MANAGING POTATO CYST NEMATODE (PCN)

Potato cyst nematodes (PCN) are undoubtedly one of the world's most significant potato pests. PCN have major impacts on production in many parts of Europe and are in plague populations in some parts of Africa. So far Australia has escaped major impacts from this pest. However, forewarned is most definitely forearmed. Dr Jenny Ekman reports.

Figure 1. Globodera rostochiensis cysts on potato roots. Image: K. Walker

Potatoes are directly impacted by two species of potato cyst nematodes (PCN); the golden (*Globodera rostochiensis*) and the pale (*Globodera pallida*). PCN are particularly hard to manage because of their rapid multiplication and persistence in the soil. Moreover, at less than a millimetre long, PCN are not easy to see in soil or on roots.

Despite potentially devastating consequences on yield, symptoms are frequently subtle; the crop can just look a bit sickly or fail to thrive. With no visible pest or disease, farmers may think there is a problem with the seed, the crop needs more fertiliser, or there is some other issue.

LIFECYCLE OF PCN

The problems start with juvenile nematodes. Juveniles not only suck nutrients, but also cause physical damage to potato plants. They bore through feeder roots, leaving a trail of open wounds and destroyed cells behind them. Such wounds provide easy entry points for bacterial and fungal diseases.

Once within the vascular system the young PCN induce formation of a syncytium. This enlarged feeding structure fuses together hundreds of cells. Protected by a thickened outer wall, this feeds the nematode until it matures.

Once close to maturity, female nematodes burst through the root surface, mate with males, and then die, their body forming a cyst on the plant root. These are about the size of a grain of sand, almost impossible to see with the naked eye on roots, let alone in soil.

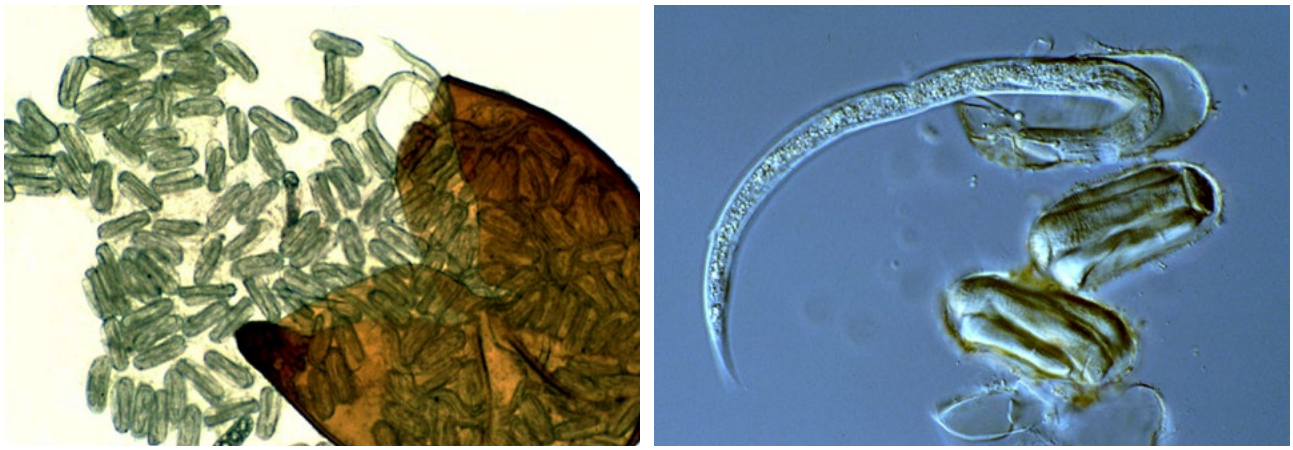


Figure 2. PCN eggs inside a cyst and juvenile PCN emerging from an egg. Images: U. Zunke, University of Hamburg, Bugwood.org

