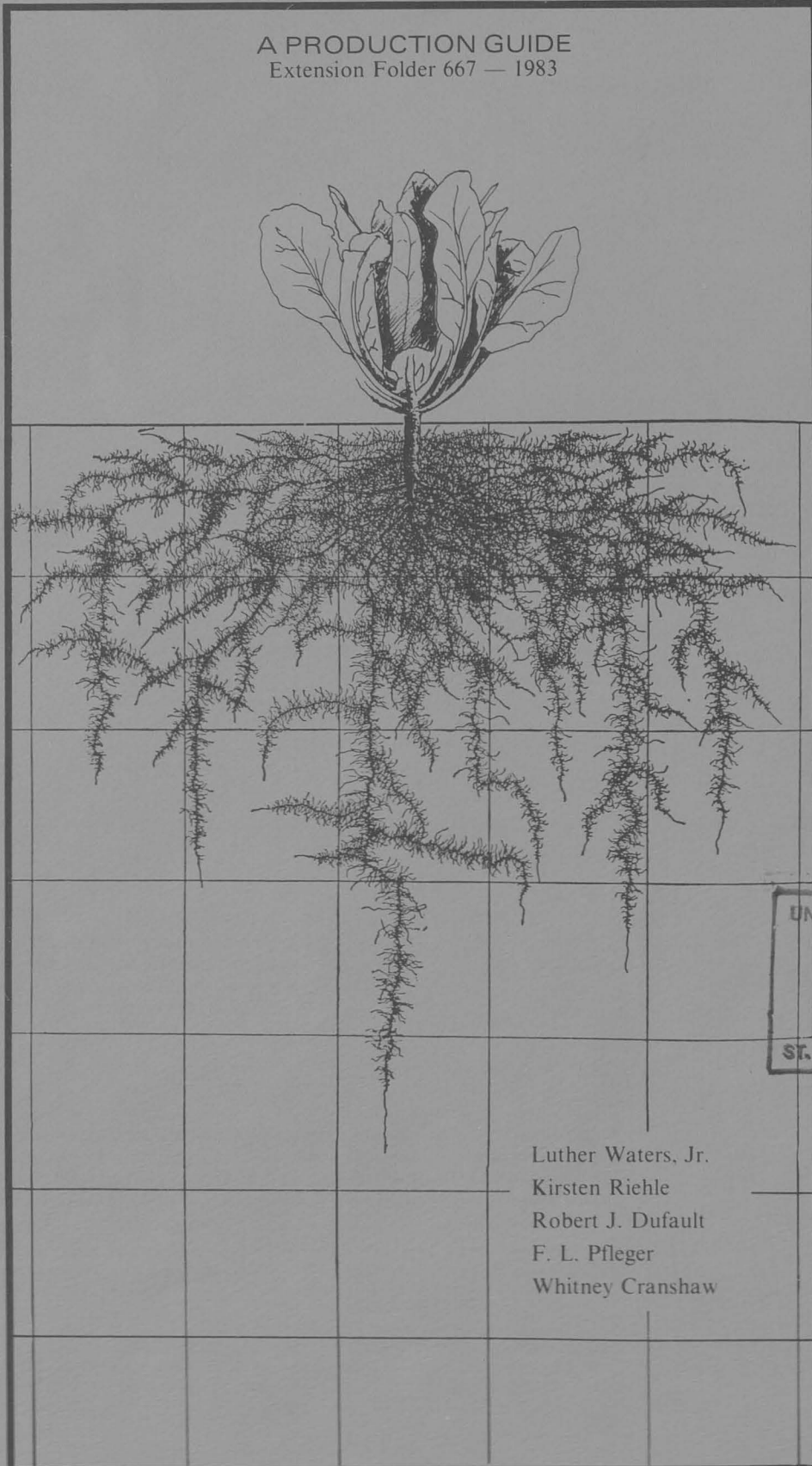


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GROWING BROCCOLI AND CAULIFLOWER IN MINNESOTA

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On the cover: Root system of a cauliflower plant eight weeks from transplanting; each block represents one foot square. From: Weaver, J., and W. Bruner. 1927. Root Development of Vegetable Crops. McGraw-Hill Book Co., Inc., N. Y.

