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CERCOSPORA LEAF BLIGHT OF CARROT
Control strategies

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In Quebec, the main disease of carrots is Cercospora blight, also called carrot blight. Since carrots account for nearly one-fifth of vegetable production, it is important that we gain a better understanding of this widespread disease and, especially, that we devise more effective means of controlling it.

Several studies have shown that it is possible to significantly reduce the number of fungicide applications in relation to the recommended schedule without affecting either yields or quality.

At the same time, production costs and environmental contamination can be reduced. This helps to maintain the long-term effectiveness of the fungicides used while also meeting the demands of consumers who prefer vegetables produced with less pesticides.

THE DISEASE

A microscopic fungus, *Cercospora carotae* (Pass.) Solh., causes Cercospora blight of carrot. It is believed that the fungus overwinters in the soil in crop residue; Cercospora blight is therefore found year after year in virtually every cultivated field.

The pathogenic fungus produces circular dark brown or grey spots on the leaves, and the extent of the spotting varies depending on the relative humidity. A necrotic area (dead, dry tissue) may appear around the spot, caused by the secretion of a toxic substance, cercosporine. Finally, a light-coloured area, termed chlorosis, can be seen around the margin.

When conditions are favourable to the development of the disease, the lesions expand quickly, merge, and can cause a reduction in photosynthesis area, and even the death of the leaf. When the lesions are located on the petiole of the leaf, the leaf detaches easily from the crown; this poses a problem especially during mechanical harvesting.

The disease goes through several cycles during the summer, depending on the weather conditions (Figure 1). The fungus releases spores which, in dry weather, are carried by the wind to healthy leaves. When it rains, the spores germinate and then penetrate the leaves, causing infection. After several days of incubation, lesions appears and produce other spores, which are dispersed by the wind.

It is at this specific moment in the cycle that the leaves must be well protected, i.e. for approximately ten

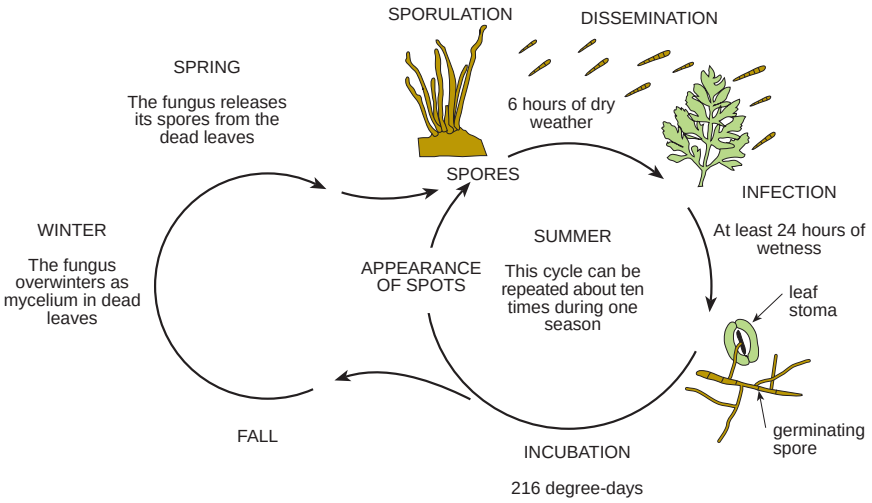


Figure 1: Life cycle of Cercospora carotae, the pathogen responsible for Cercospora blight of carrot.

days after infection until the fungus ceases to release spores, approximately four days later. Of course, the weather forecast must be for conditions favourable to a new infection during this period, namely, rain or prolonged period of relative humidity of more than 90% (Figure 2).

To cause an infection, the fungus requires six hours of dry weather (less than 90% relative humidity) for dissemination of the spores by the wind. It then needs a period of leaf wetness of at least 24 hours. This wet period can be interrupted by periods of less than 12 hours during which the leaves may dry, since the *C. carotae* spores are particularly resistant to desiccation.

