generally damaged less than early plantings. If possible, time planting dates to avoid peak fly emergence. Transplants should be planted 1 week before peak emergence while seed should be sown at least 3 weeks before or 1 week after fly emergence. These periods can be anticipated using degree days (see the sidebar for an explanation of how to calculate degree days). Begin monitoring degree days when the ground thaws in early spring, using a base temperature of 43°F. The first generation of adult flies appears once 300 DD_{43} have accumulated. The second and third generations appear once 1476 DD_{43} and 2652 DD_{43} have accumulated. Fly populations can also be monitored using yellow plastic dishpans filled with soapy water. Place dishpans at 100-foot intervals along the field edge and check them every 4–6 days. Count and record the number of flies caught to determine if the population is building or dropping off. Floating row covers are also effective in protecting plants during the flight periods. Insecticides applied at planting time are recommended in areas that have historically had problems with cabbage maggots. The cabbage maggot is resistant to many insecticides. Therefore, select an effective material and rotate among pesticide classes to prevent the buildup of resistant populations.

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).

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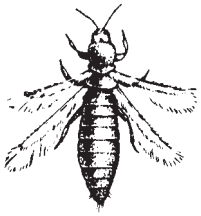
Onion thrips



Description: Onion thrips are pale yellowish or brown insects about 1/12 inch long. Wings have no veins and are fringed with long hairs. Nymphs resemble adults, except for their smaller size and lack of wings.

Life cycle: Adults and nymphs overwinter on plants or debris or along weedy field edges. Females reproduce without males and male thrips are scarce. After 5–10 days, the eggs hatch. Nymphs mature in 15–30 days. Shortly before they mature, the nymphs stop feeding and move into the soil. There are usually five to eight generations per year.

Damage/Symptoms: Onion thrips are most damaging to cabbage and cauliflower. These insects use rasping-sucking mouthparts to feed on the leaf surface, creating whitish blotches. Thrips prefer tight spaces and may be found several layers deep within developing cabbage heads. In severe infestations, when thrips populations build up inside the cabbage head, the cabbage may be underweight and misshapen. On cauliflower, thrips damage causes tan or brown streaks on the curd. Damaged curds are more susceptible to soft rot bacteria.

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 cole crops, 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 the equations 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]Substitute the base temperature if the daily low is less than the base temperature.

Management: Thrips should be controlled early, before they colonize the inside of the head, out of reach of insecticide applications. Due to their small size and reclusive habits, thrips are difficult to scout. No economic thresholds have been developed for thrips on cabbage. Yellow or white sticky traps may be used along field edges to monitor the initial migration into a field. Cleaning plant debris from the field and the surrounding area may aid in controlling thrips. Avoid planting cole crops downwind from small grains or alfalfa fields as thrips will migrate into cole crops when the small grains are cut. Looser headed varieties tend to have fewer thrips problems than tight-headed varieties. Refer to Extension publication *Commercial Vegetable Production in Wisconsin* (A3422) for specific pesticide recommendations.

Disease management

Clubroot

Hosts and severity: Clubroot is caused by a member of the slime mold group of fungi. The fungus infects the roots of many species of cole crops, wild plants, and weeds of the crucifer family. Losses due to clubroot are sometimes very heavy, and the economic importance is increased by the fact that once the soil is infested, it commonly remains so for many years, even in the absence of susceptible host plants.

Disease cycle: The organism that causes clubroot can remain in the soil for 10 years or longer. Infection occurs through root hairs and wounds. As the root enlarges and spores of the fungus are produced, soil becomes contaminated. Infested soil is disseminated by equipment, human activity, and running water.

Symptoms: The most noticeable symptom is the abnormal enlargement of the roots. These enlargements may occur on the very small roots, secondary roots, taproot, and underground stem. The root clubs are often thickest at the center, tapering toward either end. In plants where fleshy roots are normally formed, infection usually occurs only on the smallest and secondary roots. Roots may be extensively infected before any above-ground symptoms appear. Infected plants are unable to efficiently take up water and nutrients, so plant growth will be stunted, leaves may yellow or wilt, and yields will be reduced.

Management: In fields with a history of clubroot, monitor plants weekly throughout the growing season to determine the level of infection. Dig and inspect the roots of plants that appear stunted. If there are no symptomatic plants, examine the roots of healthy plants at random. Eliminate all weeds that belong to the crucifer family in and near the field. Plant cole crops on well-drained soils since the fungal spores germinate readily in wet soils. Discontinue growing cole crops on badly infested areas if possible. Avoid the infestation of new fields by growing transplants in soil free of the fungus. Long crop rotations of at least 7 years out of cole crops are recommended. If compatible with the well-being of other crops in rotation, keep the soil pH above 7.2. Liming provides good control on heavier mineral soils but is often ineffective in sandy or muck soils.

