Crop Profile for Cauliflower in Minnesota

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General Production Information

Executive Summary

In 1997 approx. 25 ac. of cauliflower were harvested in Minnesota. Another 700 acres of related crucifer crops, including cabbage, broccoli, Brussels sprouts, and Chinese cabbage (e.g., bok choi, nappa, etc.) are also produced annually in Minnesota, most of which is sold for fresh market. Cabbage and broccoli are covered in separate crop profiles for Minnesota. Despite the relatively few acres of cauliflower in the state, the high value of the crop (ca. $4,100/ac), and traditionally high insecticide use of about 5-6 sprays/ season, continues to create a demand for effective integrated pest management (IPM) programs. In response to new IPM information needs generated by the Food Quality Protection Act (FQPA), this crop profile was developed to a) summarize current IPM practices for insect, disease and weed pests, b) highlight pesticides under review by US-EPA, c) estimate the impact of the loss of selected pesticides, and d) assess alternatives for such losses.

In most years, insect pests are usually the most damaging and difficult to control in Minnesota

cauliflower. The most important insect pests include: cabbage looper, imported cabbageworm, diamondback moth, cabbage maggot and flea beetles. Diamondback moth larvae are especially critical because of their rather cryptic feeding behavior in the head and maximum size of < ½ inch. Even with high parasitism rates of diamondback moth larvae (typically 80-100%), this pest, as well as parasitized pupal cases, can become contaminants in the head, and reduce marketability. Black rot is probably the most damaging disease problem, but like most diseases of crucifers, few therapeutic treatments are available. Many broadleaf and grass weed species are potentially very damaging. However, in tandem with timely cultivation, most weeds are still controlled well with currently labeled herbicides.

Insects: The recent success of a cabbage IPM program in Minnesota, in commercial production fields, shows considerable potential for extending this program to cauliflower (see MN Cabbage Crop Profile). Three of the new "reduced-risk" insecticides (SpinTor, Proclaim and Avaunt), with good activity on the Lepidopteran pest complex, are also labeled for cauliflower. Several pyrethroids are available (e.g., Ambush, Pounce, Warrior, Capture); however Fury and Mustang are limited to use on cabbage. The pyrethroids are available for high-level infestations of the Lepidopteran pest complex, as well as flea beetles or other sporadic pests. During the next 5 years, the primary concern will be insecticide availability for cabbage root maggot, with the potential loss of Diazinon and/or Dyfonate. However, based on recent EPA rulings (2000), Lorsban should still be available for cabbage root maggot. Sevin insecticide remains a popular choice by many small-scale growers for flea beetles and other insects, because of its broad-spectrum efficacy and non-restricted use status. Future FQPA review of this carbamate insecticide and potential loss, would create new challenges for many growers.

Diseases: With a few exceptions, most of the damaging diseases in cauliflower are not treatable with fungicides or bactericides. For example, black rot, a bacterium, can be treated with copper (e.g., Kocide), but only for low-level infestations. Thus, growers must rely on crop rotation, clean cultural practices, resistant varieties and timely irrigation (where possible), to help manage most crucifer diseases. The primary materials available for cauliflower diseases include Bravo, Rovral, Maneb, Terrachlor and various copper formulations. Where possible, fungicides such as Ridomil Gold Bravo for downy mildew control, are critically important, and should remain available for selected diseases. When these products come under review, with respect to FQPA, there will be a renewed need to assess risks/ benefits.

Weeds: For both broadleaf and grass species, trifluralin (e.g., Treflan) has typically been the most commonly used herbicide on cauliflower in Minnesota. To date, we are not aware of weed resistance problems as a result of this use. This is likely due to the fact that it is only used once/planting, and may not be used significantly on surrounding crops on a given farm. Unlike some of the other herbicides, Treflan can be used for both direct-seeded and transplanted cauliflower. However, Treflan and Dacthal are not recommended for use on muck soils. In addition, Goal is not recommended for use on direct-seeded cauliflower. Post-emergence herbicides (Poast, Gramoxone and Glyphosate) are typically limited to weed escape situations, in unusually high weed pressure fields. Potential losses of herbicides would limit grower options. If and when these products come under review, with respect to FQPA, there will be a renewed need to assess risks and benefits of each.

In 1997, Minnesota had 21 acres of harvested cauliflower. Approximately half of this acreage was irrigated. The 1990-1999 national average for cauliflower production was 53,045 acres annually, making Minnesota a minor producer of the crop. The 1990-1999 national average for cauliflower production was 141 cwt/acre with an average value of $29.55/cwt. These averages gave the 1997 Minnesota cauliflower crop a total market value of $87,500 (1).