The severity of the infection, whose lesions will appear 216 degree-days (base 0^{o}C) later, depends on the duration of the period of leaf wetness and the average temperature during that period (Figure 3). The most severe infections are observed when they occur during a period of rain lasting several days at a high temperature (the optimum being around 28^{o}C) especially when the rain begins during the day. For practical considerations, infections separated by less than two days of dry weather are considered to be a single period of infection.

PROBLEMS CAUSED BY CERCOSPORA BLIGHT

Cercospora blight does not affect the taproot, i.e. the edible part of the carrot. Hence, this allows producers some latitude in terms of controlling the disease, since significant losses occur only during the epidemic stage.

1. Weakening of the leaves

The main problem caused by Cercospora blight occurs when the damage is particularly severe, at which point the petiole of the leaves may be affected. The leaves break off from the root during mechanical harvesting, leaving carrots in the ground and consequently reducing yields.

To date, no studies clearly determine the degree of disease severity at which yields begin to drop. A study on leaf blight indicates that declines in yield occur when the blight affects 20% of the leaf area, but this study seems to deal mainly with Alternaria leaf blight; we should be more conservative in the case of Cercospora leaf blight.

2. Reduction of photosynthesis

A certain reduction in photosynthesis and, consequently, in the size of the carrots occurs only during severe epidemics. During one recent study, weekly fungicide applications did not increase standard carrot yields compared to a total of two or three applications. In other words, the decrease in yields caused by the reduction in photosynthesis rarely justifies more than three or four fungicide applications per season.

3. Esthetic aspect for the fresh market

Finally, the unsightly spots make it impossible to market the carrots in packages and even, in the most severe cases, to bunch the carrots.

SOLUTIONS

The Conseil des productions végétales du Québec recommends four or five treatments at intervals of seven to ten days, depending on the frequency of rainfall, beginning when the carrots are 10 to 15 cm high. However, it is possible to reduce the number of treatments as long as mechanical harvesting can be carried out without any yield losses. Simply keep the following two methods in mind.

1. Prevention

Promote aeration

The relative humidity, the duration of the period of leaf wetness and the temperature are the three factors that influence the development of the disease. Since we obviously cannot control the temperature, it is a question of enabling the plants to dry as quickly as possible in order to halt the spread of the disease and prevent infection and sporulation.

Measures that can be considered include:

- widening row spacing;
- reducing planting density in the row;
- for late-maturing carrots, selecting cultivars with upright habits, whose leaves dry more easily. This has the added advantage of reducing the development of rot (sclerotinia, rhizoctonia) and grey mould;
- considering the direction of the prevailing winds when selecting the sites of the various plots in order to avoid contamination of late-maturing carrot fields by early-maturing carrots affected earlier in the season by the disease.

Reduce the inoculum

While it is not economically feasible to rid the field of crop residue in order to reduce the inoculum, the same effect can be achieved through crop rotation. In addition to reducing the initial inoculum, this agricultural practice also has many other advantages, such as reducing the number of nodule nematodes in the soil.

Help the carrot plants do their share

To help the plant resist infection, it is essential to maintain the foliage in excellent health. Nitrogen fertilization suited to the needs of the plant will help to combat the disease more effectively.

Another option is simply to request varieties less susceptible to Cercospora blight, since, to date, no truly disease-resistant cultivars are available.

2. Integrated management

The standard fungicide timetable recommends spraying every seven to ten days. But since the impact of the disease on yields is quite minor, it is possible to let the situation progress, within certain limits, before beginning the treatments. In Quebec, the disease can begin as early as early

July or not reach the epidemic stage until September; in some years, a considerable number of treatments can therefore be eliminated by timing the treatments rather than adopting a calendar-based application schedule.

