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PREVENTING BLACK ROT

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In 1997, crucifer harvests in Quebec and Ontario accounted for 49% and 29% respectively of total Canadian production. Unfortunately, like most other market garden crops, cruciferous vegetables are subject to various diseases, the most important being clubroot and black rot. Considerable yield losses may occur if climatic conditions are favourable for black rot. When the disease develops early in the season, the infected plants are often unmarketable and highly susceptible in the field or during storage to soft rots caused by other pathogens. However, if the infection is light or occurs late in the season, the infected leaves can simply be trimmed at harvest. In such a situation, there is no loss in yield. Outbreaks of black rot occur sporadically and disease severity depends on weather conditions, with hot, rainy weather being conducive to disease development.

THE DISEASE

Black rot is caused by the bacterium *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson. It is considered one of the most destructive diseases of cruciferous crops worldwide. Cabbage, cauliflower, broccoli, Brussels sprouts, rutabaga, Chinese cabbage, turnip, radish, kale, kohlrabi, mustard and canola are all affected. Cabbage, kale and cauliflower are the most susceptible vegetables.

Disease symptoms

Familiarity with the symptoms of black rot aids in detecting the infection on young plants. Detection is difficult at that growth stage, however, because the disease symptoms may be present on only a small proportion of infected plants. On young plants, blackening occurs along the margins of the cotyledons, which subsequently turn yellow and dry out.

When rapidly growing plants become infected, the disease first appears as diffuse spots between secondary veins along the leaf margins. Later, because the plant is not getting enough water, chlorosis occurs and characteristic yellow, V- or U-shaped lesions appear along leaf margins (Photos 1 and 2). If the weather is dry, these lesions will dry out and the symptoms will not develop further. By contrast, when the weather is rainy or hot and humid, the bacteria will multiply and progressively invade the veins, petioles and stems. Blackening of the leaf veins is a sign that they have been destroyed by the colonizing bacteria. These black areas become visible as the lesions enlarge. Severely infected leaves eventually dry out completely, die and drop off.

Infection through a wound on the leaf surface produces atypical symptoms which are often confused with several other disorders. In such a case, there is a yellowish halo around the wound which eventually turns necrotic. The bacteria rarely colonize the vascular tissue under these circumstances.

In extreme cases, soft rots caused by secondary parasites such as *Erwinia carotovora* or *Pseudomonas marginalis* may be observed. Opportunistic fungi may also be present and may mask the symptoms of black rot.

Progression of the infection

The bacteria that cause black rot usually spread from leaf edges to their interior. They enter the plants primarily through the hydathodes located at the ends of veins along the leaf margin which permit guttation. Plants transpire under conditions of high humidity and during morning dew, when many droplets are exuded along leaf margins (Photo 3). Black rot bacteria that are present in those drops of water can enter the leaves when the transpiration rate rises and stomata open up on the upper and lower leaf surfaces. Other sites of entry include wounds caused by high winds, hail, insects, tillage and so on. Root injuries also offer an entry point when the soil is saturated with water.

Within the plant's vascular tissue, *X. campestris* pv. *campestris* begins to multiply and produce a mucilaginous, extracellular polysaccharide called xanthan. As this yellow compound accumulates and the bacteria keep multiplying, the xylem tissue becomes plugged, impeding the normal flow of water and nutrients. That is when the above-described symptoms and blackening of veins may become noticeable.

Conditions favourable for infection

Temperatures between 25 and 28°C, high humidity and rainy conditions are conducive to the development of black rot. Under these optimal conditions, disease symptoms may appear eight to ten days following infection. The bacterium can also enter plants and begin multiplying at temperatures between 16 and 18°C. However, at these lower temperatures, there are no symptoms and the disease progresses slowly.

Spread of *X. campestris* pv. *campestris* in the field

An experiment conducted at the HRDC in collaboration with the AJMQ showed that the presence of black rot-infested cabbages can affect the development and spread of the disease in the field. In this research, two types of dispersion were identified: *dispersion on a given plant* , which augments the severity of the disease; and *dispersion between plants*, which increases the risk of losses at harvest.