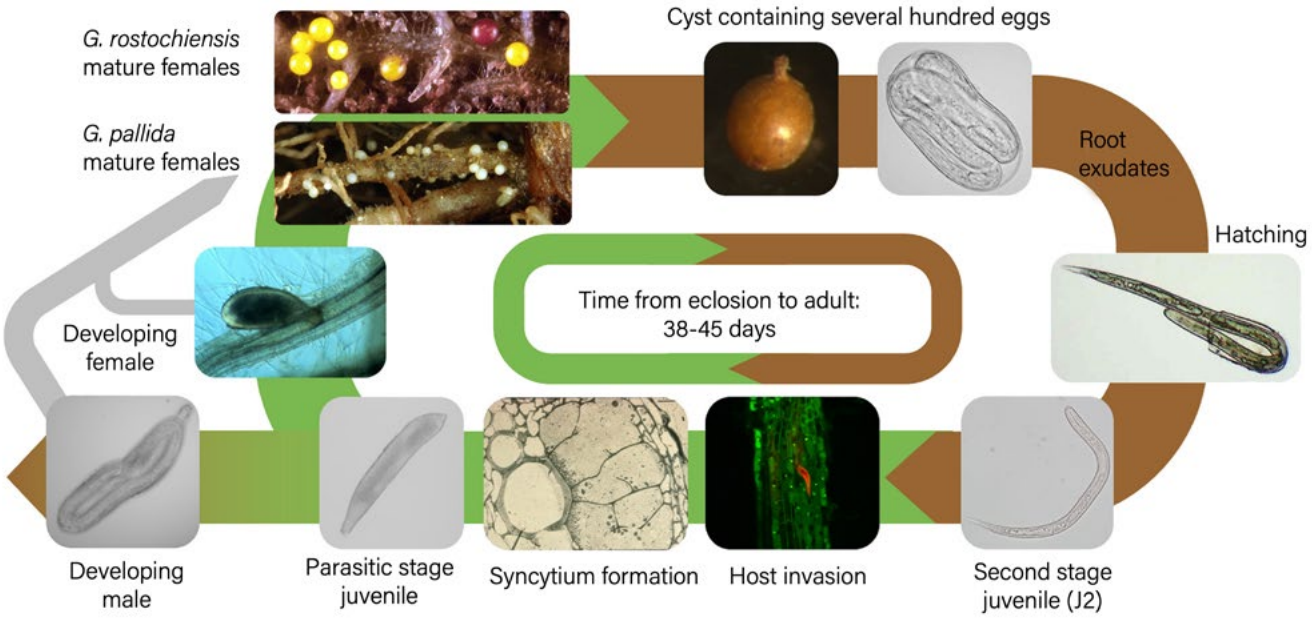


Figure 3. Life cycle of PCN. From Price et al., 2021[2].

The cyst contains up to 500 eggs. When the potatoes are harvested or the plant dies, the cysts are left in the soil. They can potentially remain dormant for at least 10 years and possibly longer, only developing in response to chemicals exuded from the roots of certain Solanaceous plants – including potatoes.

Exposure triggers a change in the outer layer of the cyst, allowing water to permeate and kickstarting metabolic activity. After using their stylet to escape the cyst, young nematodes swim through the soil along a gradient of root chemicals, finding and puncturing a suitable root and starting the cycle again.

