Crop Profile for Cabbage in Minnesota

Prepared August: 2001

General Production Information

Executive Summary

In 1997 approx. 450 ac. of cabbage were harvested in Minnesota. Another 300 acres of related crucifer crops, including broccoli, cauliflower, and Chinese cabbage (e.g., bok choi, nappa, etc.) are also produced annually in Minnesota, most of which is sold for fresh market. Broccoli and cauliflower are covered in separate crop profiles for Minnesota. Despite the relatively few acres of cabbage in the state, the high value of the crop (ca. $4,000/ac), and traditionally high insecticide use of about 6-9 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 cabbage. The most important insect pests include: cabbage looper, imported cabbageworm, diamondback moth, cabbage maggot and flea beetles. With high parasitism rates of diamondback moth (typically 80-100%), and in the absence of insecticide resistance with this pest, cabbage looper is often the most common and most difficult insect pest to control (3). 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: Recent demonstration of a cabbage IPM program in Minnesota, in commercial production fields, using action thresholds, scouting and "reduced-risk" insecticides (SpinTor, Proclaim and Avaunt), with minimal pyrethroid use, provided excellent results for lepidopteran larval pests (3, 8). The IPM program, compared with the conventional strategy and untreated check, consistently yielded a lower proportion of plants infested with late-instar cabbage looper larvae, and a higher percentage of marketable heads (90-99%) for the 4-year study. The IPM program also resulted in significant reductions in insecticide use (20-66%). The reduction in sprays combined with the increase in marketable heads resulted in increased profits (net revenue) ranging from 3.3-19.8%. Expected utility analysis also revealed that the IPM program provided the highest net revenue with the least risk. These results confirmed the economic benefit of an IPM approach, and indicate that the new reduced-risk insecticides, if priced competitively, can provide growers with multiple insect control options, compatible with an IPM approach. 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 this pest. Finally, 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 cabbage 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. Tip burn is caused primarily by a lack of water during critical development periods. 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 cabbage diseases include Bravo, Rovral, Maneb, Terrachlor and various copper formulations. Where possible, such as Ridomil Gold Bravo for downy mildew control, it is critical that these 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 cabbage 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 cabbage. However, Treflan and Dacthal are not recommended for use on muck soils. In addition, Goal is not recommended for use on direct-seeded cabbage. Post-emergence herbicides (Poast, Gramoxone and Glyphosate) are typically limited to weed escape situations, in unusually high weed pressure fields. Pyridate (lentagran), another broad-spectrum post-emergence herbicide is no longer manufactured. Potential additional 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.

Minnesota harvested 453 acres of cabbage on 1997, of which, approximately half was irrigated. Nearly all of the cabbage produced in Minnesota is destined for fresh market sale. The national average (1997-1999) for production of fresh market cabbage was 315 cwt/acre (16 tons/acre) with an average value of $11.53/cwt ($226/ton). The 1997 Minnesota fresh market cabbage crop had a market value of $1.65 million (1).

Regions

Dakota County, located at the southeastern edge of the Twin Cities metropolitan area, leads the state with 114 acres of cabbage production (1).

Cultural Practices

Cabbage is a cool season crop that may be planted early or late in the growing season. The best quality cabbage is produced with daytime temperatures of 70-80º F, sunny conditions, and moist, fertile, well-drained soil. Cabbage needs at least 1 inch of 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 (4, 7, 15).

Insect Pests

Although quality standards may vary somewhat depending on whether cabbage is being produced for the fresh market or processing, consumers have a low tolerance of insect damage in the foliage or insect excrement within the leaves. Growers may have more options to control insects early in the production that may allow survival of more beneficial insects but as harvest time approaches, the control options are more limited due to the concern about insect damage (6, 15).

Cabbage Looper (*Trichoplusia ni*)

The cabbage looper (CL) is a major economic pest of cabbage 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 (6, 12, 15, 17, 18).

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. Loopers are able to bore through 3-6 layers of tightly wrapped cabbage leaves resulting 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 (6, 12, 15, 17, 18).

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 in cabbage 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 (6, 14, 15, 17, 18).