In addition to reducing the number of fungicide applications, this increases the effectiveness of the treatments by judiciously targeting the timing of the treatment. Nevertheless, for greater certainty, it is preferable to rely on the expertise of specialists such as:

- your regional advisor through the telephone answering system
- your field scout, through the bulletins issued by the RAP (pest alerting network) of the Quebec Department of Agriculture, Fisheries and Food (MAPAQ)
- or, finally, your private advisor or pest scouting network.

Do not treat early-maturing carrots

As a general rule, avoid treating early-maturing carrots, i.e. those that require fewer than 100 days from sowing to harvest, unless the weather conditions are exceptionally humid or wet. In fact, Cercospora blight rarely has the opportunity to reach the epidemic stage in early-maturing carrots. However, it must be kept in mind that the C. carotae spores are air-borne and that a heavily infested early-maturing carrot field can increase the inoculum of a neighbouring field. It is therefore advisable to consider the direction of the prevailing winds when making your decision.

Delay the start of treatments

Several treatments can be eliminated at the outset by not systematically treating before the leaf canopy half covers the rows. In fact, according to one recent study, if treatments are begun when blight is present on 50% of the middle leaves for the late-maturing varieties and 100% for the early-maturing varieties, the same yields are obtained as when the treatments were begun immediately upon appearance of the first symptoms. The goal is to treat just enough to delay the onset of the epidemic until harvest.

The role of the fungicides is therefore to halt the spread of the disease and thus reduce the inoculum for the next cycles. To achieve this, the fungicide applications must be carefully timed in order to protect the plants during the release of spores, which occurs just after the leaf canopy half covers the rows. It is therefore necessary to treat 200 degree-days (base $0^{o}C$) after a major infection, and, once again, only when the weather forecast is for conditions favourable to the germination of these spores.

Treat less often

Next, it is possible to prolong the interval between treatments up to 15 days when the conditions are particularly dry. Dry conditions are defined as fewer than 24 consecutive hours of relative humidity exceeding 90% within the leaves and when there is no rain.

Stop the treatments earlier

Finally, for the late-maturing varieties, the treatments can be stopped in the fall, i.e. by late August/early September, when the plants are at least 60 days old and when the epidemic is under control. It has been shown that mature plants and leaves more than 21 days old essentially cease to be affected. In any event, it is generally too cold to favour the development of the disease. Nevertheless, there is still a very small risk of an epidemic of Alternaria blight, according to a study conducted in Quebec and published in 1989 (R. Arcelin and A.C. Kushalappa).

NEW TECHNOLOGIES

Forecasting system and decision-making assistance software

Ms. Odile Carisse, Ph.D. in phytopathology, and Mr. Gaétan Bourgeois, agrologist, Ph.D. in modelling, at the Agriculture and Agri-Food Canada Horticulture Research and Development Centre in Saint-Jean-sur-Richelieu, in co-operation with McGill University's Macdonald College, have developed a forecasting system for Cercospora infections of carrot using a mathematical model to describe the development of the disease. The model was validated in the field by the PRISME (Integrated Management-Based Production of South of Montreal Reg'd.) pest scouting team.

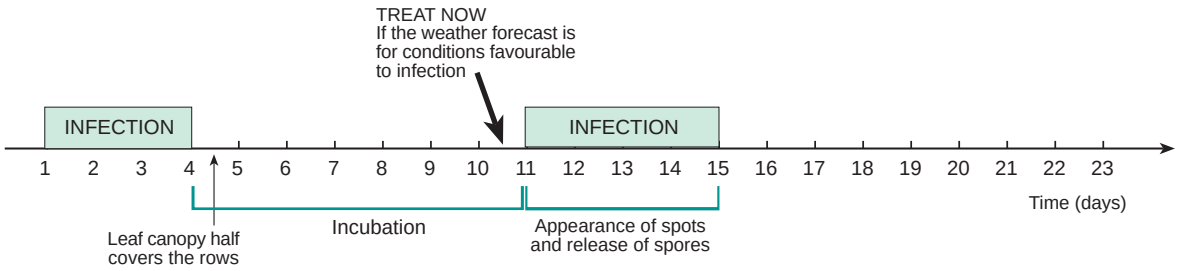
The CIPRA-carrot (Computer Centre for Agricultural Pest Scouting) software, a prototype under development, uses this forecasting system. It can therefore predict the severity of Cercospora infections as well as carrot fly and carrot weevil infestations.