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GROWING BROCCOLI AND CAULIFLOWER IN MINNESOTA

Success or failure in producing broccoli and cauliflower commercially is measured by the quality of the end product — the broccoli heads or cauliflower curds. A high quality product sells at a premium because all buyers seek growers who produce a superior product no matter what the state of the market. The challenge of producing quality cauliflower and broccoli in Minnesota can be met with experience, by growing and observing available cultivars on the farm, by altering cultural practices as necessary, and by studying available production information. Knowing the production requirements and the response of cauliflower and broccoli cultivars to local conditions is essential in producing a consistently high quality product.

Climatic Requirements

Weather is one of the most limiting factors in producing cole crops. Broccoli and cauliflower perform best with cool daytime temperatures (70°-85° F.), lots of sun, and moist growing conditions. Growers need to provide the best possible growing conditions during the summer so that plants are the maximum possible size when head (curd) development starts, since the size of the plant limits the potential size of the head or curd. Cauliflower produces best in a fertile, moist, well-drained soil that is rich in organic matter and nitrogen. Broccoli requires the same conditions as cauliflower but is less exacting and can accommodate a slightly wider range of soil and climatic conditions.

Broccoli and cauliflower do not tolerate frost in the early seedling stage of growth (before the plant has three or four pairs of true leaves). Early maturing varieties are more sensitive to low temperature damage than are those that mature later. Consequently, the initial planting date in Minnesota is seldom earlier than mid-April, and there is some risk of cold temperature damage until mid-May. The earliest maturity possible for cauliflower is approximately 50-55 days from transplanting; for broccoli, it is between 60 and 65 days. Fall season plantings should be made in early July, since the end of the season in Minnesota is approximately November 1st.

Long days and hot weather in the summer cause broccoli to bolt and go to seed and cause cauliflower curds to develop a red-purple discoloration and leaves through the center of the head. Both broccoli and cauliflower will tolerate some frost and freezing conditions to near 20° F. late in plant development. The degree of tolerance depends on how fast frost or freezing conditions occur and on the conditions that exist prior to their occurrence.

Varieties for Minnesota

A statewide vegetable variety testing program has been conducted since 1980. Contact your county agricultural extension agent for reports of broccoli and cauliflower variety trials that present yield and quality characteristics of tested varieties.

Starting Plants From Seed

Transplants can be produced as containerized plants that are planted with roots and growing media intact or as bare root transplants in flats, hotbeds, or in the field. Seedlings need a loose, well-drained soil that is fertile and does not crust. Plant seed shallowly (¼-½ inch) and thin early to allow seedlings to develop in ample space. Seedlings should be kept in the greenhouse or hotbed until field conditions permit transplanting. The most desirable growing temperature is 60°-70° F. High temperatures result in too rapid a growth rate and tall, weak plants that are difficult to handle without causing damage. Plants can be transplanted to the field when they are 25-35 days old; early maturing varieties can be transplanted at a younger age than can later maturing varieties.

Maintaining seedbed sanitation is important in hotbed transplant production. To ensure that flats, seedbeds, hotbeds, or media are free of club root, black leg, black rot, ringspot, and damping-off organisms, remove old plant debris, fumigate or steam sterilize soil or soil-less mix, and apply a seed protectant. (Note: copper materials should not be used on broccoli.)

You can construct a simple hotbed using wood or concrete framing material. The frame should be ten-twelve inches high on the south-facing side with the north side six inches higher. The frame should extend two or more inches into the ground with soil banked up around the frame to conserve heat. Concrete frames should be three inches thick and extend at least six-eight inches into the ground. Place a sheet of insulation on the ground inside the frame and cover it with approximately one inch of soil. Place electric heating cables at one-foot intervals and cover them with ½-inch mesh screen. Then cover the screen with four inches of clean sand. Transplants can be grown either directly in the sand or in flats placed on top of the sand. In either case, the bed should be heated prior to planting to ensure that the soil temperature is about 70° F. The frame should have a glass or plastic sash cover to retain the heat. The cover should be removable so ventilation can be provided on hot days. The frame can be five-six feet wide, depending on how easily the sash can be manipulated.