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 cabbage heads causing them to look deformed and encouraging the invasion of soft rot (6, 13, 15, 17, 18).

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 cabbage. The larvae are velvet green, about 1-inch long in the last instar, and move sluggishly when touched (5, 12, 13, 15).

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 with large fecal pellets (6, 14, 15, 17, 18).

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

Cabbage Maggot (*Delia radicum*)

The cabbage maggot is a sporadic pest of cabbage. 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 cabbage to look off-color, sickly and stunted. Extensive feeding can cause wilting and death. The feeding also provides entry points for fungal pathogens (2, 6, 15, 17, 18).

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 cabbage. 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 (6, 10, 15, 17, 18).

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 (6, 10, 15, 17, 18).

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. Although several flea beetle species feed on cole seedling crops, 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 (6, 15, 17, 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 (6, 10, 15, 17, 18).

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 cabbage. 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 cabbages next to or immediately downfield from a small grain or alfalfa field. Onion thrips generally prefer cabbages with very tightly wrapped leaves to the loose-head varieties. In addition, red varieties of cabbage tend to have fewer thrips than green varieties (6, 7, 15, 17, 18).

Thrips posses rasping mouthparts and can cause white or brown patches to form on the foliage. Although feeding damage on the outer leaves can be tolerated, extensive damage to the head results in an unmarketable product. A large thrips population within a cabbage head can even result in distortion (6, 7, 15, 17, 18).

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

Insect Control Options

Biological Control

Cabbage Caterpillar Complex

The DBM, ICW and CL are the most important economic pests of cabbage 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. Some parasitoids are commercially available—see table below. A recent on-farm study in Minnesota (1998-2001) has shown that the use of "reduced-risk" insecticides (SpinTor and Avaunt) based on crop scouting and action thresholds, can be used to conserve beneficial insects and be compatible in an IPM program (3, 6, 8, 15, 18, 20).

PEST	**BIOLOGICAL CONTROL**	**REMARKS**
Diamond Back Moth (DBM)	*Diadegma insulare*, Ichneumonid wasp	Consistently parasitizes 70-80% of larva populations during mid-and late-season cabbage
Imported cabbageworm (ICW) & cabbage looper (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	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 Maggots

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 (Coleoptera: Coccinellidae), syrphid fly larvae (Diptera: 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, lacewing larvae, and minute pirate bugs are commercially available (6, 15, 20).

Flea Beetles

Few natural enemies of flea beetles provide significant control. The commercially available nematode *Steinernema carpocapsae* infects flea beetle but encapsulation methods need to be improved to increase nematode persistence within the soil (6, 15, 20).

Onion Thrips

No effective means of biological control of thrips specifically on cabbage is currently available. Although some predatory mites are commercially available for control on some greenhouse and cucumber outdoor

crops, additional research is needed to increase control in cole crops (6, 15, 20).

Cultural and Alternative Control Methods

Cabbage Caterpillar Complex

Destroying crop residue immediately after harvest eliminates breeding sites where populations can build up and move to newer cabbage 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 (6, 15, 20).

Cabbage Maggots

Since the first generation of root maggots is the most damaging, planting seed or transplants after the peak of adult emergence and egg lay in the spring may provide the best control. Growers can predict the peak egg lay 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 cabbage fields to avoid infestations.
- Plant cabbage varieties that seem to have more tolerance of root maggot injury such as Flat Dutch, Red Hollander, and Red Acre. Although red cabbage has shown less damage than the green varieties, resistance to root maggot is not related to the color itself (2, 6, 15, 20).

Cabbage Aphids

Aphids are less attracted to crops when a cover crop is planted between rows rather than having the crop highlighted against a bare soil background. Some cover mulches may provide additional food sources to the aphids' natural enemies, however, 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 (6, 9, 15, 20).

Flea Beetles

Early spring planting may help fields avoid high flea beetle populations 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 fields may help to reduce flea beetle populations. Weedy plots may provide

food sources for the natural enemies of some of the other cabbage pests (6, 11, 15, 20).

