SOUTHERN
FEBRUARY 2016

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

WHEAT

SECTION 8

NEMATODE CONTROL

ABOUT NEMATODES | VARIETAL RESISTANCE OR TOLERANCE | MANAGEMENT | SYMPTOMS AND DETECTION | NEMATODES AND CROWN ROT | TESTING FOR ROOT-LESION NEMATODES

SECTION 8

Nematode management

Root-lesion nematodes (RLN; *Pratylenchus* spp.) are microscopic, worm-like animals that extract nutrients from plants, causing yield loss. In the southern grains region, the predominant RLN are *P. thornei* and *P. neglectus*.

Intolerant crops such as wheat can lose 20–60% in yield when nematode populations are high. [1] Resistance and susceptibility of crops can differ for each RLN species. A tolerant crop yields well when large populations of RLN are present (the opposite is intolerance). A resistant crop does not allow RLN to reproduce and increase in number (the opposite is susceptibility). [2]

Pratylenchus penetrans and *P. crenatus* have been reported, but at a very low frequency; *P. quasitereoides* (formerly known as *P. teres*) has been identified only in crops in Western Australia and is not known to occur in other regions of Australia. Other species of RLN may occur, and if this is suspected, you should follow up with your state department of agriculture.

Cereal cyst nematode (CCN; *Heterodera avenae*) is a damaging pathogen of broadacre cereal crops in South Australia and Victoria. It affects wheat, barley, oats and triticale, and can cause yield losses of up to 80%. The damage caused by the feeding nematode results in a proliferation of roots at the feeding site, which forms a knot in the root, giving the plant the characteristic symptoms. CCN has been successfully managed by growing resistant cereal varieties.

Two races of stem nematode (*Ditylenchus dipsaci*) have been recorded in South Australia: the oat and the lucerne race. The oat race is found in parts of Yorke Peninsula and the Mid North of South Australia. The main hosts are susceptible varieties of oats and faba beans. Symptoms on oats include stunted plants and the bases of each tiller becoming swollen. Other crops such as field peas, chickpeas, canola and lentils are damaged extensively by stem nematode when they are seedlings (i.e. there is seedling intolerance). Symptoms include stunted and distorted leaves and stems. As crops mature, they become both resistant and tolerant. [3]

8.1 About nematodes

Root-lesion nematodes use a syringe-like ‘stylet’ to extract nutrients from the roots of plants (Figure 1). Plant roots are damaged as RLN feed and reproduce inside plant roots. *Pratylenchus thornei* and *P. neglectus* are the most common RLN species in Australia. Nematodes can be found deep in the soil profile (to 90 cm depth) and are found in a broad range of soil types, from heavy clays to sandy soils. Wheat is susceptible to both *P. thornei and P. neglectus*. [4]

[1] KJ Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes: crop rotations to manage nematodes—key decision points for the latter half of the year, Bellata. GRDC Update Papers, 16 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

[2] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

[3] GRDC (2015) Root-lesion nematodes. Plant Parasitic Nematodes Tips and Tactics, GRDC, February 2015, http://www.grdc.com.au/TT-RootLesionNematodes (Southern Region)

[4] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

CSIRO research funded by the GRDC is examining how nematodes inflict damage by penetrating the outer layer of wheat roots and restricting their ability to transport water.