Regions

Dakota County, located at the southeastern edge of the Twin Cities metropolitan area, leads the state with 7 acres of cauliflower production (1).

Cultural Practices

Cauliflower is a cool season crop that may be planted early or late in the growing season. The best quality cauliflower is produced with temperatures ranging from 59-68º F and the upper limit temperature range is 68° to 77°F. Cauliflower also requires sunny conditions and moist, fertile, well-drained soil. Excessive heat can damage the quality of cauliflower. During prolonged heat spells, some cauliflower cultivars may grow too fast, causing loose heads and a "riceyness" texture in the curds. On the other hand, prolonged cold temperatures may result in small, unmarketable heads (13).

Cauliflower needs at least 1 inch of either rainfall or irrigation water each week. Irrigation may be needed to obtain good quality and high yields. Cole crops generally need 120-150 pounds of nitrogen, 50-150 pounds of phosphorous, and 120-250 pounds of potassium per acre. The addition of phosphorous and potassium should be based on soil tests. All cole crops are susceptible to deficiencies in calcium and boron and also need the micronutrients of manganese, magnesium, and molybdenum. Throughout the growing season, foliar tissue tests can be performed (3, 6, 13).

The cauliflower curds (or heads) should be white and compact just before harvesting. The longest leaves are generally tied over the head to prevent the sun from discoloring it. When the curds becomes discolored due to sun exposure, the cauliflower sometimes develops a bitter taste. Cauliflower is hand-harvested and cut with 1 or whorls of leaves to protect the head (14).

Insect Pests

Although quality standards may vary somewhat depending on whether cauliflower is being produced for the fresh market or processing, consumers have a low tolerance of insect damage or insect excrement in the foliage or curds. Growers may have more options to control insects early in the production that may allow survival of more beneficial insects. As harvest time approaches, however, the control options are more limited due to the concern about insect damage. The same pests typically attack all the cole crops although particular insect species may prefer one type of cole crop (5, 13).

Cabbage Looper (*Trichoplusia ni*)

The cabbage looper (CL) is a major economic pest of cauliflower in Minnesota and the upper Midwest. The cabbage looper does not overwinter in the upper Midwest but migrates into the region from southern states from mid-June through September. There are 1-3 generations depending on temperature and summer wind patterns. Larvae are pale green with narrow white lines running along each side. Larvae have a characteristic looping motion as they move across vegetation (5, 10, 13, 15, 16).

Larvae feed for 2-4 weeks after hatching from eggs. When they initially hatch, they feed between the veins on the underside of the lower leaves producing small holes that generally do not break through to the upper leaf surface. Later instars, however, chew large, ragged holes in the leaves and often move to the center of the plant to feed. Looper feeding results in unsightly holes and large amounts of frass. Damage can be severe enough that plants are severely defoliated, stunted, and more susceptible to invasion of disease pathogens (5, 10, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/looper.htm

Diamondback Moth (*Plutella xylostella*)

The diamondback moth (DBM) is another economically important pest of cauliflower in the upper Midwest. Adult moths may survive winters in protected locations, but generally, DBM either migrate to the upper Midwest via southerly winds or are shipped to the upper Midwest on cabbage transplants that originating from southern regions. DBM larvae are small (5/16 inch long), light green, tapered at both ends and wriggle vigorously when touched (5, 11, 13, 15, 16).

DBM larvae are initially leaf miners. As they grow, they feed on the leaf surface, eating all the layers except the outer layer which results in characteristic "windowpaning". Larvae also feed on the developing cauliflower heads causing them to look deformed and encouraging the invasion of soft rot (5, 11, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/diamond.htm

Imported Cabbageworm (*Pieris rapae*)

The imported cabbageworm (ICW) is a day-flying butterfly that overwinters in the upper Midwest. ICW is also an economically important pest that annually infests cauliflower. The larvae are velvet green, about 1-inch long in the last instar, and move sluggishly when touched (5, 12, 13, 15, 16).

ICW usually feed on the upper surface of leaves, leaving irregularly shaped holes. As the caterpillars become larger, they move towards the center of the plant. They tend to feed on the edges of the leaf, leaving the large veins intact. They also contaminate the leaves and heads with large fecal pellets (5, 12, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/cabbworm.htm

Cabbage Maggot (*Delia radicum*)

The cabbage maggot is a sporadic pest of cauliflower. Adults look like small houseflies while larvae lack legs, are yellowish-white in color, and reach the maximum length of ¼ inch.

