What causes cavity spot and forking in carrots?

Two *Pythium* species are mostly responsible for forking and cavity spot of carrots in Australia. In most cases, *P. sulcatum* cause the symptoms. In an earlier survey, *P. violae*, has only been identified in South Australia. Further studies are in progress to investigate the spread of *P. violae*.

*P. sulcatum*, the main pathogen causing cavity spot of carrots in Australia, (Davison and MacKay 2000), mostly affects the carrot family of plants. It also causes severe root rot diseases of parsley and coriander. *P. violae* is the main cause of cavity spot of carrots in most other countries and has a much wider host range that includes plants from several plant families.

Apart from *P. sulcatum* and *P. violae*, other species of *Pythium* or *Rhizoctonia* pathogenic to carrots, nematodes or any other type of early damage to the root tip can cause forking.

*Pythium* spp. survives as resting spores between susceptible crops.

The primary source of *Pythium* inoculum, causing cavity spot and forking of carrots, are dormant resting spores formed during colonisation of plant tissue. They can survive in the soil for several years.

Cavity spot caused by *P. sulcatum* is most severe in summer and autumn harvested crops. In wet soils this species also produces motile spores (zoospores) which are attracted to roots where they encyst and create infection. Although zoospores only survive for a day or so they can increase the population concentration of this pathogen by over 1000-fold, which greatly increases chances of finding roots to infect. This can lead to multiple infection sites on any one carrot.

*P. violae* does not produce motile spores; it produces spherical swellings which spread with irrigation water. Cavity spot caused by *Pythium violae* is most severe in winter harvested crops.

Factors affecting cavity spot development and management approaches

- **Temperatures** - The prime growth temperatures for *P sulcatum* are: minimum 2 to 3°C, optimum 20 to 28°C, and maximum 36 to 37°C. The optimum temperature for saprophytic growth of *P. sulcatum* (25°C) is higher than that for *P. violae* (19°C).

  Temperatures of 30°C and above are lethal for *P. violae*1. This sensitivity to high temperatures may be a reason for the low number of *P. violae* detections in Australia. The relatively high optimum temperature for *P. sulcatum* may be one reason why it is not a predominant species causing carrot cavity spot in most Northern Hemisphere countries.

- **Soil moisture** – high soil moisture leads to greater incidence and higher severity of *Pythium* infections.

Previous work on a *Pythium* species showed that cyclic wetting and drying reduced the in field population in the absence of host plants\(^2\). Observations by growers confirm that high soil moisture levels support the development of cavity spot. However, the critical crop growth stages, the threshold soil moisture and the period required at that threshold to cause infection with *P. sulcatum* or *P. violae* are still unknown. Recommendations in recent published literature suggest minimising total water inputs at key production times (e.g. < 30 mm/wk for *P. violae* control under UK production conditions). UK research showed that using fungicides early in the season, with at least 15 mm of water applied simultaneously to activate fungal growth, achieved good disease control.

**Varieties, genetic tolerance** – some varieties are more susceptible than others. Variety selection can greatly help in minimising the occurrence of cavity spot. However, market demands and other production considerations have to be taken into account.

**Chemical control – Metalaxyl-M** can reduce the incidence and severity of cavity spot disease when applied at or shortly after seeding. However, if it is used too frequently it can lose its effectiveness because of an increase in its rate of breakdown in the soil\(^3\). Various researchers have demonstrated this effect caused by soil bacteria using the fungicide as a food source. There have been reports where the metalaxyl half-life in sandy soils has been reduced to as little as 1 day. Enhanced breakdown of metalaxyl appears to be a widespread problem; growers should not rely on it for cavity spot control. Overseas work demonstrated that some *Pythium* species have developed resistance to metalaxyl. Metalaxyl leaches from sandy soils.

**Metham sodium** has failed to control cavity spot\(^4\) in trials in WA. Enhanced breakdown with repeated use has been implicated. Still, Metham sodium is used commercially for carrot production to manage the disease.

**Soil pH** - In WA, it has been shown that liming soil to increase pH reduces the incidence and severity of cavity spot\(^5\). The recommended pH range is pH 6.5-7.5 with a target pH of 7.2 or higher (measured in calcium chloride)\(^6\). The positive effect of lime (calcium carbonate) may be due to inducing a soil microflora that is inhibitory to filamentous fungi like *Pythium*. However, this is not confirmed. The application of lime may also be beneficial in the longer term via positive effects on soil structure and thus aeration as well as increased calcium availability to the crop.

**Nutrition** – UK research found that increasing the level of exchangeable calcium above 8 meq/100 g soil decreased the incidence of cavity spot\(^7\). High inputs of available calcium pre-planting (e.g. 15 t/ha of a product called Limex) also decreased cavity spot incidence. In both cases, *P. violae* was the target organism. There does not appear to be any consistent relationship between cavity spot disease severity and other plant nutrients, although Canadian research experience suggests that moderate mineral fertiliser use overall, compared to their industry standard, reduced this disease.

**Rotation** – Views on the positive effect of rotation differ in the international literature. Rotation with broccoli has shown promising results in WA where the primary pathogen was *P. sulcatum*. Other research on this pathogen suggests that rotation with lettuce or onions

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may also be beneficial. However, *P. violae* can attack broccoli\(^8\) and using this as a rotational crop may exacerbate cavity spot if *P. violae* is present. In this case, rotation with onions, corn, potatoes or beans may be more beneficial.

**Cover crops / biofumigation** – Reports on the benefits of cover crops and biofumigants vary. In some instances, good control or reduction of disease incidence were achieved, especially with mustards. In other trials and field experiments by growers, cavity spot incidence or severity were not altered or the disease was worse. It appears that biofumigation or cover crops may not reduce inoculum levels, even in cases where disease expression is reduced. The conclusion is that the effect of cover crops on *P. sulcatum* and *P. violae* is currently not understood well enough to make general or regional recommendations.

**Other** - Crop hygiene, selection of planting date and crop density, tillage approaches that ensure good soil structure and drainage, crop residue management to foster their breakdown, and timely harvest are some cultural practices that reduce the impact of root diseases.

Some integrated crop protection (ICP) strategies that may help reduce the likelihood of infection in combination with other management practices listed above include: application of the products formulated with the beneficial bacterium, *Bacillus subtilis* or other biopesticides\(^9\), Calcium Cyanamide or the use of silicon (which provokes plant defences). To date, reports on the efficacy of integrated approaches vary.

**Conclusions**

While some general rules apply, especially the need for managing soil moisture, pH, soil calcium and crop maturity; carrot producers should find their own optimum combination of additional management strategies that fit their production systems and growing conditions.

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