The initial dissemination of the bacterium on a single cabbage is aided primarily by drops of contaminated water. Dispersal of the bacterium over greater distances is attributable to the combined effects of flow of contaminated water droplets, splashing rainfall and windy conditions during hot weather. The extent of dispersal varies with the intensity of rainfall and prevailing winds. Based on the study findings, the causal pathogen of black rot can travel a distance of almost eight metres during major storms. However, in the absence of rain, the disease cannot spread and the symptoms remain stable.

From the HRDC experiment, it can be concluded that the magnitude of economic losses depends on rainfall frequency during periods of hot weather. Heavy rainfall causes the infection to spread to more foliage, augmenting disease severity. Hence, if some plants are already infected with black rot and the period from late June through July happens to be rainy, there is a high risk of yield losses.

Canada

CONTAMINATION SOURCES AND PREVENTION

There are many contamination sources and dispersal agents for this bacterial disease. Wind, rainfall, sprinkler irrigation, insects, agricultural machinery and workers are key factors in the spread of phytopathogenic bacteria like *X. campestris* pv. *campestris*. It is important to be familiar with these factors in order to make informed decisions about the best control measures for greenhouse- and field-grown crops.

Since very few products are available for controlling or minimizing the effect of the bacterial pathogens, prevention remains the best approach. This involves using a combination of production practices to reduce contamination sources rather than relying on pest control chemicals.

Seed treatment

Infested seed is the main contamination source for black rot. As few as three to five infected seeds in 10,000 can cause a high incidence of black rot in fields. In many seed-producing countries such as the United States, Japan and various European nations, the disease is always present to some extent. Consequently, it is important to make sure that the prevalence of black rot is not greater than 1 seed in 30,000 in any seedlots purchased. However, since *X. campestris* pv. *campestris* can live both in and on seeds and since quality control of crucifer seeds is a difficult task, it is a good idea to treat all seeds.

Treating seeds with hot water is strongly recommended as a means of eliminating the bacteria (seed of cabbage, broccoli and Brussel sprouts should be treated at 50°C for 25 minutes, and seed of cauliflower, turnip, rutabaga and kale for 15 minutes). Hot-water treatment is not well accepted by the industry, because it reduces seed viability and does not eradicate the bacterium. Nonetheless, the reduced field infection level that can be achieved by this method outweighs the losses in terms of damaged seeds (which often harbour the bacterium anyway).

Warning: Although treating seeds with streptomycin is an approved practice in Canada, this treatment can be toxic to certain crucifer cultivars. For recommendations on this topic, please consult an agronomist with your provincial agriculture department.

Production of transplants

The potential presence of *X. campestris* pv. *campestris* on greenhouse-grown seedlings must not be overlooked. Bacteria present on the surface of cotyledons may cause problems during the growing period, because they can be spread from plant to plant by irrigation booms. Water sprayed on the foliage may cause the formation of aerosols and micro-droplets which can transport the bacteria over short distances, either within a given plant or from plant to plant.

In the greenhouse, it is difficult or even impossible to identify black rot symptoms, because the temperatures maintained for quality transplant production are often too low for symptom expression. Although the plant leaves may look healthy, they may have been colonized by the bacteria, which can persist for quite some time in a latent state. If the environmental conditions after transplanting are conducive to disease development, there will be a sudden explosion of symptoms in the field: the greater the number of pockets of contamination, the faster the infection will spread.

Disease management in fields

Roguing of infected plants Early scouting for infected plants in the greenhouse and field and removal of affected foliage can assist in reducing black rot damage. Do not leave piles of potentially infected crucifer debris near production fields because the disease could be spread by rainfall, insects and human activity. (See *Crop residues* below)

Transplanting After being transplanted to the field, infested plants may infect nearby plants over varying distances depending on the effect of wind, rainfall, sprinkler irrigation, insects, agricultural machinery and workers. Rain splashing on cabbage leaves undergoing guttation has been shown to be an excellent means of dispersal for the causal pathogen.

Crop rotation In order to eliminate bacteria that have survived in crop residues, crop rotation should be performed every three years by alternating between cruciferous crops and unrelated plant species. Solanaceous plants (tomatoes, peppers, potatoes) and curcubits (cucumbers, melons) are not susceptible to black rot.