Seedlings and transplants are more susceptible to cabbage maggot injury during cold wet springs with most of the damage limited to the first planting. Transplants or seedlings planted later in the growing season may also be susceptible to maggot damage. Cabbage maggots chew into the fine root hairs and create extensive, slimy tunnels on and throughout cabbage roots. Maggot feeding can cause cauliflower to look off-color, sickly and stunted. Extensive feeding can cause wilting and death. The feeding also provides entry points for fungal pathogens (2, 5, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/cabmag.htm

Cabbage, Turnip, and Green Peach Aphids (*Brevicoryne brassicae, Lipaphis erysimi, Myzus persicae*)

Both cabbage and green peach aphids are found on cauliflower. The green peach aphid has numerous host plants whereas the cabbage aphid is usually found only on cole crops. Cabbage aphids are serious pests only occasionally. Turnip aphids prefer mustard, turnip, and radish but will occasionally damage cole crops (5, 8, 13, 15, 16).

Aphid populations tend to increase and cause more damage during hot, dry weather. Under cool and humid conditions, beneficial insects usually keep aphid populations in check. Aphid feeding injury can kill seedlings or young transplants while injury to older plants can result in yellow, curled leaves, stunted growth and deformed heads (5, 8, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/aphid.htm

Flea Beetles (*Phyllotreta spp.)*

Flea beetles occasionally feed on cole crops causing significant damage on crops planted early. Flea beetles seem to prefer cauliflower to the other cole crops. Although several flea beetle species feed on cole seedlings, the striped flea beetles, the western black flea beetles, and the crucifer flea beetles are the most common flea beetles found on cole crops. Flea beetles are small with large hind legs that enable them to jump a considerable distance when disturbed (5, 13, 15, 16, 18)

Although some larvae may feed on the roots, the adult flea beetles cause more damage when they feed on cotyledons, stems and foliage. The beetles gouge out small (usually less than 1/8 inch) holes that result in a "shot hole" appearance in the foliage. A heavy flea beetle infestation on seedlings may cause stunted growth, invasion points for fungal pathogens, wilting, and even death. Transplants and older plants tolerate more damage than young seedlings (5, 13, 15, 16).

Also see fact sheet: http://vegedge.umn.edu/vegpest/colecrop/flea.htm

Onion Thrips (*Thrips tabaci*)

Onion thrips are slender, minute insects (1/16 inch) that are sporadic pests of cauliflower. Thrips tend to be more of a problem in hot, dry weather. Heavy rains may wash thrips off the plants. They usually overwinter in clover, alfalfa, wheat, and other grasses. They may move to other vegetable crops if a wheat or alfalfa field is harvested. Growers should avoid planting cauliflower next to or immediately downfield from a small grain or alfalfa field (5, 6, 15, 16).

Thrips' rasping mouthparts cause whitish marks or brownish patches on the foliage and heads. Although the feeding damage on the outer leaves can be tolerated, extensive damage on the heads results in an unmarketable product. Large thrip populations within a cauliflower head may result in distortion (5, 6, 15, 16).

Also see fact sheet: http://www.gov.on.ca/OMAFRA/english/crops/facts/99-027.htm

Insect Control Options

Biological Control

Caterpillar Complex

The DBM, ICW and CL are the most important economic pests of cauliflower in the upper Midwest. Of these pests, CL is often the most difficult for growers to control. Several species of wasps and flies parasitize the eggs, larvae, or pupa of the caterpillar pests. Avoiding use of broad-spectrum insecticides during the early growth stages of cabbage when DBM and ICW have low populations and cause

moderate damage may help to conserve populations of natural enemies that may help to suppress caterpillar populations later in the season. Some natural enemies occur in high enough numbers to provide good control whereas other species need to be mass released to provide control. Only some parasitoids, however, are commercially available—see table below (5, 13, 16, 18).