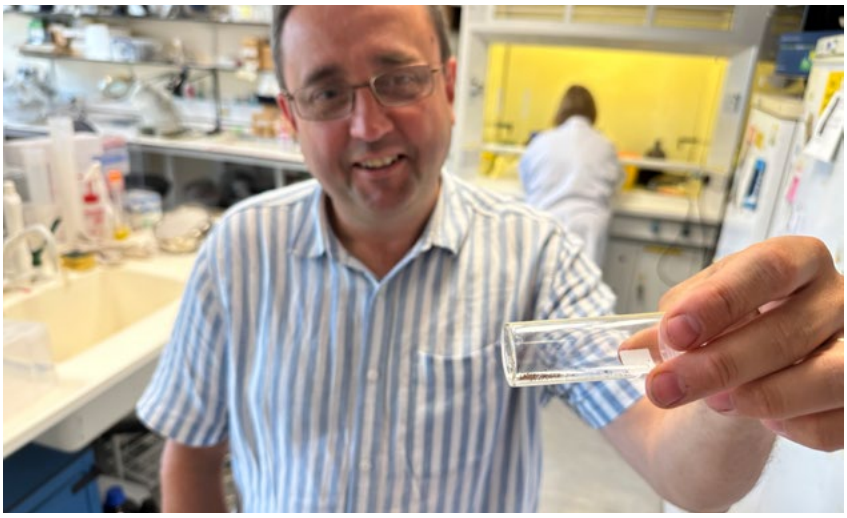
IMPACTS OF PCN

Professor John Jones is now head of the Cell and Molecular Sciences Department at the James Hutton Institute in Dundee. However, his research passion is the genomics and host-parasite interactions of nematodes, particularly PCN. Much of his work has focussed on the factors that stimulate development of dormant cysts in the soil, as well as the proteins produced by PCN that suppress potato plant defence mechanisms.

Understanding these factors will help to develop strategies that control PCN under field conditions. "We have been working a lot in Africa, because they have terrible potato cyst nematode problems there. Kenya, Uganda, Rwanda, and likely other countries as well, have big problems," states Professor Jones.

Figure 4. Professor John Jones has spent more than 25 years researching plant parasitic nematodes, particularly PCN.

Figure 5. Although only the size of a pin head, exposure to potato root exudates can still trigger development and emergence of nematodes 10 years or more after the cysts were formed.



"Potatoes are really important in that part of the world because they are one of the few crops that smallholders grow both as food for themselves and for cash. Unfortunately, they grow multiple crops a year, with no real rotation and no winter break, so nematode populations can explode. In some cases, they may even abandon the land and clear more forest, which is clearly undesirable."

Both golden and pale PCN are found widely in Scotland, as well as parts of Europe. Golden PCN is thought to have been introduced to New York State on the muddy tyres of equipment returning after WW1, while pale PCN is present in part of Idaho as well as Newfoundland, Canada. In all these areas, spread has been contained through survey and certification requirements.

Similarly, Australia's strict quarantine regulations mean that we have prevented spread of this pest. The golden potato cyst nematode has been detected in a few, clearly defined regions of Victoria. These areas are subject to plant quarantine requirements, with permits required to move host materials. Golden PCN has previously been detected in Western Australia but now considered eradicated from that state. Pale PCN has never been detected in Australia and is more often a pest in cooler to temperate climates.

While Australian farmers appear to be managing the problem well, Professor Jones argues that there is no room for complacency. "The time to hit nematodes is when populations are low. If you have a small population but grow a susceptible potato variety you will very soon have an extremely high population. Moreover, while we can control golden PCN well with the H1 ('Hero') gene – which is present in resistant varieties – the problem is that these varieties aren't necessarily the ones consumers want."

MANAGING PCN IN SCOTLAND

One of the key control measures to managing PCN is preventing spread in the first place. This means ensuring that seed potatoes are PCN free. Any detection of PCN not only renders the seed crop unsaleable but takes land out of seed production for many years.

Detections of golden and pale PCN are therefore a major challenge for Scottish seed producers. The pest is projected to cost the local potato industry £125 million by 2024. With virgin land running out, PCN could potentially end the Scottish seed industry within the next 25 years unless new mitigation strategies are found[1].