Apply fertilizer to developing seedlings beginning when the first true leaves appear. Use a half-strength starter solution once a week. After two true leaves are present, apply fertilizer twice a week.

Transplanting

In Minnesota, transplanting to the field normally begins mid-April to early May and may continue until approximately mid-July. Plants are normally set into rows spaced 30-36 inches apart with in-row spacings of 8-12 inches for broccoli and 15-18 inches for cauliflower. If possible, avoid using transplants that are older than six weeks. Use a transplant starter solution that is high in phosphorus and low in nitrogen and potassium. If necessary, use irrigation to establish the

planting, especially if you don't use a transplant solution. Include an insecticide such as diazinon in the transplant solution for maggot control (check pesticide label for rates).

Transplants must be handled carefully. Transplanting shock can be prevented by using containerized transplants, by shortening the time between seeding and transplanting, and by using transplants that have been properly hardened. Early varieties like Snow Crown should be transplanted no later than 28 days after seeding. Remove plants from the seedbed, flats, or containers very carefully, leaving as many roots as possible on each plant. Be extremely careful not to break the growing point of the plants, since this results in barren (non-heading) plants.

To ensure rapid vegetative growth after transplanting, follow these recommended practices:

1. Do not transplant before the last killing frost in the spring. Cold temperatures may slow growth or injure transplants.
2. Use transplants that are less than four inches tall and have good root systems.
3. Use starter solutions high in phosphorus with an insecticide to control cabbage maggot.
4. Irrigate after transplanting and as necessary to ensure that transplants receive at least an inch of water weekly.
5. Starting approximately the third week after transplanting, sidedress with 40-60 pounds actual nitrogen (depending on the native fertility of the soil) at two-week intervals for a total of three sidedressings. For very sandy soils low in clay and organic matter content, one or two of the sidedressings should include an equal amount of potassium.

Direct Seeding

Broccoli and cauliflower plantings scheduled for harvest in summer or fall can be seeded directly in the field. Direct-seeded crops require approximately three weeks longer to reach maturity than do crops transplanted at the same time, although there are some differences among varieties. Plantings can be either precision-seeded to the desired stand or overseeded and thinned to the desired stand after emergence.

Plant seed shallowly ($\frac{1}{4}$ - $\frac{1}{2}$ inch) and use irrigation to ensure adequate moisture in the seed zone. Avoid soil crusting by using one of the many available anticrustants or by keeping the soil moist during emergence with irrigation. Do *not* use cultivation to break crusts.

Fertility Requirements

Soil testing in production areas is important because deficiencies of macro- and micronutrients can lead to an unmarketable product. All cole crops are subject to calcium and boron deficiencies and all require manganese, magnesium, and molybdenum; cauliflower also requires copper. Soil application is preferable during seedbed preparation, but foliar sprays can be used for calcium and the micronutrients to correct deficiencies based on soil test results, tissue analysis, or visual symptoms. Plant tissue samples can be analyzed to determine nutrient deficiencies and toxicities, but these tests are somewhat more costly and usually provide only an after the fact analysis of the problem.

Deficiencies can be recognized by the following plant symptoms:

Nitrogen deficiency: Causes buttoning or premature head formation (also caused by lack of water, poor drainage, and cold shock to transplants), pale green leaf color, and poor growth.

Boron deficiency: Causes hollow stem. In cauliflower, curds become discolored and deformed; in broccoli, florets turn brown.

Manganese and magnesium deficiency: Older leaves lose their green color except in the veins.

The specific fertility for an individual field program should be based on recommendations from soil tests. In general, fertility requirements are 120-150 pounds of nitrogen, 50-150 pounds of phosphorus, and 120-250 pounds of potassium per acre. The amount of nitrogen and potassium applied at or prior to planting and the number of sidedressings and amount per sidedressing depend on the native fertility of the soil. Sandy soils should receive more nitrogen and potassium applications at smaller increments. Phosphorus usually is applied in a single application at or before planting.