PEST	**BIOLOGICAL CONTROL**	**REMARKS**
DBM	*Diadegma insulare*, Ichneumonid wasp	Consistently parasitizes 70-80% of larva populations during mid-and late-season cauliflower.
ICW & CL	*Trichogramma* spp.	Timely mass releases during peak flight could be an effective control agent. Parasitism can reach 100% of ICW eggs. Many *Trichogramma* spp. are commercially available in large quantities. Determining the right species or strain that may provide the most effective control may be difficult. *T. pretiosum* may provide the best control for cole crops but results may

		vary.
CL	*Cotesia marginiventris*, Braconid wasp	Parasitizes early instars of different noctuid caterpillars, including CL. Available for commercial release to control CL.
DBM, ICW, CL along with other caterpillars and beetle larvae	*Perillus bioculatus*, twospotted stink bug *Podisus maculiventris*, spined soldier bug	Some stink bug species are predaceous and feed on a number of insects including caterpillars and Colorado potato beetle larvae
Small DBM, ICW, CL and other caterpillars, aphids, along with a wide variety of soft-bodied insects	*Chrysoperla* sp., Green lacewings	The green lacewing larvae are voracious feeders. Providing adequate food supply such as pollen and nectar when their prey is not present keeps the lacewings in the area.

Cabbage Maggot

Some ground beetles will attack cabbage maggot eggs. In addition, some parasitic wasps and rove beetles parasitize eggs and maggots. The nematode *Steinernema carpocapse* that is typically present in the soil provides some control of a variety of soil-inhabiting insects, including cabbage maggots.

Additionally, *S. carpocapse* are commercially available. Nematodes must be mass released under moist conditions to provide control. None of the other natural enemies, however, are commercially available. Naturally occurring populations of predators and parasitoids enemies usually do not provide sufficient control to prevent economic damage (6, 15, 20).

Cabbage Aphids

A small aphid wasp, *Diaeretiella rapae*, is the most common parasite of cabbage aphids. Although *D. rapae* is very common, it is does not effectively control the cabbage aphid. By the time wasp populations have increased to sufficient numbers to control aphids, the aphid population has often exceeded threshold levels. Moreover, *D. rapae* is often killed by hyperparasites. Releases of this commercially available wasp could provide effective control.

In addition, some of the generalist predators such as ladybird beetles (family Coccinellidae), syrphid fly larvae (family Syriphidae), green lacewing larvae (*Chrysoperla* sp.), minute pirate bugs (*Orius* sp.), and damsel bugs (*Nabis* sp.) provide some control of aphids especially when the aphid colonies are small. Some ladybird beetles species, along with lacewing larvae, and minute pirate bugs are commercially available (5, 13, 18).

Flea Beetles

Few natural enemies of the flea beetles provide substantial control. The commercially available nematode *Steinernema carpocapsae* infects flea beetles but encapsulation methods need to be improved to increase nematode persistence within the soil (5, 13, 18).

Onion Thrips

No effective means of biological control of thrips specifically on cauliflower is currently available. Although some predatory mites are commercially available for control on some greenhouse and cucumber outdoor crops, more research is needed to increase better control in cabbage crops (5, 13, 18).

Cultural and Alternative Control Methods

Caterpillar Complex

Destroying crop residue immediately after harvest eliminates breeding sites where populations can build up and move to newer cauliflower plantings. Clean cultivation also destroys potential overwintering sites.

In well-drained fields, overhead irrigation may wash off DBM larvae and disrupt adult activity to reduce DMB populations by as much as 80%.

In small fields, floating row covers can prevent adult moths from laying eggs on plants (5, 13, 18).

Cabbage Maggot

Since the first generation of root maggots is the most damaging, planting seeds or transplants after the peak of adult emergence and egg laying in the spring may provide the best control. A grower may predict the peak egg laying period using degree days. Other cultural control practices consist of the following:

- Avoid plowing fresh animal manure, weeds, green manure or other cover crops in spring because root maggots are often attracted to rotting organic matter.
- Rotate cauliflower crop fields to avoid infestations (2, 5, 13, 18).

Cabbage Aphids

Aphids are less attracted to crops when a cover crop mulch is planted between the rows than when the crop is highlighted against a bare soil background. Moreover, some cover mulches may provide additional food sources to the aphids' natural enemies. However, some weedy plots may increase flea beetle populations. Destroying and removing crop residue after harvest provides fewer overwintering sites for aphids, along with the DBM, ICW, and cabbage maggot (5, 8, 13, 18).

Flea Beetles

Planting early in spring may avoid high populations of flea beetles when plants are small and most susceptible to damage. In addition, flea beetles tend to have higher populations in weedy fields. Clean sanitation practices in and around the field may help to reduce flea beetle populations. Weedy plots, however, may provide food sources for the natural enemies of some of the other cabbage pests (5, 9, 13, 18).