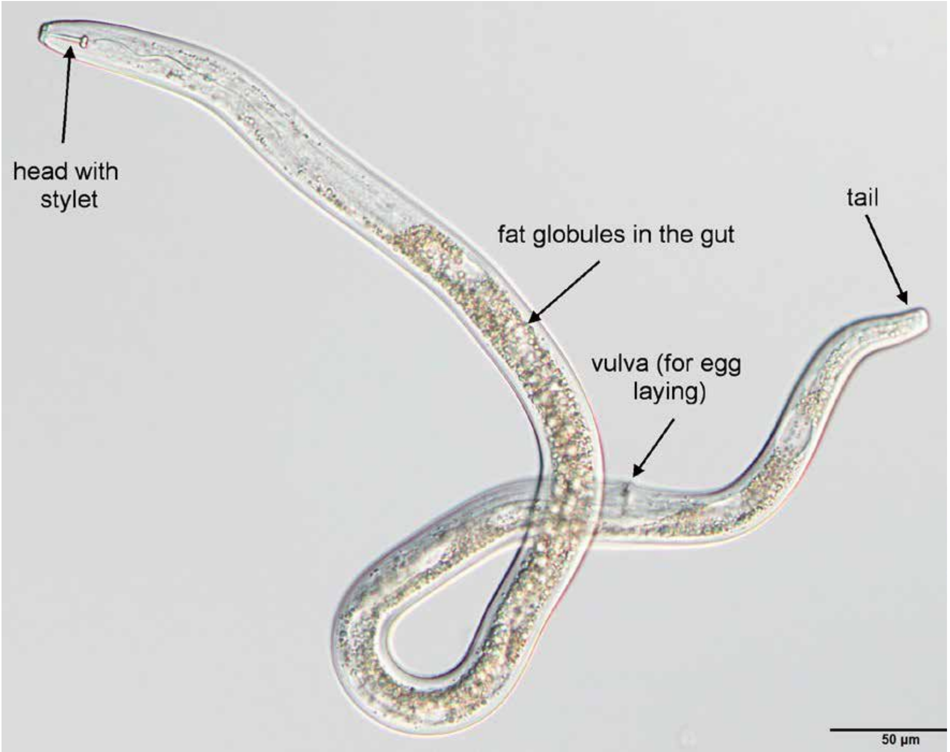

Figure 1: Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.

8.1.1 Life cycle

In the Southern Region, the life cycle of RLN begins after the opening rains in autumn. Juvenile and adult nematodes rehydrate, become active and invade plant roots, where they feed and multiply as they move through the root (Figure 2).

As the nematodes feed and multiply, lesions (sections of brown discoloration) are formed in the cortex of the plant root.

Eggs are laid within the root or soil, and the first larval stage and moult occur within the egg. Second-stage larvae emerge from eggs and undergo three more moults before reaching adulthood.

There may be 3–5 cycles within the plant each growing season, depending on temperature and moisture. The optimum temperature for nematode reproduction is 20°–25°C. The life cycle is generally completed in 40–45 days (~6 weeks) depending on temperature.

As the plants and soil dry out in late spring, RLN enter a dehydrated survival state called anhydrobiosis. In this state, nematodes can survive high soil temperatures of up to 40°C and desiccation over summer. RLN can survive many years in this dehydrated state if the soil remains dry. Nematodes can also survive in root pieces.

More than one RLN species can be found in the roots of an individual crop, although one species usually dominates.

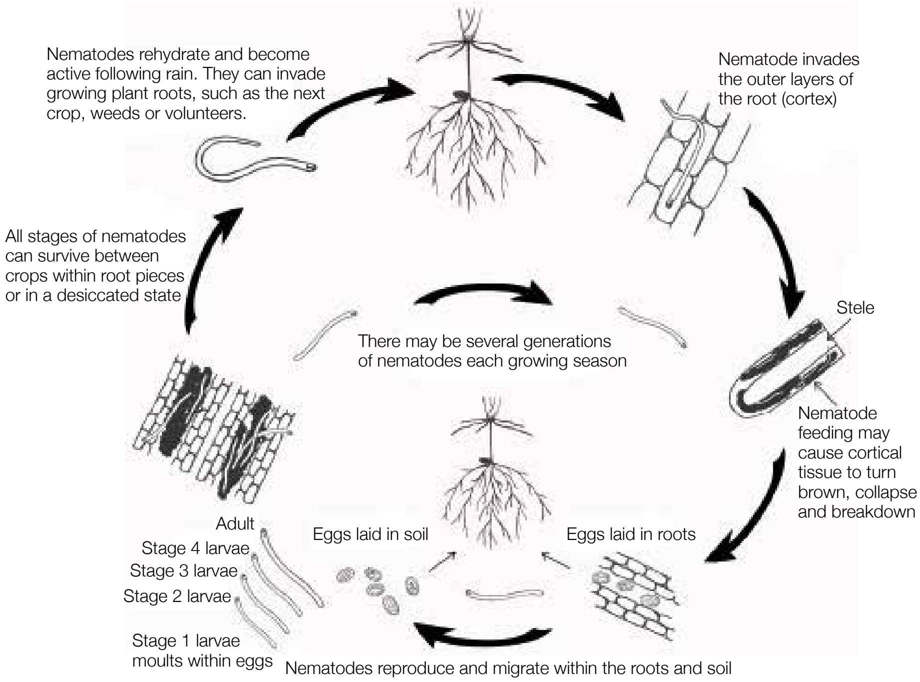

Figure 2: Disease cycle of root-lesion nematode, adapted from: GN Agrios (1997) Plant pathology, 5th edn (Academic Press: New York). (Illustration by Kylie Fowler)

