

COLE CROPS

Broccoli, Brussels Sprouts, Cabbage, Cauliflower

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This bulletin has been prepared as a guide for commercial production of the cole crops. The cole crops are members of the *Cruciferae* (mustard) family, which also includes Chinese cabbage, col-lard, horseradish, kale, kohlrabi, mustard, radish, rutabaga, turnip, and watercress. The term "cole" probably originated in ancient Roman times as a name for leafy vegetables in the mustard family, but now we use it primarily for broccoli, Brussels sprouts, cabbage, and cauliflower. They are important fresh market and processing crops in Michigan, with a combined total of about 7,000 acres grown each year.

Production

The yield figures (Table 1) are based on the experience of Michigan growers over many years. Experienced growers should be able to produce cole crops at good or higher yield levels regularly.

Types and cultivars

Broccoli, Brussels sprouts, cabbage, and cauliflower are all botanical varieties of the genus and species *Brassica oleracea*. Because they are closely related, their culture is similar. However, there are important differences both between and within the botanical varieties.

BROCCOLI: Most broccoli cultivars produce good quality heads during cool weather, but only a few are productive at temperatures above 85° F. By selecting cultivars adapted to different environmental conditions, it is possible to produce good broccoli from June through October in Michigan.

Broccoli plants produce large central heads. After the main heads are cut, the plants produce side-shoots in the axils of the leaves. Most older cultivars produce many sideshoots, but most recently-developed cultivars produce very few sideshoots. Some new cultivars produce heads on an elongated stem, so that the heads are exposed at the top of the plant. These heads are easier to cut and bunch than heads on short stalks, and they are less susceptible to diseases caused by contact with surrounding leaves.

Other characteristics to consider when choosing a broccoli cultivar are head size, head uniformity, color, firmness, and days to maturity.

BRUSSELS SPROUTS: Brussels sprouts require a long, cool growing season to produce good quality buds. Most areas in Michigan are not

Table 1. Yields of cole crops in Michigan

	Yields—Tons per acre		
	Low	Good	Excellent
Broccoli (main heads)	2.5	4	5
Brussels sprouts (buds)	4	5	6
Cabbage, fresh market	10	15	20
Cabbage, processing	25	30	40
Cauliflower	4	7	10

well-suited to Brussels sprout production because summers are too hot, and the cool, fall growing season is too short for efficient production.

There are two basic types of Brussels sprout cultivars: short or dwarf types that are very compact with no space between sprouts on the stalks; and tall or standard types. The short types mature sooner and are more suited to production in Michigan.

CABBAGE: There are several types of cabbage, including white or green, red, and savoy. There are several head shapes, the most common being round, flat, and oval. Early-maturing cabbage cultivars are very compact and grow rapidly. Mid- and late-maturing cultivars are larger, and heads can be harvested early for market, or later for processing. Some late-maturing cultivars can be stored for several months and marketed during the winter.

CAULIFLOWER: The main differences between cauliflower cultivars center around maturity. Early-maturing cultivars tend to be smaller, are not self-blanching, have lighter heads, and are usually more susceptible to environmental stress. Mid-season and late-maturity cultivars grow larger, many are self-blanching, and the heads are larger and more dense.

Some recent mid- and late-season cultivars have a more compact growth habit than traditional cultivars. Heads are borne on a taller stalk and leaves are smaller. These cultivars may be planted at a closer spacing than larger plants, but require more careful management in the field.

Climate and Irrigation

All of the cole crops are cool-season crops. They grow well under moderate temperatures and withstand moderate frosts. Cole crop seeds will germinate at 40° F, but germinate best at 70 to 75° F. Of the cole crops, cabbage is the least susceptible to high temperatures. It grows and produces well at temperatures up to 85° F. Brussels sprouts grow well at temperatures below 70° F and are grown commercially in areas with cool summers or mild winters. Broccoli and cauliflower grow well at temperatures of 70 to 85° F, but heads tend to be soft and become over-mature

quickly at temperatures over 80° F. Cauliflower is usually grown as a fall crop in Michigan to avoid hot summer temperatures.

Cauliflower is the most sensitive of the cole crops to adverse weather. Mature cauliflower plants can withstand temperatures as low as 25° F for several hours late in the fall without damage to the curd. However, young plants subjected to freezing temperatures often "button" (form heads prematurely). Cauliflower heads maturing during warm weather (above 80° F) often suffer from one or more disorders: leafy heads, riciness (over mature florets), purple or green color, soft, loose heads, and poor wrapper leaf development.

Cole crop roots penetrate the soil to a depth of only 18 to 24 inches. They have a relatively high and constant moisture requirement. Thus, even moderate drought stress any time during the growing season may cause significant reductions in growth and yield. Growth during dry periods causes internal tipburn in cabbage and buttoning and tipburn in cauliflower. Cole crops require 1 to 2 acre inches of water as rainfall or irrigation per week, depending on plant size, stage of growth and soil type.