Onion Thrips

Avoid planting next to or down wind from wheat or alfalfa fields. Thrips populations often build in wheat or alfalfa and may move to cabbage after those crops have been harvested.

Some cabbage varieties, especially those with loose heads, are less susceptible to thrips damage. In addition, some red varieties seem to attract fewer thrips than green varieties. Red varieties, however, seem to attract more cabbage loopers (6, 15, 20).

Insect Chemical Control (16)

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 (16, 18, 19)

Alternaria leaf spot (*Alternaria brassicae*)

Alternaria leaf spot may be more prevalent during warm and moist conditions. Seedlings can be especially susceptible although this disease is also a problem in stored cabbage. On seedlings, small black dots appear on the stems, often leading to their collapse. Leaf spots on the cabbage head begin as small, dark dots that can enlarge to dark, circular, water soaked lesions. Large masses of spores are produced in 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 cabbage but applying preventive measures can control it. Cool, humid conditions provide the most favorable condition for its development. Black leg can infect cabbage during any of its growth stages. Initial symptoms typically include the appearance of a depressed canker at the base of the stem that may eventually encircle the entire stem. At first, the black, circular spots or lesions on the foliage are inconspicuous. As the spots get larger, however, they develop gray centers filled with small black dots (the

fungal structures). The spots on the lower leaves are more linear shaped with purple 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. 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 persist for up to 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 cabbage 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. It then spreads throughout the water conducting tissue of the cabbage causing leaves to turn 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 become brittle. Entire leaves may fall off. When the stem is cut, a black discolored ring is visible throughout the vascular region.

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 cabbage crop. Additionally, 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 hot days, may occur for 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 cabbage.

The first symptom that typically appears is a gray-white growth on the underside of the leaves. Irregular yellow and brown spots may then develop on the upper yellow leaf surface. The spots often develop in into purple, sunken spots on the cabbage. If the lower leaves are infected, the fungus can invade the plant systemically. Additionally, soft rot bacteria may also invade the lesions.

Spores are spread between plants through air currents and by rain. 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, a soil-born fungus, can be a problem for susceptible cabbage cultivars. The disease is most severe when temperatures exceed 70° F.

The first symptom is yellowing of one of the lower leaves. As the disease spreads, more leaves turn yellow. The yellowing often occurs more intensely on one side of the cabbage although sometimes the entire plant turns yellow. The disease progresses from the lower leaves upward. Leaves become brown and brittle while the veins may turn black and resemble black rot.

Spores can remain dormant in the soil for years until the right environmental conditions and susceptible cabbages are planted. When a susceptible cabbage is planted, the spores germinate, and the fungus penetrates the plants through the roots or wounds. The fungus then progresses through the water conducting tissue to infect the rest of plant. The spores are also spread through infested soil on farm machinery and tools, and transported via animal and human foot traffic.

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

Damping off, or seedling diseases, are caused by soil-born 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 cabbage 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 problematic when seeds are planted in cold, damp soils. Rhizotinia, however, can be a problem in warmer, damp soils. Fields with high levels of organic matter, poor drainage, or compacted soils can make seedlings more susceptible to these diseases.

The best control is good sanitation practices, good preparation of seedling beds, use of seed treatments, and planting seeds in warm soils. Seed germinate quickly and plants grow more vigorously in warm versus cool soils, and have less time to be susceptible to dampening off diseases.

Disease Control (15, 16, 18, 19)

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

Weeds

Weeds compete with cabbage for light, nutrients, and water. Weeds in and around the field can also harbor disease pathogens and insect pests that can invade the cabbage field after planting. Many annual weeds produce copious amounts of seeds that often remain viable in the soil for years. Early in the growing season, cultivation may control weed seedling. As the growing season progresses, however, cultivation may damage cabbage roots. Application of herbicides may be the only effective control method (15, 16).

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 discing 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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Acknowledgements

The Minnesota cabbage crop profile was compiled by and edited by Patrick O'Rourke, Kathleen Bennett and W. D. Hutchison, Minnesota Pesticide Survey and Impact Group, Department of Entomology, University of Minnesota.

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