Cabbage yellows

Hosts and severity: Cabbage yellows affects most cole crops, but it is especially serious on cabbage. It is most prevalent in warm weather. In Wisconsin, yellows was one of the greatest hazards to cabbage production until resistant varieties were developed. The use of resistant varieties currently is the only way to successfully control this disease.

Disease cycle: The fungus that causes cabbage yellows overwinters on infected plant debris and may persist in the soil in the absence of debris for many years. The fungus spreads readily when infested soil particles are moved from one place to another. The fungus enters the plant through wounds and secondary roots. Once inside the plant, the fungus moves to the leaves and stem. The fungus produces a toxin that causes discoloration of infected vessels.

Symptoms: Cabbage yellows affects plants at any age. Initial symptoms are lifeless, yellow-green leaves. Frequently, discoloration is more intense on one side of the leaf or plant, causing the leaves and stem to warp or curl. The lower leaves are affected first, but symptoms progress upward. As the yel-

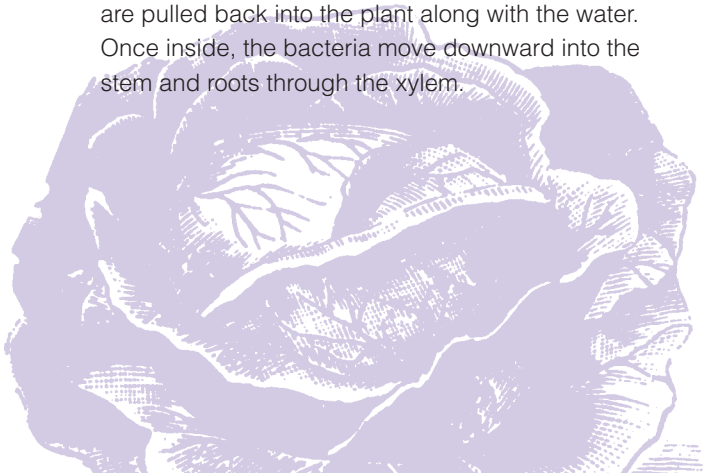
lowed tissue ages, it turns brown and becomes dead and brittle. Affected leaves drop prematurely and normal growth is distinctly retarded. The veins in stems and leaves of diseases plants become yellow to dark brown. Plants infected with cabbage yellows usually show the characteristic symptoms 2–4 weeks after being transplanted. The rate of disease development depends on the degree of susceptibility of the host plant and environmental conditions.

Management: Yellows is best controlled through the use of resistant varieties. Monitor fields weekly throughout the season. Although there is little that can be done once fields are infested, knowing the level of infection will be useful in planning rotations in subsequent years. Avoid transplanting diseased seedlings, especially where the disease has not previously occurred. Cultural practices such as crop rotation, destruction of diseased refuse, and seed treatment are of little value for yellows control.

Black rot

Hosts and severity: Black rot is a serious bacterial disease of cole crops in Wisconsin. The losses from this disease can be high in years when rainfall is plentiful or dews are heavy and average temperatures are 60°–70°F. Black rot lesions can also provide an entry site for soft rot diseases.

Disease cycle: The bacteria that causes black rot overwinters in diseased plant debris and seed. Plants can be infected at any stage of development. The initial infection usually originates from infected seed or transplants. Infection occurs most frequently through the water pores, which are located along the leaf margins. These pores exude water droplets in the early morning and pull them in later in the day. Any bacteria that come in contact with these droplets are pulled back into the plant along with the water. Once inside, the bacteria move downward into the stem and roots through the xylem.



Symptoms: Black rot is primarily a disease of the above-ground plant parts. The first signs of the disease appear at the edges of leaves, where initial infections most often occur. Infected leaves turn yellow, usually in a V-shaped area with the base of the V toward the midrib. These areas soon die and become tan and dry as the disease progresses. In the yellowed tissue, the veins become dark in color. Holding the leaf up to a bright light reveals a network of black veins. Infected leaves may be stunted on one side and may drop prematurely. Invaded cabbage and cauliflower heads are discolored and usually have soft-rot decay and an unpleasant odor.

Management: Plant only disease-free seed or transplants. Resistant cultivars of broccoli, cauliflower, and cabbage are available and recommended. All seeds of susceptible cultivars should be given a hot water bath to kill the pathogens that cause black rot, blackleg, and damping off (for details on treating seeds, see the sidebar on page 3). An alternative to the hot water bath is to treat seed with calcium hypochlorite to eliminate bacteria prior to planting.

Inspect transplants carefully for symptoms of black rot before planting, removing any suspect plants. Do not dip transplants in water prior to planting. Also, do not clip transplants, since clipping wounds provide entry sites for bacteria.

After planting, monitor fields weekly early in the season. Remove infected plants immediately to reduce spread of the disease. A 3-year rotation with crops other than crucifers helps keep the seedbeds and fields free of the pathogen. When watering, avoid splashing water from plant to plant.