Irrigate cole crops with ½ inch of water immediately after transplanting to avoid moisture stress on young plants. If the soil is dry at the time of transplanting, irrigate the land to be planted 2 days before transplanting with ½ to 1 inch of water, and follow the transplanting with ½ inch of water.

Cole crops are also very sensitive to waterlogged soil. If the roots are under water for over 24 hours, many plants will die. Therefore, plant cole crops only on soil with good surface and sub-surface drainage.

Soils and Field Preparation

Cole crops grow well on well-drained soils with good moisture-holding capacity. They are very sensitive to nutrient deficiencies and low pH. Loams, clay loams, and muck soils are ideal for cole crop production, but lighter soils can also produce good cole crops if managed carefully. Because of potential disease problems, use a crop rotation that does not include members of the

Cruciferae family more than 1 year in 3. Eliminate weeds in the *Cruciferae* family, such as wild mustard, yellow rocket, shepherdspurse, and wild radish since they serve as hosts for several cole crop diseases.

Prepare the field for transplanting by broadcasting the fertilizer and incorporating the herbicide and boron. A slightly rough soil surface will help reduce sand movement and blasting of the transplants. If preparing the field for direct seeding, make a smoother seedbed. Cole crops normally germinate and emerge easily unless a hard crust forms on the soil surface.

Fertilizer

The cole crops require careful nutrient management to obtain good quality and maximum yields. They are sensitive to several micronutrient deficiencies and require nitrogen throughout the growing season. Maintain the soil pH at 6.2 to 6.8 on mineral soils and 5.5 or higher on organic soils. Add lime as recommended by your soil test to achieve the desired pH level.

Cole crops require moderate to high amounts of nitrogen, phosphorus, and potassium. As a basis for good nutrient management, maintain soil test levels of phosphate (P_2O_5) at 150 to 200 lb per acre and of potash (K_2O) at 300 to 350 lb per acre. Each year add a minimum of 120 lb P_2O_5 and 120 lb K_2O . Total nitrogen (N) rates will vary with crop and cultivar, but all require at least 150 lb N per acre.

To prepare fields for planting, broadcast and plow down or disc in 60 lb N, 120 lb P_2O_5 , and 120 lb K_2O . Sidedress all crops with 50 lb N 3 weeks and 6 weeks after transplanting. Apply a third sidedressing of 50 lb N to cauliflower and Brussels sprouts. Sidedress with ammonium nitrate (33-0-0) or urea-ammonium nitrate 28 percent N solution if they are available. Urea (45-0-0) is a good source of N, but it has to be incorporated into the soil to avoid volatilization and is slower reacting than ammonium nitrate. It should be used for the final sidedressing to extend N availability in light soils.

Secondary and Micronutrients

The cole crops are sensitive to deficiencies of calcium, magnesium, manganese, boron, and molybdenum.

Calcium (Ca) deficiency within the plant causes internal tipburn of cabbage and external tipburn of cabbage, cauliflower, and Brussels sprouts. There is sufficient calcium for plant growth and development in most soils. However, during hot, dry weather plants grow rapidly and sufficient calcium does not reach the developing leaf tips, which subsequently die. Calcium is not readily available to plants at soil pH below 6.0, and young cole crop plants growing at low pH often demonstrate calcium deficiency symptoms of poorly developed leaves with dead margins, especially during cool weather. Maintain soil pH above 6.5 to reduce incidence of calcium deficiency.

Magnesium (Mg) deficiency occurs in cabbage and cauliflower plants when they are grown on low-pH soils. Magnesium is a very mobile element and is transported within the plants from older to newly-formed leaves when it is deficient. The older leaves of deficient plants become mottled and yellow. Younger leaves remain a normal green color.

When a soil test indicates a low magnesium level and a need for lime, apply finely ground dolomitic limestone. If magnesium deficiency occurs during the growing season, apply 2 lb actual magnesium as 20 lb magnesium sulfate (epsom salts) per acre in a foliar spray, including a surfactant. Repeat after 10 days if symptoms persist.

Boron (B) deficiency occurs to some extent in all the cole crops, but is a major problem in cauliflower, causing hollow stem and brown, water-soaked spots on the head. Hollow stem also occurs in cabbage and broccoli. Most forms of boron are very soluble and leach from the soil rapidly. There is very little chance of boron toxicity to sensitive crops as a result of carryover. However, if boron is applied in the spring with anticipation of planting cole crops, there may be sufficient boron in the soil to adversely affect small grains, beans, peas, and cucumbers planted

there the same growing season.