Onion Thrips

Avoid planting next to or down wind from wheat or alfalfa fields. Thrips often build up large populations in wheat or alfalfa and may move to cauliflower crops when the wheat or alfalfa is harvested (5,13,18).

Insect Chemical Control (14)

Insects	*Treatment*	*Remarks*

Treatment Thresholds for ICW, CL: Seedbed: 10% Transplant to Cupping: 30% Cupping to early Head: 20% Mature head 10%	Treatment is most effective when early instar larvae first appear.	Use of some insecticides may reduce populations of beneficial insects that suppress caterpillar populations
ICW, CL, DBM	*Bacillus thuringiensis* (MVP, Javelin, Dipel, Biobit, Agree, Xentari, Lepinox)	Begin applications when larvae are small. Use of Bt products will help conserve beneficial insets. 0 day Pre-Harvest Interval (PHI)
	Warrior 1EC; 1.9-3.8 fl. oz/Ac	<1.92 pts./Ac/yr, 1 day PHI
	Capture 2EC; 2.1-6.4 fl. oz/Ac	<32 oz/Ac/yr, 7 day PHI
	SpinTor; 1.5-6 fl. oz/Ac	<29 oz/Ac/yr, observe resistance mgmt. restrictions. 1 day PHI
	Proclaim 5WDG; 2.4-4.8 oz./ Ac	<2 sequential applications, 7 days between apps., 7 day PHI
	Thiodan, Endosulfan, Phaser 50 WP	<4 apps/yr, 7 day PHI
	Lannate LV; 1-3 pts/Ac	also controls aphids, 1 day PHI
	Pounce 3.2EC; 2-8 fl. oz/Ac	< 1 lb AI/Ac/yr; 1 day PHI
	Ambush 2E; 3.2-6.4 fl. oz/Ac	< 1 lb AI/Ac/yr; 1 day PHI
	Larvin 3.2AF; 16-40 oz/Ac	<240 fl. oz/Ac/yr; 7 day PHI
	Asana XL; 5.8-9.6 oz/Ac	<0.4 lb AI/Ac/yr; 3 day PHI
	Dibrom 8EC; 2 pt/Ac	Also controls aphids; 1 pt/Ac for aphids; 1 day PHI
	Ammo 2.5EC; 2.5-5 oz/Ac	<0.6 lb. AI/Ac/yr; 1 day PHI
	Fury 1.5EC or Mustang 1.5EW; 2.4-4.2 oz/Ac	1 day PHI
	Avaunt 30WDG; 2.5-3.5 oz/Ac	<14 oz/Ac/yr; 3 day PHI
Root maggot (caggage maggot)	Cabbage maggot injury is usually more severe when fields have decaying organic matter present, such as plowed under cover crops or when cool, wet conditions prevail.	Transplant mixture will require approximately 200-300 gallons of water/Ac based on plant density. For use in transplanting water, mix chemicals with 50 gallons water.

	Lorsban 4EC; 1.6-2.75 oz/1000 feet row	Apply as water-based spray direced at the base of the plants immediately upon setting into the field using min 40 gallons/ Ac. Don't apply as foliar application. 30 day PHI.
	Diazinon 50WP; 0.25-0.5 lb/50 gallon water	Water treatments can reduce plant stands due to stress. Drench applications can be made at a rate of 1/2-1 cup/plant.
	Dyfonate 4EC; 1-2 qt/Ac	Mix in 200-400 gallons water/ Ac. Apply drenching spray to base of plants following transplanting.
Aphids (threshold=20% plants infested)	Conserve natural enemies.	Limit the use of insecticides to conserve predators and parasites.
	Admire 2F; 10-24 oz/Ac	<0.5 lb AI/Ac/yr; 21 day PHI
	Provado 1.6F; 3.75 oz/Ac	0 day PHI
	Dianinon AG500; 1 pt/Ac	21 day PHI
	Dimethoate; 0.75-1.5 pt/Ac	Repeat applications as needed; 7 day PHI
	Methasystox-R 2SC; 1.5-3 pt/ Ac	<4 applications/yr/max; 7 day PHI
	M-Pede; 1-2% volume/volume	Must contact aphids to be effective; 0 day PHI
	Orthene, Thiodan, Dibrom	Follow label
	Capture 2EC	<32 oz/Ac/yr; 7 day PHI
Flea Beetles	Any material applied for caterpillar control will control flea beetles except Bt (MVP, Dipel, etc.)	Examine plants soon after they are set in the field to determine need for control
	Sevin XLR Plus; 1-2 pts/Ac	3 day PHI
	Mustang 1.5EW; 2.39-4.24 oz/ Ac	<25.6 oz/Ac/yr; 7 day PHI
	Provado 1.6F; 3.75 oz/Ac	<18.75 oz/Ac/yr; 0 day PHI
	Capture 2EC; 2.1-6.4 oz/Ac	<32 oz/yr; 7 day PHI