Crop residues Experiments conducted in Georgia (U.S.A.) and in the Moscow area have shown that *X. campestris* pv. *campestris* can survive within cabbage residues for about two years in soil covered with these residues. According to the same studies, the bacteria can also persist freely in the soil for 40 to 60 days. Another study, undertaken in the State of Washington, revealed that the bacterium can be detected in diseased cabbage residues until they are thoroughly decomposed.

To gain insight into the survival of *X. campestris* pv. *campestris* under winter conditions in Quebec, an HRDC experiment was undertaken in the Montérégie region, with joint funding from the Association des Jardiniers Maraîchers du Québec (AJMQ). The results showed that the pathogen's ability to survive through the winter increased in the presence of slightly decomposed cabbage debris. Surviving populations could therefore cause a massive infection when the next cabbage crop is cultivated.

Cabbage residues present in fields during the fall, either on or in the soil, seldom decay completely by the end of winter. To speed decomposition and thus reduce the inoculum source, this plant debris should be shredded before it is incorporated into the soil after harvest. Adding nitrogen and compost can help to accelerate the process.

Elimination of secondary hosts Weeds represent an important source of contamination, particularly cruciferous weeds growing in production fields and along their margins. Tillage and herbicide treatment shortly after transplanting can help to reduce weed germination during the summer.

These secondary hosts provide a physical support for the bacterium, allowing it to multiply and create a major source of inoculum. Although weeds sometimes exhibit the characteristic symptoms of black rot, they generally remain asymptomatic. Rainfall combined with high winds helps to spread the bacteria to other plants, some of which may be susceptible to the disease. Experiments carried out in Georgia and California indicate that *X. campestris* pv. *campestris* can spread from a weed plant to a cabbage more than 12 metres away and can infect it, provided conditions are favourable for disease development. If there is a high incidence of black rot in a cabbage field under production, the proportion of diseased weeds in the surrounding area will be higher. In such a case, the estimated maximum distance of dispersal may exceed 12 metres.

Here are a few examples of cruciferous weeds that can serve as hosts for *X. campestris* pv. *campestris*: bird rape (*Brassica campestris*), black mustard (*Brassica nigra*), wild mustard (*Sinapsis arvensis*), shepherd's-purse (*Capsella bursa-pastoris*), pepperweed (*Lepidium* spp.) and wild radish (*Raphanus Raphanistrum*). Special attention should be devoted to eradicating these weed species.

Irrigation and drainage Sprinkler irrigation, which simulates the action of rainfall, should be used in moderation in black rot-infested fields because the bacterium can be spread by splashing water. A well-drained field with good air circulation is preferable to fields where water can collect and provide an environment conducive to disease development.

Insect control To minimize insect feeding injuries, which provide entry for bacteria, it is important to control cabbage maggot, cutworms and lepidopterous larvae, in keeping with recommendations provided by the provincial department of agriculture.

Sanitation practices

To reduce the risk of contamination, producers should use clean greenhouse equipment**,** agricultural machinery and irrigation booms, and flats which have previously been disinfected with bleach. Operations should not be carried out when the plants are wet with dew or rain. Growers should avoid taking agricultural machinery into a clean field section after operating in an infected area. Furthermore, after working in an infested field, all workers should wash their hands and disinfect their boots and work clothes.

Resistant and tolerant varieties
Only two varieties of cabbage are considered to be resistant to black rot—'Early Fuji'

developed in Japan and ‘Badger Inbreds’ created in the United States. The cabbage varieties used in Quebec show variable levels of resistance to the disease, but some appear to be more sensitive than others.

A study conducted at the HRDC compared several of the currently employed cabbage and cauliflower varieties in terms of their sensitivity to bacterial infection. Four cabbage cultivars were found to exhibit considerable tolerance to black rot, namely ‘Tenacity,’ ‘Pacifica,’ ‘Izalco’ and ‘Tristar.’ Although the ‘Albion’ cultivar displayed good tolerance during the season, it was highly sensitive to soft rots at harvest. Only one cauliflower cultivar, ‘White Rock,’ exhibited tolerance to black rot. See Table 1.