Apply boron to all land to be planted to cole crops. To avoid boron deficiency, apply 3 to 4 lb of actual boron per acre (30 to 40 lb borax or 15 to 20 lb Solubor) and disc in before planting. Borax can be mixed with granular fertilizer and broadcast on the field. Solubor can be sprayed on the soil and incorporated with the herbicide. Boron can also be applied to foliage, but it is less effective than soil application. If additional boron is needed during the season, apply 0.3 lb actual boron per acre (1.5 lb Solubor) in 30 gallons of water as a foliar spray.

Manganese (Mn) deficiency in cole crops is similar in appearance to magnesium deficiency, but yellowing is more general over the whole plant. Interveneal areas turn pale-green to mottled-yellow, while veins remain dark green. The deficiency frequently occurs at soil pH above 7.0. At pH below 5.5, manganese toxicity may occur, with symptoms similar to the deficiency. Maintain pH above 6.0 to avoid manganese toxicity. Broadcast soil applications of manganese are relatively inefficient in solving manganese deficiency because of its high fixation and immobility in the soil.

When a soil test or previous experience indicates that manganese is deficient, apply 8 to 12 lb of manganese per acre (30 to 45 lb manganese sulfate) in a band 2 inches below the seed or as a sidedressing after plants are established. For foliar application, apply 1 to 2 lb manganese (4 to 8 lb manganese sulfate) in a foliar spray 3 to 4 weeks after transplanting, or when plants are about 6 inches high after seeding. Reapply every 2 weeks until symptoms disappear.

Molybdenum (Mo) deficiency occurs occasionally in cole crops, primarily on low-pH soils. Cauliflower is very susceptible. Recently matured leaves of molybdenum-deficient plants are light green or slightly yellow. Leaf margins may curl in and die. Some leaves may not expand fully, causing a condition called whiptail.

If the deficiency occurs in the field, apply 3 ounces of sodium molybdate per acre as a foliar spray that includes a surfactant. One or two applications should overcome the deficiency.

Transplant Production

Cole crop transplants can be grown in the greenhouse or field. Plants for transplanting into the field during April and May are grown in the greenhouse. Plants for later field establishment can be grown in the greenhouse or field seedbeds. Many of the cabbage and broccoli plants transplanted during April and May in Michigan are grown in field seedbeds in the southern United States and shipped north by truck.

Greenhouse Plant Production: Grow cole crop transplants in $\frac{3}{4}$ to 1 inch diameter cells. Two hundred or 288 square-cell greenhouse flats (11 by 22 inches) are ideal for cole crop plant production. Plants grown in smaller cells require more careful watering and fertilizing and often become spindly and root bound. Early cauliflower plants are very sensitive to root binding and often button if held in cells too long.

Use a moderately coarse, pasteurized soil or artificial mix that is well drained but holds some moisture. Soak the media thoroughly at least one day before seeding. Sow seeds about $\frac{1}{4}$ inch deep, and water after seeding. After seedlings have emerged, water daily or as needed; soak the cells completely, but do not overwater. Do not use sprinkler or mist systems that keep the leaves and media wet continuously.

After the first true leaves appear, water once or twice a week with 100 ppm of a soluble complete fertilizer (such as 20-20-20). Do not over-fertilize or plants will become tall and thin. Cole crop seeds germinate rapidly at temperatures above 60° F. After emergence, maintain 60 to 65° F night and 70 to 75° F day temperatures.

Cole crop plants are ready for transplanting 4 to 5 weeks after seeding, when they are 4 to 6 inches tall with 3 to 4 true leaves. If the plants are ready but cannot be transplanted immediately, reduce water and temperature slightly to slow their growth. Cole crop plants should not be hardened before transplanting during cool weather. If they will be transplanted during hot, dry weather, harden the plants for 2 or 3 days before transplanting by exposing them to ambient conditions while still in flats. The day before transplanting, water the plants with a complete fertilizer solu-

tion. Soak the media thoroughly with water before taking the plants to the field.

Transplant Production in Field Seedbeds:

Establish field seedbeds on light, sandy soil that has not had cole crops on it during the preceding 3 years. Before seeding, disc in 300 lb 12-12-12 or the equivalent per acre. Sow 3 to 4 seeds per inch $\frac{1}{4}$ to $\frac{1}{2}$ inch deep in moist soil in rows 10 to 12 inches apart. Three to four ounces of seed will provide enough plants for one acre of field transplanting. Be sure to apply an herbicide, either preplant incorporated or after seeding.

After sowing the seed, drench the soil with a soil insecticide to avoid maggot and cutworm damage. Irrigate the seedbed regularly so that plants do not suffer moisture stress. Sow cabbage and broccoli seeds in early April to have plants ready for transplanting in May and thereafter. Sow seeds every week to maintain a constant supply of young plants. Sow Brussels sprouts in late May for transplanting in early July. Cauliflower seedlings are sensitive to cool weather and frost and should not be sown in the field before May 1. Sow cauliflower seed May 15 to 30 for plants for the fall harvest.