The computer program works as follows: just before the leaf canopy half covers the rows, it checks to determine whether an infection has occurred. The system assigns an infection severity index, on a scale of 0 to 10, to this period of infection. When the fungus is ready to release its spores some 200 degree-days later, the system again evaluates the weather conditions for the next four days and assigns another index.

The index issued by the forecasting system is the average of all the risks of all the infections that occurred during a period of infection. This index is very concrete and has been validated in the field. It is directly proportional to the increase in the number of spots on the leaves. For example, when this index is less than 2, few or no spots are observed on the leaves after the number of degree-days required for incubation.

The index is a multiplication factor, i.e. if the index is 4 but there are no spots in the field, the risk of an epidemic is very low. But if the index is 3 and the field is already affected to a moderate degree, and if the weather forecast is also calling for a long wet period, it is preferable to treat.

CIPRA is already used by the RAP network to assist in decision-making.



Note: After the first infection, nothing can be done to prevent the appearance of the spots, but the leaves can be protected against the infection by released spores.

Figure 2: When to treat?

Any producer who has a computer with the Windows environment will be able to use this program.

IN BRIEF

To reduce the number of fungicide treatments applied to control Cercospora blight of carrot without reducing yields, it is necessary to:

- Take steps to reduce the wetness period
  - seed at lower density
  - use cultivars with an upright habit whose leaves dry more quickly.
- Select tolerant varieties
- Reduce the inoculum through crop rotation
- Ensure adequate fertilization
- Target the timing of the applications:
  - whenever possible, avoid treating early-maturing varieties
  - protect the leaves just prior to the release of spores, i.e. seven to ten days after a major infection
  - whenever possible, begin treating later in the season
  - if the risks are low, stop the treatments earlier.
- Assess the plant's capacity to resist infection:
  - bear in mind that leaves more than 21 days old and plants more than 60 days are much less susceptible to infection
- Consult the specialists.

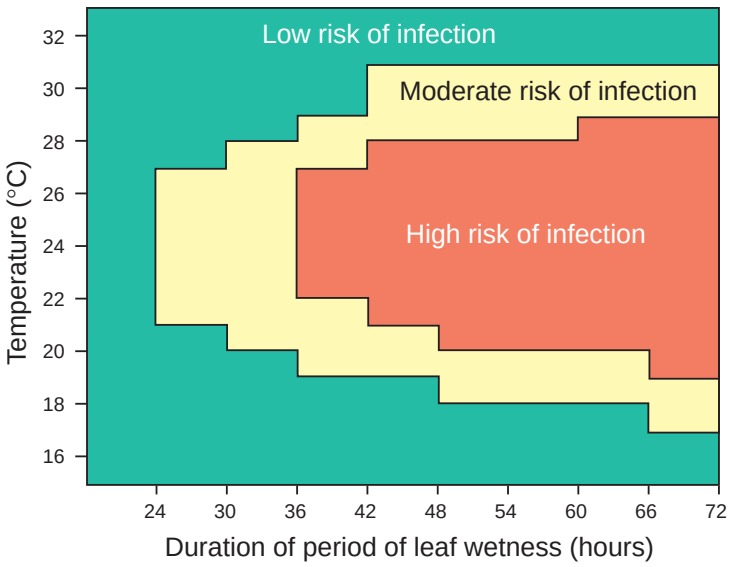


Figure 3: Risk of infection as a function of temperature and duration of the period of leaf wetness.

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