Important Disorders of Broccoli and Cauliflower

The most important disorders are hollow stem, buttoning, blindness, whiptail, and browning.

Hollow Stem

Causes: Heavy fertilization, which results in rapidly growing plants, especially during warm weather (no internal discoloration), or boron deficiency (dark brown internal discoloration).

Symptoms: Hollowing of the stem and branches of the head or curd.

Remedy: The hollow stem resulting from rapid growth can be reduced somewhat by spacing plants closer together or by reducing the fertilizer applied. Hollow stem resulting from boron deficiency can be controlled by soil (preferably) or foliar application of low rates of boron.

Buttoning

Causes: Nitrogen deficiency, cold temperature shock to young transplants, drought stress, or other factors that markedly restrict vegetative growth.

Symptoms: Development of small heads or curds (buttons) on immature plants. Plants that develop buttons are small and have small leaves that do not cover the developing head.

Remedy: Follow practices that will result in rapid vegetative growth, and delay planting until the danger of frost has passed (varieties differ in the amount of cold they can tolerate).

Blindness

Causes: Damage to terminal growing point due to low temperature, cutworm damage, or rough handling of transplants.

Symptoms: Plants have lost their terminal growing points.

The leaves that develop are large, dark green, thick, and leathery. The plant does not produce a marketable head or curd.

Remedy: Handle transplants carefully, control cutworms, and avoid low temperatures.

Whiptail

Cause: Deficiency of molybdenum in the soil, or growing these crops on very acid soils.

Symptoms: Leaf blades do not develop properly and may be straplike and severely savoyed (crinkled). In severe cases only the midribs develop, which accounts for the name whiptail. The growing point is usually severely deformed and does not produce a marketable head. In severe cases there is a stimulation of sprouts on the base of plants.

Remedy: Lime the soil to pH 6.5 and use soil applications of low rates of molybdenum where deficiency exists. Deficiency seldom occurs on soils with pH 6.0-7.0.

Browning (Heads and Curds)

Cause: Boron deficiency (also causes uneven head formation in broccoli) and exposure of cauliflower curds to light during development.

Symptoms: Water-soaked areas develop in the center of the stem and the branches of the head and curd stem; stems may become hollow and black inside. The first external appearance in cauliflower is on the surface of the curd. Later, these areas change to a rusty brown that often is associated with hollow stem. Curds affected are bitter, both in the raw and cooked state. Other symptoms of boron deficiency are changes in color of foliage and thickening, brittleness, and downward curling of the older leaves, which is followed by the development of blisters on the upper side of the midrib. In severe cases the small leaves and the growing point may die.

Remedy: Use soil (preferably) or foliar application of low rates of boron. Deficiencies are more common on sandy soils and may be detected in a soil test.

Weeds and Pests

Pesticides available and application rates for controlling weeds, insects, and diseases change frequently. Always read pesticide labels carefully before using a product. Consult your county agricultural extension agent for specific recommendations.

Weeds

Currently the only herbicides available for use with broccoli and cauliflower are Treflan and Dacthal. Read labels carefully to determine rates. Carefully timed shallow cultivation also can be used to control weeds effectively. Crops should be rotated on land to be used for broccoli and cauliflower. Such rotation prevents the buildup of weeds resistant to Treflan or Dacthal; it also helps to control soil-borne diseases that infect these crops. Careful, long-term records should be maintained for farmland used for vegetable crops to develop a history of weed infestations as well as other problems. A history provides a valuable source of crop production information.