Soak the seedbed, or loosen the soil around the plants with a fork before pulling to keep root systems intact. It is best to pull the plants needed each day. However, if more plants are ready than can be planted immediately, pull and pack them loosely in boxes, and store at 50° F for up to 1 week. Make sure plants are dry before packing in boxes to prevent disease development.

Field grown plants are ready for transplanting when they have 3 to 4 leaves and are 5 to 6 inches tall. They are usually ready 5 to 6 weeks after sowing, but early plantings may take 1 or 2 weeks longer. Plants older than 6 weeks can be transplanted, but they become established slowly, suffer higher mortality, and are more likely to button.

Spacing and Planting

The recommended planting dates and spacings for cole crops are given in Table 2. Cole crop seeds vary considerably in size, with 4,000 to 12,000 seeds per ounce. At a 3 ft by 1 ft field spacing, there are about 15,000 plants per acre; at a 3 ft by $1\frac{1}{2}$ ft spacing, there are about 10,000 plants per acre.

Cole crops are usually transplanted in Michigan. To help plants become established in cool soil, include a high-phosphorus starter fertilizer in the transplant water. Apply 2 to 4 fl. oz. of water with each plant. Use the higher rate when soil is dry. Also include an insecticide for maggot control in the transplant water, or drench the plants with a soil insecticide after transplanting.

Cole crops can be established relatively easily by direct seeding. The seeds germinate and plants emerge quickly, even in cool soils. The seeds are round and thus are well adapted to precision seeding. Seeded cole crops normally take 20 to 30 days longer from planting to harvest than the same transplanted crop. A precision seeder is essential for direct seeding of cole crops. Belt, cup,

Table 2. Planting dates and final spacing for direct-seeded and transplanted cole crops.

Crop	Establishment method	Planting date	Row spacing (inches)	Plant spacing (inches)
Broccoli	Transplanted	4/15-7/15	24-36	12
	Seeded	4/15-7/15	20-36	6-8
Brussels sprouts	Transplanted	6/20-7/10	36	24
Cabbage	Transplanted	4/1-7/15	30-36	12-18
	Seeded	4/15-6/15	30-36	12-20
Cauliflower	Transplanted	6/20-7/10	36-40	18-24
	Seeded	5/15-5/30	36-40	16-24

and vacuum planters can plant uncoated seed. Since seed size varies considerably between cultivars, several different belts or cups will be needed to plant different crops and cultivars. Clean seed is essential for vacuum planters because seed trash blocks the small plate holes, causing skips in the row.

To obtain a uniform stand, make sure the seeder singulates the seed. Plant double or triple the desired stand, and thin with a hoe 2 to 3 weeks after emergence. If saving time is more important than a perfect stand, plant to the desired stand. You should be able to obtain about an 80% stand by seeding cabbage and broccoli to stand. Cauliflower should always be planted thicker and thinned to stand because there are fewer total plants per acre, and stand reductions thus have a greater impact on potential yield.

Harvest and Postharvest

Each of the cole crops has different harvest and postharvest requirements. Broccoli is ready for harvest 45 to 60 days after transplanting, or 60 to 75 days after direct seeding. Hybrid cultivars mature very uniformly and most heads in a planting can be harvested in two trips over the field within 7 days. Some older cultivars mature over a longer period of time and may require three to four harvests to cut over 90% of the main heads. Some cultivars produce sideshoots for 4 to 6 weeks after initial harvest. The sideshoots become progressively smaller, and it usually does not pay to harvest them after the main heads have been cut. They may be a good source of broccoli for U-pick operations.

Cut **broccoli** by hand and transport it to a packing shed in containers or in bulk wagons. Harvest broccoli heads that are 3 to 6 inches in diameter and have a uniform green color. Cut the heads so that the total length from the top of the head to the end of the stem is 6 to 8 inches. Strip large leaves off the harvested stems.

The size of broccoli heads is directly related to plant spacing: the closer the spacing the smaller the heads. Broccoli is usually sold in 6- to 7-inch diameter bunches containing 1, 2 or 3 heads. Tie the bunches with paper-covered wire, rubber, or

plastic bands, and pack 14 or 18 bunches in 23-lb broccoli boxes.

No. 1 broccoli is solid with no open florets; it has uniform green or blue-green color; the heads are clean and contain no insects, soft rot, or hollow stem, with few or no leaves in the heads.

Harvest broccoli early in the morning so that the heads remain cool. Pack, hydrocool, ice it, and place in a cold storage at 32° F as soon as possible. If broccoli is kept iced at 32° F and 95% relative humidity, it should remain in good condition for 3 to 4 weeks.