Recognising the urgency of this issue, the Scottish Government is now funding a major project examining ways to manage PCN. The project aims to improve understanding of how some varieties tolerate PCN, as well as identifying critical genes associated with resistance. Outcomes will include IPM tools for growers, accelerated

1. Toth I. et al. 2022. Year one project report. Delivering a sustainable potato industry for Scotland through management of potato cyst nematode (PCN). http://pcnhub.ac.uk/publications

2. Price JA, Coyne D, Blok VC, Jones JT. 2021. Potato cyst nematodes *Globodera rostochiensis* and *G. pallida*. Molecular Plant Pathology 22:495-507

breeding programmes and better understanding of the costs and benefits of different approaches.

One of the keys is further developing PCN resistance and/or tolerance. While these may appear the same, tolerance and resistance are quite different things.

Dr Phil Burgess, together with field officer Kerry Leslie, is running field trials developing management strategies for PCN. He explains: "Resistant varieties can still be quite badly affected by PCN. However, the juvenile nematodes can't form feeding sites (syncytia) in the roots, preventing them reaching the adult stage. As a result, the population could be reduced from, say, 30-50 eggs/g soil to less than 2 eggs/g soil following a crop of potatoes."

"In contrast, a tolerant variety can still grow and yield well in the presence of low levels of PCN. This may seem a good strategy in the short term, but populations will inevitably increase unless the tolerance is combined with resistance. You could easily end up with 500 eggs/g soil or more the next year. Eventually, even the most tolerant variety will be unable to grow under this pest pressure."

The field trials are being run at Barnyards Farm near Forfar, the property of third-generation potato grower Neill Smith. Neill first realised he might have a PCN problem when yields started to decline despite good growing conditions. He suspects that populations had been building up over time, especially when short 4-year rotations were used in the 1970's.

Both golden and pale PCN are found on the 400 acres (~162ha) Neill uses to grow potatoes, with pale PCN the most common. While there are some varieties (Amanda and Elland) that are highly resistant to pale PCN, they are not well accepted by the market. As a result, he also grows non-resistant varieties in fields with undetectable or low nematode populations.

He also uses the granular nematicide fosthiazate (Nemathorin®) to control

Figure 6. Dr Phil Burgess (left) and grower Neill Smith inspecting a range of PCN resistant varieties at the field trial site

PCN. However, the future of this chemical is uncertain. Another nematicide (Vydate®) has already been withdrawn. In Australia there are no nematicides registered for control of *G. rostochiensis*.

What remains is an IPM approach using a range of control strategies. These include:

- Growing resistant varieties, noting that most varieties are resistant to either golden or pale PCN, with few resistant to both.
- Cover crops, particularly oil seed radish (*Raphanus sativus*). This is sown in spring, topped in early summer, then sprayed off and incorporated before preparation of the ground for potatoes.
- Application of maleic hydrazide to the growing crop. This reduces sprouting, limiting growth of potatoes left in the soil after harvest.
- Planting winter wheat (instead of spring barley) as a rotation, allowing effective control of volunteer potatoes.
- Minimum six year rotations between potato crops.

Even though a cover crop costs him a year of spring barley, Neill is convinced this is worthwhile. "The system gives me good control of free-living nematodes, as well as reducing PCN," comments Neill.

"It's an investment in the future of the farm, as nematodes are a bigger worry than the short-term cost of missing a year's cropping."

Dr Burgess, with project partners, Scottish Agronomy, is trying some other, novel approaches as well. One is the application of chitinous soil amendments. These are made from crustacean shells combined with woodchips. "Our hypothesis is that these will shift the microbial balance in the soil towards organisms that feed on chitin. PCN cysts are chitinous, so this should reduce persistence of eggs in the soil," he explained.

"We are also growing tomatoes, which may seem a surprising choice for Scotland! However, we are not growing them for fruit, but rather for their root exudates, which should trigger emergence of PCN in the soil. PCN can't reproduce on this particular variety of tomatoes, so this should crash the population."

PCN isn't currently a major problem in Australia. However, it just takes one tourist's muddy boots to introduce this significant pest to new areas, or to bring *G. pallida* into the country. Understanding the different varieties, growing techniques and other control strategies means that our industry will be prepared if and when any such incursion occurs.