Insects

All of the cole crops, including broccoli and cauliflower, are subject to attack by several kinds of insects throughout the growing season. Repeated insecticide applications may be necessary to produce a high yielding, quality crop. If fields are scouted during the growing season, however, the number of treatments often can be reduced and application timing can be improved. The following insects cause losses in broccoli and cauliflower through damage to the plant by reducing yield, lowering quality, or contaminating the product, making it unsalable:

- Cabbage looper
- Imported cabbageworm
- Diamondback moth
- Cutworm (climbing and nonclimbing)
- Zebra caterpillar
- Thrip
- Cabbage webworm
- Cabbage aphid
- Green peach aphid
- Turnip aphid
- Cabbage maggot
- Flea beetle

Because insecticides are available in a variety of concentrations, the insecticide application rates referred to in the following paragraphs are expressed in pounds of *active* ingredient.

As a general rule, a treatment for cabbage maggot control is advisable at planting time. During the larval stage, this insect feeds on the plant roots and, when abundant, causes plants to grow slowly and produce poor quality heads. Plants may be killed during serious infestations. Cabbage maggot damage is most common on soils that are high in fresh organic matter. Infestations intensify during extended periods of cool, wet weather. Recommended insecticides include diazinon at two-three pounds per acre either as a furrow drench or in the transplant water and chlorpyrifos (Lorsban) at one pound per acre incorporated into the soil around the plant roots.

Cutworms, flea beetles, and aphids tend to be most damaging to young plants. Cutworm feeding results in plants that are cut off at or just below the soil surface. Often this type of feeding is preceded by some leaf chewing. If you notice cut plants or leaf feeding, check under dirt clods and crop debris to confirm that cutworms are present and use a recommended insecticide treatment promptly. Use carbaryl (Sevin) at two pounds per acre or trichlorofon (Dylox) at one pound per acre.

Flea beetle injury is characterized by a "shot hole" type of feeding wound. Infestations often are restricted to spot locations in a field. Seedling plants are particularly susceptible to this injury; insecticide treatment occasionally is warranted. Carbaryl (Sevin) at 1½ pounds per acre, endosulfan (Thiodan) at ¾ pound per acre, methoxychlor at 1½ pounds per acre, or diazinon at ½ pound per acre are recommended spray treatments. Beyond the seedling stage, only extremely severe infestations will cause yield reductions.

Several species of aphid (e.g., cabbage aphid, turnip aphid, and green peach aphid) commonly are found on broccoli and cauliflower. When abundant on new growth, they can cause curling and other deformations of the expanding leaves. Eco-

nomie infestations of aphids often are associated with extended periods of cool weather, or they may be induced by repeated applications of insecticides that destroy natural aphid enemies. Aphid injury to mature plants is rare. Recommended aphid control treatments include diazinon at ½ pound per acre, dimethoate (Cygon, Defend) at ¼-½ pound per acre, endosulfan (Thiodan) at ¾ pound per acre, malathion at ½-¾ pound per acre, oxydemetonmethyl (Metasystox-R) at ½ pound per acre, or mevinphos (Phosdrin) at ¼ pound per acre. Thorough coverage of the plants is necessary; the addition of a wetting agent often improves control.

Several species of caterpillars can be found feeding on the foliage of broccoli and cauliflower. Usually imported cabbageworm, which is the larval stage of the familiar cabbage butterfly, is the most abundant species. Late in the season, cabbage looper may be important. Zebra caterpillar and the smaller larvae of the diamondback moth and webworms also may be present. Feeding injury may be economically important on young plants, although it occurs rarely. Established plants (beyond the four-five true leaf stage) can tolerate 50-percent defoliation until the preheading stage without yield loss. If serious infestations threaten, recommended treatments are: azinphosmethyl (Guthion) at ½-¾ pound per acre, *Bacillus thuringiensis* formulations as labeled, carbaryl (Sevin) at 1½-2 pounds per acre, fenvalerate (Pydrin) at 0.05-0.1 pound per acre, methylparathion or parathion at ¼ pound per acre, methomyl (Lannate, Nudrin) at ½-1 pound per acre, or permethrin (Pounce or Ambush) at 0.05-0.1 pound per acre. When cabbage looper is present in large numbers, fenvalerate or permethrin can be used.