Brussels sprouts mature 90 to 120 days after transplanting. When sprouts at the bottom of the stalk are $\frac{3}{4}$ to 1 inch in diameter, cut off the top of the plant so that no more sprouts form. The sprouts that have developed will then fill out and mature in about 4 weeks. Remove leaves with a knife or machete before harvesting the stalks. Harvest the stalks by chopping them off at ground level. The stalks may be sold with sprouts attached (for local sales), or the sprouts can be removed and packed in small baskets.

Cabbage matures 60 to 80 days after transplanting. It is mature when heads are solid. Harvest early cultivars soon after they reach maturity to prevent the heads from splitting. Most full-season cultivars are less susceptible to splitting and continue to gain size until harvested. Cut cabbage for market with 4 or 5 wrapper leaves. No. 1 heads for market weigh 2 to 5 lb. An ideal size is 2½ to 3 lb so that 20 heads will fill a 55 lb, 1¾-bushel box or wirebound crate.

No. 1 heads are solid, have uniform green color, no insect injury or debris, no soft rot or black rot, no thrips damage, and no internal tipburn.

Cabbage stores well and should last 4 to 6 weeks at 32° F and 95% relative humidity. Some late-maturing cultivars store well for 5 to 6 months and can be marketed during the winter.

Depending on the cultivar and season, **cauliflower** matures 50 to 90 days after transplanting. Cauliflower is ready for harvest when heads are 6 to 8 inches in diameter. Cut the heads before

they become overmature and florets begin to separate.

Most cauliflower needs to be blanched to produce uniformly white heads. Blanching is any process that prevents sunlight from contacting the heads and turning them yellow. Most recently-developed, late-season cultivars are moderately to very self-blanching; i.e., wrapper leaves naturally curl over and cover the heads so that sunlight doesn't penetrate, making tying unnecessary. Self-blanching occurs most effectively after September 1 when night temperatures fall below 50° F. At higher temperatures the wrapper leaves do not cover the heads well and the plants have to be tied. Cauliflower that does not require blanching is being developed and should be on the market soon.

Tying is the traditional method of blanching cauliflower. When plants are nearing maturity, check fields every 3 or 4 days for visible white heads. Gather the outer leaves together over the heads and tie them together with colored rubber bands or twine, so that sunlight cannot penetrate to the head. Repeat the process twice a week, tying all the visible heads on a day with the same color band. Use a different color each day. Tie the leaves together as high as possible to allow air movement over the heads to avoid head rots.

Cauliflower heads mature 7 to 14 days after tying, depending on temperature. One week after tying, check several heads to determine if they have reached the desired size. When 75% or more are large enough, harvest all the heads tied with that color band. Some small heads will be harvested, but since some plants produce small heads which do not reach marketable size, little total yield will be lost. Cauliflower heads become overmature quickly when temperatures are above 70° F.

Cut cauliflower by hand with the leaves intact and transport the heads to a packing shed. Remove most of the leaves and trim the butt. "Michigan pack" cauliflower is the most common packing system in Michigan. Four to six leaves are left attached to the butt and trimmed 2 or 3 inches above the top of the head. The heads are packed 12 or 16 to a 2-layer box. In the western pack, four to six leaves are left attached to the butt, but are trimmed back to the base of the head. The heads

are then wrapped in cellophane and packed 9, 12, or 16 to a single-layer box.

No. 1 cauliflower heads are uniformly white or cream color, 4 to 8 inches in diameter, solid, with no insect damage or debris, no soft rot, no spots or discoloration, and no hollow stem, riciness or leaves in the heads and weigh 2 to 3 lb each. Some late-maturing cultivars produce heads that remain solid up to 6 lb. Heads this size may be used for processing or local sales but are generally too large for fresh market.

If cauliflower is refrigerated soon after harvest, it can be stored for 2 to 3 weeks at 32° F and 98% relative humidity. Hydrocooling will improve storability and extend storage life. Handle cauliflower heads carefully because they are susceptible to bruising and abrasion and spots turn brown soon after contact with other heads or the container.

Physiological Disorders

Hollow stem occurs in cauliflower, broccoli, and cabbage. It is primarily a result of boron deficiency, but may be influenced by excessive nitrogen fertilizer application and rapid growth. Boron deficiency may appear as brown water-soaked spots on cauliflower heads, but often there are no external symptoms of hollow stem. In serious cases, the hollow stem proceeds upward through the surface of the head and the internal surface of the cavity becomes brown or black. Bacterial soft rot may develop, causing a soft, odoriferous rot of the head surface and the internal cavity. Some cauliflower cultivars are more susceptible to hollow stem than others. It is difficult to avoid hollow stem completely, especially during the summer. It is less of a problem in the fall when plants mature slowly. Use of resistant cultivars, maintenance of correct soil pH, irrigation, application of boron and sufficient but not excess N-P-K reduces the problem.