Thrips		Some varities are thrips resistant (Ruby, Perfection, Titanic 90, King Cole, Bravo, etc.)
	Ammo 2.5EC;	<0.6 lb. AI/Ac/yr; 1 day PHI
	Dimethoate; 0.75-1.5 pts/Ac	7 day PHI
	Fury 1.5EC or Mustang 1.5EW; 3.4-4.3 oz/Ac	1 day PHI
	Warrior T; 2.56-3.84 oz/Ac	1 day PHI
	Capture 2EC; 2.1-6.4 oz/Ac	<32 oz/Ac/yr; 7 day PHI

Diseases

Diseases & Control Options (13, 16, 17)

Alternaria leaf spot (*Alternaria brassicae*)

Alternaria leaf spot occasionally infects cauliflower during moist, warm conditions. Seedlings may be especially susceptible although this disease is also a problem when storing cauliflower. On seedlings, small black dots appear on the stems, often causing their collapse. Leaf spots on the cauliflower head begin as small, dark dots that can enlarge to dark, circular, water soaked lesions. Large masses of spores are produced in the infected areas.

Moist wind currents can carry spores between fields. Rain and equipment can also disseminate the spores. The spores can also overwinter in old, infected plant debris and within the seed coat.

Also see fact sheet: http://www.extension.umn.edu/distribution/horticulture/DG1169.html

Black leg (*Phoma lingam*)

Black leg can be a serious disease of cauliflower but applying preventive measures can control it. Cool, humid conditions provide the most favorable condition for its growth. Black leg can infect cauliflower during any of its growth stages. The first symptom that typically appears is a depressed canker at the base of the stem that may eventually surround the entire stem. At first, the black, circular spots or lesions on the foliage are inconspicuous. As the spots get larger, the yellow spots develop gray centers filled with small black dots (the fungal structures). The spots on the lower leaves are more linear shaped with

purplish margins and many small black dots filling the center. If the disease spreads throughout the plant into the root system, the entire plant may collapse. The leaves wilt but generally do not fall off.

The disease remains dormant in plant debris and seed coats. If a plant or seedling is infected, spores can be spread to other susceptible plants through splashing and running water, insects, animals, and equipment. The fungus can survive for 2 winters in plant debris.

Also see fact sheet: http://www.extension.umn.edu/distribution/horticulture/DG1169.html

Black rot (*Xanthomonas campestris* pv. *campestris*)

Black rot, which is caused by the bacterium *Xanthomonas campestris* pv. *campestris*, is a very serious disease on cauliflower crops. Losses from this disease tend to be higher in years when moisture is plentiful and the average temperature ranges from 60-70° F.

The bacterium often enters the pores on the leaf or through holes caused by hail or insects. The bacterium then spreads throughout the water conducting tissue of the cauliflower. The leaf turns yellow in a v-shaped pattern with the wider area at the fringe of the leaf. The veins often turn black within the yellow area. The yellow sections then typically turn brown and brittle. The entire leaf may fall off. When the stem is cut, a black discolored ring is visible throughout the vascular region. In severe cases, the disease may cause taste changes in the cauliflower curd which may make it unmarketable.

The disease is transmitted via infected seeds. Bacteria can also overwinter in infected cruciferous weeds or in field debris. Infected seeds may produce diseased heads which can infect surrounding plants. Splashing water from rain or irrigation, large animals, insects, or farm machinery infected with black rot can also spread the disease.

Also see fact sheet: http://www.extension.umn.edu/distribution/horticulture/DG1169.html

Club root (*Plasmodiophora brassicae*)

Club root, caused by the fungus *Plasmodiophora brasicae*, can seriously damage the current year's cauliflower crop. In addition, the resting spores can survive within the soil for many years and infect any subsequent crucifer crops. Acidic soil and cool weather are favorable environmental conditions for its growth.

Club root causes the roots to become enlarged and distorted which decreases the ability of the plant to take in water and nutrients. Yellowing and wilting, especially on a hot day, may occur some time after the roots are distorted. Younger plants may die whereas older plants may have stunted growth or never develop marketable heads.