IN SUMMARY

Despite all the intensive research on black rot, the disease occurs or remains latent year after year. Proper use of treatment methods calls for in-depth knowledge of the main sources of contamination (Figure 2), which are summarized below:

- Crucifer seedlots infected by black rot below the detection level.
- Greenhouse production of transplants infected by *X. campestris* pv. *campestris*. Despite the seedlings’ healthy appearance, the bacterium may often be present in a latent state on the surface of young leaves.
- After the seedlings are transplanted to the field, black rot symptoms will develop if environmental conditions are favourable.
- The presence of decomposing cabbage residues and weeds in fields can cause a secondary infection.
- The causal pathogen may be spread by rainfall, insects, agricultural machinery, humans, sprinkler irrigation; nearby cabbages may also become infected by bacteria that gain entry via hydathodes, stomata and wounds.
- Infection may be spread to other parts of a contaminated plant by drops of water.
- Infection by secondary parasites during storage.

Interesting Web sites :

http://axp.ipm.ucdavis.edu/PMG/r108100211.htm
http://ohioline.ag.ohio-state.edu/hyg-fact/3000/3125.htm
http://www.elders.com.au/Elders/merch/hortic/hrdc/vg/vg204.htm
http://www.orst.edu/dept/botany/epp/guide/C/cabaurot.htm
http://www.acesag.auburn.edu/department/ipm/blackrot.htm

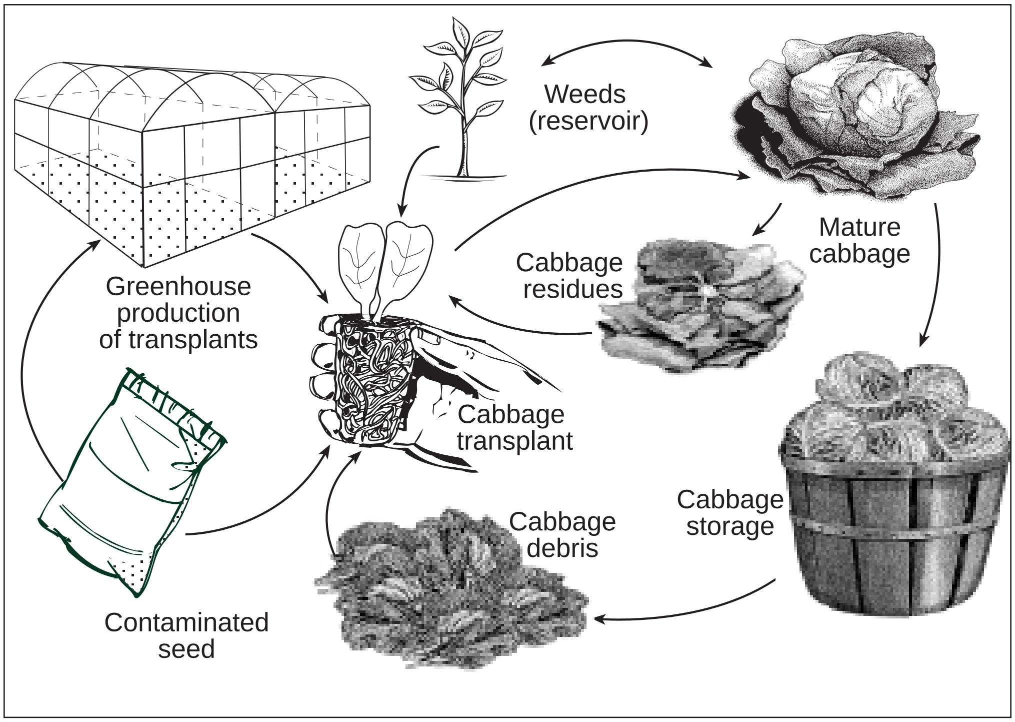

Figure 2. Schematic diagram illustrating the pathogen’s survival.

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Table 1. Sensitivity of different cabbage and cauliflower cultivars to black rot

Very Susceptible	Susceptible	Slightly Susceptible
King Cole	Danish Ball (CF)	Pacifica
Alladin	Lennox	Izalco
Bartolo	Storage 4	Albion
Storage 48	Rocket F1	Tenacity
Charmante	Incline (CF)	White Rock (CF)
Store Head	Amtrack	
Custodian	Tristar	
	Yukon (CF)	
	Andes (CF)	
	Hiton	
	Quisto	

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