Brown spotting of the heads is sometimes caused by drops of moisture which are exuded from the leaf tips, usually at night. This process is called guttation. The water contains dissolved salts that kill cells on the surface of the heads, leaving small brown spots. It is especially a prob-

lem in low, foggy areas where the heads remain wet much of the day and the guttation water does not evaporate quickly. The brown spots make the heads unattractive but usually do not cause rots.

Riciness is sometimes a problem in mature cauliflower. Individual florets develop and elongate, causing them to look like grains of rice. In extreme cases, the floral parts may extend $\frac{1}{4}$ inch above the head and turn green. Riciness often occurs as cauliflower reaches and passes maturity. It is affected by adverse environment, especially high temperature conditions. Some cultivars are much more susceptible than others. When riciness has been a recurring problem, use other cultivars.

Buttoning is premature heading of cauliflower. Any heading that occurs before the plant has attained sufficient vegetative growth to support production of a marketable head is called buttoning. It is caused by stress on young plants, especially during the first 8 weeks of growth. The most common causes of buttoning are: exposure of young transplants to frost for 4 or more hours; exposure of young plants to temperatures below 50° F for 5 or more consecutive days in the field; use of overhardened, rootbound, or old (over 6 weeks) transplants; excessively wet or dry conditions, especially immediately after transplanting; inadequate fertilizer, especially nitrogen; and insect, disease, or weed pressure that severely reduces vegetative growth. Early maturing cultivars are more susceptible to buttoning than later-maturing cultivars. To avoid buttoning, do not expose transplants to low temperatures, plant only young, vigorous plants in the field, irrigate after transplanting, maintain recommended soil pH and nutrition levels, control pests, and use full-season cultivars.

Blindness is a condition in cauliflower in which the growing point dies at an early stage of growth but the plant remains alive. A long, narrow leaf often develops at the apex, which sometimes causes this disorder to be confused with whiptail, caused by molybdenum deficiency. The other leaves become thicker and darker green than normal. The plants do not develop heads. The exact cause of blindness is not known. Exposure of young plants to frost may kill the growing point. However, it often occurs in summer-planted

cauliflower that has not been exposed to frost. Insects may also damage the growing point, inducing blindness. Some cultivars are more susceptible than others.

Tipburn: In cabbage, tips of individual leaves inside the head turn brown. There may be one or several leaves with dead tips. The affected leaves develop during periods of rapid growth of the plant, usually during warm weather with moisture stress. Apparently, sufficient calcium for normal cell development does not reach the leaf tips. Internal tipburn is only visible by cutting heads open. The discolored leaves make the affected heads unacceptable for fresh market or processing. Some cultivars are more susceptible than others.

In cauliflower, tips or margins of young and recently-developed leaves die and soft rot often develops. The problem usually occurs as the heads begin to form. The rotting leaf tips often stain the heads and sometimes the soft rot spreads to the heads. The problem is more common on light, sandy soils, and during warm growing conditions. Some cultivars are very susceptible. Tipburn cannot be avoided completely. To reduce its incidence, use cultivars which are less susceptible. Grow the crops on soils that contain sufficient organic matter or clay and irrigate regularly to maintain a constant supply of moisture for the plants. Apply nitrogen at adequate levels.

Insects

See Extension Bulletin E-968, *Cole Crop Insect Pests*, for pictures and detailed descriptions of insects. See Extension Bulletin E-312, *Control of Insects, Diseases, and Nematodes on Commercial Vegetables*, for current pest control recommendations.

Cabbage maggot (*Delia brassicae*) is a serious pest of early direct-seeded or transplanted cole crops. The adult flies emerge from the soil in early May and lay their eggs on cole crop plants and related weeds near the soil surface or in the soil at the base of the plants. The short ($\frac{1}{4}$ inch), white maggots emerge a few days later and begin to eat and burrow into the plant stems and roots. Young plants that are invaded by maggots usually wilt and die.

There are three generations of cabbage maggot each year. The first generation does the most damage because it emerges when transplants and seedlings are small. Later generations do less damage because many are killed by high soil temperatures and the crops are advanced enough to withstand some injury. Protect transplanted cole crops with a soil insecticide either in the transplant water or as a drench after transplanting. Treat direct-seeded plantings and seedbeds before seeding or with a drench over the rows after seeding.

Imported cabbage worm (*Pieris rapae*) adults, the white butterflies often seen around cruciferous crops, emerge from the pupal stage in early May and lay their eggs on cole crops and other cruciferous crops and weeds. The velvety green worms, which grow to over one inch in length, eat holes in leaves and leave large amounts of green debris on the leaves. There are several generations a year, and the adults and larvae may be active until frost.

Observe fields for adult activity and check plants for eggs and larvae. Treat cabbage with an insecticide as soon as the insects appear. Broccoli and cauliflower can tolerate some injury prior to head formation, but should be treated during head formation to avoid insect contamination of the harvested product.