Never cultivate, spray, or move irrigation pipe in infected fields when foliage is wet. Cultivate or spray infected fields last to avoid carrying the bacteria to new areas. To avoid carryover to next year's crop, sterilize crates, cultivators, harvest equipment, and any other item that comes into contact with infected fields. Disinfest equipment using steam treatment or a 10% bleach solution. Plow under plant debris after harvest to hasten decomposition.

Downy mildew

Hosts and severity: Downy mildew of cole crops is present in all cool, humid parts of the world. The disease causes losses in broccoli, cauliflower, cabbage, Brussels sprouts, and edible roots of other crucifers. The lesions caused by downy mildew provide openings for invasion by the soft rot bacteria.

Disease cycle: The fungus survives as mycelium between crops within a single growing season and overwinters as thick-walled oospores in plant debris. The following spring, these resting spores germinate and produce infective spores that are carried for a long distance in cool moist air. If the weather is favorable, these spores germinate in 3–4 hours and produce a new crop of spores within 4 days.

Symptoms: Plants are susceptible to infection at any stage of development, although young tissue is more susceptible. The mildew fungus produces a white, fluffy growth (mycelium) primarily on the lower leaf surface. Often the corresponding upper surface of the leaf yellow-brown spots with a somewhat scorched appearance. Young leaves may yellow and drop while older leaves become tan and leathery. When the disease is severe, the entire leaf dies. Stems and seed pods are also affected with irregular dark-purplish spots. On cabbage, the fungus may cause numerous sunken black spots. A similar blackening occurs on the curds of cauliflower and broccoli.

Management: Always plant seeds that have received a hot water bath or approved chemical treatment to kill the fungus. In the field, practice a 3-year rotation with crops other than cole crops. Eradicate weeds, especially mustard weeds, in and around the field. Plow under plant debris soon after harvest so it will decompose and not provide a means for the fungus to survive between crops. Resistant varieties are also available.

Bacterial soft rot

Hosts and severity: Bacterial soft rot is a disease that affects many vegetables.

Disease cycle: The bacteria often enter susceptible plants that are infected by other disease-causing organisms but they may also gain entrance through wounds. Not only are wounds necessary for the bacteria to gain entrance into the plant, but conditions must be such that the wounds are not corked over before soft rot is initiated. For example, the gnawing action of cabbage maggots keeps the tissue freshly wounded and predisposed to soft rot. 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. In addition, the bacteria are spread by tools, clothing, decayed plant tissue, rain, and running water. Concave broccoli heads (depression in the center of the head) are more susceptible to soft rot infection in the field because rain and irrigation water does not readily drain from the heads.

Symptoms: Cole crop losses from bacterial soft rot occurs most often in storage or transit, but the disease may also be destructive in the field. The first symptom is a small, water-soaked area that rapidly enlarges and becomes soft. On cabbage a slimy decay, which usually begins at the base of the head, spreads rapidly through the entire plant. There is a slight browning of the diseased portion. An offensive odor is usually present in diseased crucifers.

Management: To control soft rot, one must first control other diseases and avoid injury to the plants. Control insects such as the cabbage maggot that wound plants and transmit the bacteria. Cole crops should be planted on well-drained soils. Space rows and plants adequately so that soil dries easily. Avoid planting in shaded areas that keep plants wet from dews or rains. Overhead irrigation may increase the rate of infection if other conditions are favorable for the disease. Practice a 3-year rotation out of susceptible crops with corn, small cereal grasses, beans, or beets.

Environmental disorders

Cauliflower is the most difficult of the cole crops to grow due to its specific environmental requirements. As a result, many of the disorders exhibited by cauliflower are caused by less-than-optimal growing conditions. Spring crops that are exposed to excessive sun and heat will produce ricey curds, where the surface of the curds separate into very small grains. High temperatures also result in excessive leaf development at the expense of inflorescence initiation. Cool temperatures prolong the vegetative state. Plants exposed to near-freezing temperatures before they reach the seventh leaf stage may not head at all, a condition known as blindness.

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 with a cover crop (such as buckwheat), by solarization with black plastic, by hand removal, or by using herbicide sprays. In most cases, early season cole crops mature before annual weeds become a problem. However, winter annual weeds, particularly those belonging to the mustard family, should be controlled prior to planting. Early in the season, cultivate to manage seedling weeds as they germinate. However, as the crop develops, cultivation may damage the shallow root system of the crop. A thick straw mulch will prevent weed germination and growth by blocking sunlight from reaching the soil. Preplant, preemergence, and postemergence herbicides are available for control of most weeds encountered in cole crop production. Refer to Extension publication *Commercial Vegetable Production in Wisconsin* (A3422) for specific herbicide recommendations.

Additional reading

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