The spores invade the plant by entering its root hairs or wounds. The spores stimulate root growth which resembles large knots or clubs. Eventually, the club root release spores and infects the surrounding soil. Spores are also spread by splashing and running water, farming equipment, animals, and humans that carry spores to an uninfected field.

Also see fact sheet: http://www.extension.umn.edu/distribution/horticulture/DG1169.html

Downy mildew (*Peronospora parasitica*)

Downy mildew is an important disease that is typically more prevalent on early or late maturing crops in moist, cool conditions. The disease typically attacks seedlings but it may it may also attack in a later growth stage, causing discolored cauliflower.

The first symptom that typically develops is a grayish white, fluffy growth on the underside of the leaves. Irregular yellow and brown spots may then develop on the upper yellow leaf surface. The spots often turn purplish and later light brown or yellow. If the disease spreads to the curds, dark brown or purplish areas will develop. If the lower leaves are infected, the fungus can invade the plant systemically. Moreover, soft rotting bacteria may also invade the lesions as secondary infections.

The spores are spread between plants through air currents and rainstorms. The fungus overwinters as resting spores in plant debris left in the fields.

Also see fact sheet: http://www.extension.umn.edu/distribution/horticulture/DG1169.html

Fusarium yellows (*Fusarium oxysporum* f. sp. *conglutinans*)

Fusarium yellows, which is a soilbourne fungus, can be a problem for susceptible cabbage cultivars but typically does not affect cauliflower.

Damping off (*Pythium* spp.) and Wirestem (*Rhizoctonia solani*)

Damping off or seedling diseases are caused by soilborne fungi, *Rhizoctonia solani*, or several of the *Pythium* spp. *Pythium* can attack seeds and cause them to rot before they germinate. *Pythium* can also attack seedlings before they emerge above the soil line or after the emerge above soil line. *Pythium* often causes lesions on the stems that cause the seedling to collapse, and then becomes dark and shriveled. *Rhizotina* invades the cortical cells of seedlings which may girdle the stem. Some cauliflower crops continue to grow slowly after *Rhizoctonia* invasions but the stem is typically obtains a small, spindly, woody characteristic that is referred to as wirestem.

Either disease may occur anywhere in field but typically occurs under wet conditions. *Pythium* is more of a problem when seeds are planted in cold, damp soils. *Rhizotinia*, however, can be a problem in

warmer, damp soils. Fields high in green organic matter, poor drainage, or compacted soils provide conditions that make seedlings more susceptible to these diseases.

The best controls are good sanitation practices, good preparation of seedling beds, seed treatment, and avoiding planting seeds in cold soil. In warmer soils, seeds grow more vigorously, and have less time to be susceptible to dampening off diseases.

Disease Control (13, 14, 16, 17)

Disease	***Control***	***Remarks***
Black Rot	Plant disease free seed/transplants, use 3-4 year crop rotations, apply 1-2 lb. Cu/Ac, repeat at 5-7 day intervals if wet weather persists early in the season.	Hot water treatments help eliminate seed born-pathogens. Rotate to unrelated crops as bacterium can overwinter 2 years, maximum. Resistant varieties include Bravo, Olympic, Solid Blue. Copper slows black rot.
Black Leg	Plant disease free seed/transplants, use 3-4 year crop rotations.	Hot water treatments help eliminate seed born-pathogens. Rotate to unrelated crops as bacterium can overwinter 2 years, maximum. Resistant varieties include Bravo, Olympic, Solid Blue. Copper slows black rot.
Club Root	Plant disease free transplants, 7 or more year crop rotation. Apply Terrachlor 75W at 37 oz/1000 feet row.	Avoid poorly drained soils wtih club root history, rotate to non-cruciferous crops. Losses can be avoided by raising soil pH to 7.2-7.5
Downy Mildew	Use a 2-3 year crop rotation. Apply Ridomil Gold Bravo 81W at 0.2 lb/Ac at the first sign of disease.	Rotate to non-cruciferous crop to reduce pathogen population and increase efficacy. Second and third applications of Ridomil should be applied at 14 day intervals; 7 day PHI.
Fusarium Yellows	Plant yellows-resistant varieties	Many resistant varieties available
Alternaria Leafspot	Use 3-4 year crop rotations; Bravo 500, 2.25 pt/Ac; Maneb 80W, 1.5-2 lb/ Ac; Manex, 1.2-1.6 pt/Ac	Apply protective fungicides at the first sign of disease and repeat at 7-10 day intervals. Begin application sooner if field has history of disease. 7 day PHI for most labeled fungicides.
Seed Contamination	Captan 50WP, 1 oz/100 lb seed	Most distributed seed is treated

Wirestem	Terrachlor 75W, 12.2-18.4 oz/1000 feet rot	Raise seedlings in disinfected seed beds (use steam or chemical fumigants).