As heading of plants begins, these insects become more important as potential contaminants of marketed vegetables. Caterpillars are particularly common in broccoli heads. Two insecticide applications spaced four-seven days apart prior to harvest are suggested to eliminate insect contaminants. In cauliflower, insect contaminants are less frequent, but insect excrement may fall on the head from larva feeding on the wrapper leaves. A spray application made immediately prior to blanching and again seven-ten days prior to harvest should eliminate this problem. The insecticides recommended above are suitable for preventing insect contaminants.

Diseases

The following diseases are serious and destructive in both broccoli and cauliflower:

- Black rot
- Black leg
- Club root
- Leaf spot
- Powdery mildew
- Downy mildew
- Damping-off (root and stem rots)
- Mosaic virus

Always use disease-free seed, maintain sanitary seedbed conditions, control weeds that might be alternate hosts, and control insects that may spread diseases. Watch continuously for any discoloration of plant growth. The symptoms, methods of dissemination, and control of the more serious diseases are described below.

Black Rot (*Xanthomonas campestris*)

Black rot, which is distributed worldwide, is the most serious disease affecting broccoli and cauliflower. The disease symptoms usually appear first on the edges of the leaves. The bacteria enter through leaf pores and wounds, eventually producing a V-shaped necrotic area on the margin of the leaf. These areas become dry, brown, and brittle. The bacteria then become systemic and are translocated throughout the plant. The vascular tissue of the plant becomes discolored and the veins of the leaves become darkened. Eventually plants become stunted, wilt, and die. High temperatures and humid conditions speed the disease process, but unfavorable environmental conditions may prevent detection of the disease.

Black rot is transmitted by infected seed. The pathogen is spread in the field by equipment, people, animals, and rain or irrigation. The disease agent may survive from year to year on weeds or on plant residues.

The pathogen must be eliminated from seed production fields, transplant beds, and production fields by:

- Seed testing and seed quality control.
- Elimination of alternate hosts (weeds, etc.).
- Crop rotation.
- Disposal of all crop residue.
- Seed treatment.
- Use of resistant cultivars.

Black Leg (*Phoma lingam*)

This fungal disease causes a dry rot on cole crops and is more active at cooler temperatures than is black rot. The fungus is seedborne and survives in infected plant debris. When the seeds germinate, the fungus infects the seedlings and forms fruiting bodies that spread the disease. The fungus produces spores that become airborne.

Black leg is transmitted on infected seed or plant debris. The disease can be spread by dipping transplants into vats containing pesticide solutions.

Disease symptoms appear on greenhouse transplants two-three weeks prior to transplanting. Circular lesions form on the leaves and grey-colored fruiting bodies form within these lesions. Eventually the fungus girdles the stem and plants become stunted. Control measures for black leg are the same as for black rot.

Club Root (*Plasmodiophora brassicae*)

Club root is a serious disease that occurs worldwide. The infection process begins when the resting spores germinate and enter the plants through root hairs or wounds. The fungus then increases and infects other roots cells, stimulating cell growth and division. Eventually the roots form large club-like masses that crack, dispersing the spores into the soil. The development of this disease is favored by warm temperatures, high soil moisture, and an acid pH.

The initial symptoms of club root are difficult to detect. Later symptoms include pale yellow leaves and a tendency to wilt during hot, sunny days. Young plants may be killed by the disease within a short time after infection, whereas older plants may survive but fail to produce marketable heads. Club root is transmitted by infected transplants, equipment, windblown dust, and irrigation. Club root can be controlled

by maintaining soil pH at 7.3 or above by additions of lime. Avoid planting any cabbage family plant in the same fields for long time periods. The resting spores can survive in the soil for many years, so the effect of rotation is not great. Always use plant transplants that are disease-free, and do not move equipment used in diseased fields to clean fields.

Black Leaf Spot (*Alternaria* spp)

Black leaf spot is a fungal disease. The fungus survives in the seed and as spores in infected plant debris. Spore germination is favored by warm temperatures approaching 90°-95° F. The disease symptoms first appear as dark spots on the leaves. The spots are circular and zonate and often are water-soaked. The spores are spread from field to field by damp air currents. The seed often is infected during development in seed production fields. This disease is most destructive during storage and transit of marketable heads. Heads must be handled carefully to avoid bruises, and excess moisture must be allowed to dry off before heads are stored.