Cabbage looper (*Trichoplusia ni*) adults migrate into Michigan during July and August. The adults are about 1 to 1½ inches across, gray-brown, and fly and lay eggs mostly at night. The larvae are light green, with a white stripe on each side, about 1 inch long, and move by humping their back like an inch-worm, from which they get their name "looper." There may be 2 or 3 generations per year. As the larvae grow, they become more difficult to control. Plant damage and product contamination are similar to that of imported cabbage worm.

Monitor fields regularly for eggs, larvae, and damage. Apply insecticides as needed for control. Cabbage loopers are much more tolerant of insecticides than imported cabbage worms. Be sure of your identification and use higher rates or more toxic materials on loopers.

Diamondback moth (*Plutella maculipennis*) does not do major damage but is often seen in Michigan. The gray adults overwinter on trash in the field, lay eggs in the spring, and the small (1/3 inch) yellow-green larvae emerge soon thereafter. The worms eat numerous small holes in the leaves. They leave a few small webs in the center of the plant. Control of diamondback moth is similar to that for other worms.

Thrips (*Thrips tabaci*) are very small (1/16 inch), yellow or brown insects that damage cole crops by rasping the leaf surface and sucking the sap. They cause economic injury primarily on cabbage, where they live and eat inside several layers of leaves. Injury looks like rust spots on the inner leaves. Large areas of leaves can be affected during heavy infestations. Badly infested heads are not usable for fresh market or processing. Thrips damage usually increases during the hot, dry weather of late summer. Once thrips are inside cabbage heads, it is very difficult to control them. High pressure sprays for worm control directed down into the heads will give some thrips control. If thrips are present, begin insecticide application as soon as heads begin to form.

Cabbage aphids are small (1/16 inch), blue-gray insects that suck sap from the plants. They are generally most abundant from mid-summer through October. Heavy infestations cause leaves to cup and curl inward. Aphids live in the outer leaves of cabbage, and the presence of live or dead ones makes the cabbage unmarketable. Aphids can be controlled relatively easily with insecticides.

Diseases

Rhizoctonia solani causes a number of closely-related diseases of cole crops, including damping off, wirestem, bottom rot, and head rot. If the fungus attacks very young seedlings, the disease is called damping off. The fungus penetrates seedlings near the soil line causing water-soaked constrictions of the stem, which girdle the plant. The plants then wilt and topple over. If plants survive the initial attack, the center of the stem decays while the outer stalk provides sufficient support to keep the plants erect. At this stage the disease is called wirestem. Stems are

brown or black and wiry above the soil line. The plants grow very slowly and usually do not develop to maturity. Bottom rot occurs as a carry-over from wirestem. Lower leaves wilt, rot and darken, but remain on the plant. Head rot may develop, causing a darkening and decaying of the stem at the base of the heads and spotting and wilting of the leaves in the center of the head.

Control damping off and wirestem in the greenhouse and field seedbeds by using sanitized media and containers, treating seed or soil with a fungicide, and avoiding overwatering. Do not grow cole crops in low-lying fields with heavy soils, and do not use diseased transplants.

Black rot (*Xanthomonas campestris* *pv.* *campestris*) is a bacterial disease that affects all the cole crops. Cotyledons on infected plants become water soaked and then shrivel and drop off. On true leaves, the infection generally appears as a yellow v-shaped area along the leaf margin. As the lesions enlarge, the leaf veins within them turn black. Numerous brown specks appear in yellow areas on the leaf surface. The pathogen moves through the leaf into the water-conducting (vascular) system, causing a blackening and a plugging of the veins. Early infections usually cause plant wilting and death. Later infections cause stunting, smaller heads, or possibly only leaf spotting.

Under conditions favorable for black rot development (80 to 86° F and high humidity), the disease moves rapidly through infected plants and spreads to adjoining plants in wind and rain. The black rot organism overwinters on crop debris in the field, but infection occurs more often from infected seed. To avoid black rot, use seed that has been hotwater-treated or assayed and found to be completely free of black rot. Rotate fields out of cole crops for at least 2 years to avoid reinfestation in the field. Copper sprays applied with a boom sprayer may reduce spread of the organism in the field. Do not use an airblast sprayer, because it will increase spread of the pathogen.

Club root (*Plasmodiophora brassicae*) is a fungal disease that attacks the roots of all cole crops and other cruciferous crops and weeds. Infected plants wilt in the middle of hot, sunny days, and leaves turn pale green to yellow. Eventually, infected

plants wilt permanently and die, or survive in a stunted condition.

Swimming spores of the pathogen enter roots through root hairs or wounds. The organism stimulates plant cell multiplication, causing roots to enlarge and form spindle-shaped galls or "clubs." The growth of the clubs inhibits development of a normal root system and blocks the vascular system. The clubbed roots eventually decay and are invaded by soft rot bacteria which release a toxin. Lack of sufficient water and the presence of the toxin causes foliar wilting.