Weeds

Weeds compete with cauliflower crops for light, nutrients, and water. Weeds that exist in and around the field can also harbor disease pathogens and pest insects that can invade the cauliflower crop after planting. Many annual weeds produce copious amounts of seeds that often remain viable in the soil for many years. Early in the growing season, cultivation may control weed seedlings. As the growing season progresses, however, cultivation may damage the cauliflower roots. Application of herbicides may be the only effective control method (13, 14).

Chemical Control

Preemergence

Herbicide	*Treatment rates*	*Remarks*
DCPA (Dacthal 75WP)	Apply 8 lb. on light-colored soils (<2% organic matter), 14lb/Ac on darker colored soils; use at least 50 gal water/ acre. Must be incorporated into soil with water.	Apply immediately after seeding or transplanting. Use 50-mesh or larger screens. Not effective on muck soil and other high organic soils. Provides good control of many grass weeds such as barnyard grass, crabgrass, fall panicum, foxtails, goosegrass. Also provides good control of the annual broadleaf weeds such as lambsquarter and purslane.

Napropamide (Devrinol 50DF)	Apply 2 lb/Ac on light-colored soils (<2% organic matter), 4 lb/Ac on other soils.	Incorporate 1-2 in. deep before seeding or transplanting. After harvest or prior to planting succeeding crops, must complete either a deep moldboard or disc plowing operation. Provides good control of many grass weeds such as barnyard grass, crabgrass, fall panicum, foxtail, and goosegrass. Also provides good control of the annual broadleaf weeds such as pigweed and smartweed. Provides fair control of lambsquarter.
Trifluralin (Treflan 4 lb/gal.)	Apply 1 pt/Ac on light-colored soils (<1% organic matter), 1.5 pt/Ac on darker soils.	Apply before planting and incorporate immediately into soils by double disking or with other equipment to mix thoroughly 3-4 in. deep. Not effective on muck and other high organic soils. Provides good control of many grass weeds such as barnyard grass, crabgrass, fall panicum, foxtail, and goosegrass. Also provides good control of the annual broadleaf weeds such as pigweed, smartweed, and lambsquarter.
Oxyfluorfen (Goal 2XL)	Apply 1-2 pt/Ac in minimum 20 gal water. Use lower rate on course textured soils.	Apply after completion of soil preparation but prior to transplanting. Transplant within 7 days of application. Do not use on direct seeded cabbage or over the top of existing crops. Provides good control of some annual broadleaf weeds such as lambsquarter, nightshade, pigweed, purslane, ragweed, and smartweed.

Bensulide (Prefar 4E)	Apply 5 qt/Ac on light-colored sandy soils (<1% organic matter), 6 qt/Ac on other soils.	Apply before planting, and incorporate 1-2 inches. May also apply after seeding and before crop emerges, and irrigate within 24 hours. Provides good control of many grass weeds such as barnyard grass, crabgrass, fall panicum, foxtail, and goosegrass. Provides only fair control of some annual broadleaf weeds such as lambsquarter, pigweed, and purslane.

Postemergence

Herbicide	*Treatment rates*	*Remarks*
Sethoxydim (Poast 1.5E)	Apply 1-1.5 pt/Ac plus 1 qt COC/Ac	Maximum of 3 pt/Ac/yr. 30 day PHI. Provides good control of most annual grass weeds.
Paraquat (Gramoxone Extra 2.5E)	Appy 2-3 pt/Ac plus 1 qt COC or 4-8 oz nonionic surfactant/25 gal spray solution.	Apply to emerged weeds before seeding or transplanting, or after seeding but before crop emergence. RUP. Provides good control of most annual grass and annual broadleaf weeds.
Glyphosate (Roundup Ultra)	Apply 0.75-1.1 acid equivalent (ae)/Ac. Equivalent to 32-48 oz of 3 lb ae/gal; 24-36 oz. of 4 lb. ae/ gal; 1.2-1.8 of 64.9% ae WSG.	Apply to emerged weeds before planting in spring or after final harvest. These rates are for annual weeds at volumes of 10-40 gal/Ac. See label for rates at lower application volumes for perennial weeds, and suggested adjuvants.

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