Black leaf spot can be controlled by:

- Planting high quality clean seed.
- Removing infected plants.
- Avoiding excessive irrigation.
- Using fungicides when necessary.

Downy Mildew (*Peronospora parasitica*)

Downy mildew is a fungal disease that damages young seedlings and causes heads to rot during transit. The fungus overwinters on perennial plants, winter annuals, or infected plant debris. The fungus penetrates into the plant directly and grows between plant cells, sapping cellular materials through projections into the cells. The optimal temperature for disease development is 50°-60° F.

The disease symptoms are easy to detect. The undersides of plant leaves have a cottony mildew growth. Later, purplish, irregular spots appear on the leaves and stems. The spots eventually enlarge and become yellow on the upper side of the leaves. Heavily infected young plants usually die.

Downy mildew can be controlled by:

- Plowing down crop residue.
- Rotating crops.
- Avoiding overwatering.
- Using tolerant varieties.
- Using fungicides.

General Disease Control Guidelines

Successfully avoiding disease problems in broccoli and cauliflower requires careful attention to good management practices. The following production practices will reduce the risk of disease epidemics:

- Practice a three-year crop rotation schedule with cole crops.
- Avoid irrigation runoff from infected to clean fields.
- Control weed and insect vectors.
- Work in fields only when plants are dry.
- Plant only assayed, disease-free seed.
- Inspect transplants regularly before field planting.
- Disinfect equipment used in the field if disease is present.
- Do not top transplants.

- Do not dip transplants before field planting.
- Do not use cultivation equipment used in seedbeds in other cole crops.
- Destroy unused plants in seedbeds.

Harvest

Cauliflower

To prevent discoloration, cauliflower curds must be shielded from the sun as soon as they start to develop (when they are two-three inches in diameter). Tie leaves together to protect and blanch the developing curd. Tie the leaves close to the top of the plant to allow adequate space for curd expansion and air circulation and to avoid riciness. Tying is commonly done with color-coded rubber bands to indicate the day on which the plant was tied. Several cultivars show a semi-upright (White Empress) or upright (Stovepipe) leaf habit with leaf-free curd and tolerance to high temperatures at maturity. Self-Blanche and other early-maturing, self-blanching types also are currently on the market. Varietal selection to improve the ease of cauliflower curd blanching greatly reduces the amount of labor necessary to produce a superior product.

In warm weather, heads may develop in as little as three to five days after blanching, but with cool temperatures they may take as long as two weeks. Ideally, heads are mature, clear white, compact, and six-eight inches in diameter. Overmature heads are somewhat loose and unmarketable. It is better to cut a little early than risk losing the head to overmaturity. Harvest should begin when head diameter reaches six inches. Heads need to be trimmed and cooled immediately after harvest. Hydrocooling, or forced air cooling, is necessary to remove field heat during hot weather. Short-term storage is possible under the proper low temperature, high humidity conditions.

Broccoli

Cut broccoli, with eight-ten inches of stem, before the individual florets in the head open enough to show yellow. When mature, the central heads usually are three-six inches across. Overmaturity causes woodiness in the stems, loose heads, and reduced market value. In many varieties you can get followup harvests of side shoots that continue to develop after the central head has been cut. Side shoots measure one-three inches across and are generally very good quality.

Packing

Proper cleaning, size grading, and packing are essential in marketing cauliflower and broccoli. It is important that growers be aware of and strive to meet specifications of the market they serve. In Minnesota, cauliflower curds should be closely trimmed, wrapped in perforated film, and packed in cartons with either nine, twelve, or sixteen heads per carton. If a crate is used, allow a few leaves to remain attached. Cut them off just above the curd, leaving a jacket of stalks and part of the leaf blades to protect the head. Tie broccoli in bunches and pack in crates or in wax-impregnated cartons. Broccoli is very perishable. Cool broccoli promptly after harvest, and put ice in the carton before closing it.

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