Clubroot incidence can be reduced by using uninfected transplants, avoiding movement of machinery from infested areas into clean fields, and maintaining soil pH of 7.3 or higher. Crop rotation is not very effective because the resting spores can survive in the soil for many years.

Downy mildew (*Peronospora parasitica*). The initial symptom of this fungal disease is the appearance of small, irregularly shaped grayish-purple spots on stems and the undersides of leaves. Under cool, moist conditions, the spots enlarge and become covered with fluffy, grayish-white mycelia. The upper leaf surface turns yellow and dries out. Heavily infected leaves eventually drop off. The organism may move systemically in the plant causing internal darkening of broccoli, cabbage, and cauliflower heads. Downy mildew overwinters in plant debris or on cruciferous weed hosts. It spreads in the field with splashing water during cool weather, and is primarily a problem during the fall. Fungicide applications help prevent spread of the organism in the field.

Blackleg (*Phoma lingam*) is most common on cabbage, but it also affects other cole crops. Symptoms may appear early in the growing season on seedlings not yet transplanted in the field. Inconspicuous, small, circular, dark lesions appear on the leaves of the infected plants. The spots gradually enlarge, becoming well defined with a gray center filled with numerous black, pimple-like, spore-bearing structures called pycnidia. The lesions on stems are oval shaped and often surrounded by a purplish margin. Spots spread over the whole plant including the root system. The dark cankers which form on affected roots may

eventually destroy the fibrous root system. The disease causes wilting, stunting and death of affected plants. To avoid blackleg, use disease-free seed and rotate fields out of cole crops for at least three years.

Alternaria spp. fungi cause leaf spotting and head rotting of crucifers. The initial disease symptom is the appearance of small dark spots on older leaves. The spots are generally circular, ranging from ½ to 1½ inches in diameter. A brown or black velvety mold, composed of masses of fungal spores, rapidly covers the lesion. These spores rub off the lesion surface easily. Lesions may coalesce to form large, irregular, diseased areas on the leaf surface. Cabbage leaf margins are often colonized by *Alternaria spp.* after tipburn or other injuries to the plant. Bacterial soft rot often follows *Alternaria* infection. On cauliflower, tiny brown sunken lesions appear on the curds. On broccoli heads the lesions are yellow. The spots enlarge rapidly and are eventually covered with black spores.

To avoid *Alternaria* diseases, use high quality, disease-free seed; irrigate early in the day so that leaves dry rapidly; and tie cauliflower leaves as high as possible to allow air movement and to reduce free moisture on the head. Apply fungicides when necessary.

Soft rot (*Erwinia carotovora*) bacteria cause a watery, soft, foul-smelling rot of the cole crops. Bacterial infection often occurs after chemical, mechanical, pest, or other injury. It often follows external or internal tipburn. The bacteria soften the cell walls of plant tissue, which results in a rapid collapse into a slimy mess. Soft rot may be a primary pathogen on broccoli heads, especially during warm, humid weather. The bacteria become established in small droplets of water that remain on the heads. Cultivars with domed heads that shed surface water are less susceptible. To avoid soft rot, grow cole crops on well-drained soils and maintain adequate soil moisture to avoid tipburn. Select cultivars recommended for Michigan, and avoid injury to plants.

Turnip mosaic virus and cauliflower mosaic virus sometimes cause economic losses in stored cabbage. Early infection in the field causes leaf spotting and leaf drop. The spots become black

and sunken on inner cabbage leaves during long-term storage. Turnip mosaic spots are larger than cauliflower mosaic spots. The viruses are transmitted by aphids. Aphid control is the primary means of virus control. Where the viruses have been a problem, make an extra effort to control cruciferous weeds near seed beds. Select cabbage cultivars that are resistant to virus infection.

Additional Information

More information on cole crop production is contained in the following bulletins which are available from county Cooperative Extension Service offices or from the MSU Bulletin Office, P.O. Box 6640, East Lansing, MI 48826-6640.

E-312, *Control of Insects, Diseases, and Nematodes on Commercial Vegetables*

E-433, *Weed Control Guide for Vegetable Crops*

E-486, *Secondary and Micronutrients for Vegetables and Field Crops*

E-550, *Fertilizer Recommendations for Vegetable and Field Crops in Michigan*

E-675, *Vegetable Varieties for Commercial Growers*

E-968, *Cole Crop Insect Pests*

E-1565, *Yields of Michigan Vegetable Crops*

E-1668, *Disorders of Cole Crops*

E-1751, *Identifying Diseases of Vegetables*

E-1998, *Costs of Producing Broccoli in Western Michigan*

E-2003, *Costs of Producing Cauliflower in Western Michigan*

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2P-5M-TCM-SP-Revision, destroy previous editions. Price 60 cents, for sale only.

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