8.1.2 Economic importance

In the Southern Region, high densities of RLN generally cause yield losses of 10–20% in wheat crops. The extent of damage, and subsequent grain yield loss, depend on seasonal conditions, the tolerance of the crop and the numbers of nematodes present at sowing. In field trials carried out by the Victorian and South Australian state departments from 2011 to 2013, *P. thornei* reduced grain yield in intolerant varieties by 2–12%, and *P. neglectus* by 2–8% (Table 1).

Table 1: Grain yield loss (%) caused by root-lesion nematodes in Victoria and South Australia
Values are average percentage yield loss in the five most intolerant wheat varieties

	P. thornei		*P. neglectus*	
	South Australia	Victoria	South Australia	Victoria
2011	7.7	12.2	No trial	4.3
2012	9.0	5.3	8.0	6.6
2013	No trial	2.4	3.8	2.6

8.2 Varietal resistance or tolerance

A tolerant crop yields well when large populations of RLN are present (in contrast to an intolerant crop). A resistant crop does not allow RLN to reproduce and increase in number (in contrast to a susceptible crop) (Tables 2 and 3).

Table 2: The four possible combinations of tolerance and resistance, with examples [5]

Tolerant–resistant e.g. sorghum cv. MR43 to *P. thornei* *and wheat breeding lines released for development*	**Tolerant–susceptible** e.g. wheat cv. EGA Gregory to *P. thornei*
Intolerant–resistant *No commercial wheat lines in this category*	**Intolerant–susceptible** e.g. wheat cv. Strzelecki to *P. thornei*

[5] K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes: crop rotations to manage nematodes – key decision points for the latter half of the year, Bellata. GRDC Grains Research Update, July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

Table 3: Susceptibility and resistance of various crops to root-lesion nematodes [6]

RLN species	Susceptible	Intermediate	Resistant
P. thornei	Wheat, chickpeas, faba beans, barley, mungbeans, navy beans, soybeans, cowpeas	Canola, mustard, triticale, durum wheat, maize, sunflowers	Canary seed, lablab, linseed, oats, sorghum, millet, cotton, pigeon peas
P. neglectus	Wheat, canola, chickpeas, mustard, sorghum (grain), sorghum (forage)	Barley, oat, canary seed, durum wheat, maize, navy beans	Linseed, field peas, faba beans, triticale, mungbeans, soybeans

Wheat breeding has provided a number of varieties with moderate or higher levels of tolerance to *P. thornei*, e.g. Sunvale⚘, Baxter⚘, EGA Wylie⚘ and EGA Gregory⚘. These varieties will reduce the level of yield loss due to *P. thornei*.

Crop varieties are rated for resistance and tolerance to RLN and results published each year at National Variety Trials Online. The mechanisms of resistance and tolerance are different and need to be treated as such.

Eradication of RLN from an individual paddock is highly unlikely, so effective long-term management is based on choosing options that limit RLN multiplication. This involves employing crop or varieties that have useful levels of *P. thornei* resistance and avoiding varieties that will cause large 'blow-outs' in *P. thornei* numbers.

8.3 Management

There are four key strategies for the management of RLN (Figure 3):

1. Test soil for nematodes in a laboratory.
2. Protect paddocks that are free of nematodes by controlling soil and water run-off and cleaning machinery; plant nematode-free paddocks first.
3. Choose tolerant wheat varieties to maximise yields (National Variety Trials Online). Tolerant varieties grow and yield well when RLN are present.
4. Rotate with resistant crops to prevent increases in RLN (Table 3, Figure 3). When large populations of RLN are detected, you may need to grow at least two resistant crops consecutively to decrease populations. In addition, ensure that fertiliser is applied at the recommended rate so that the yield potential of tolerant varieties is achieved. [7]

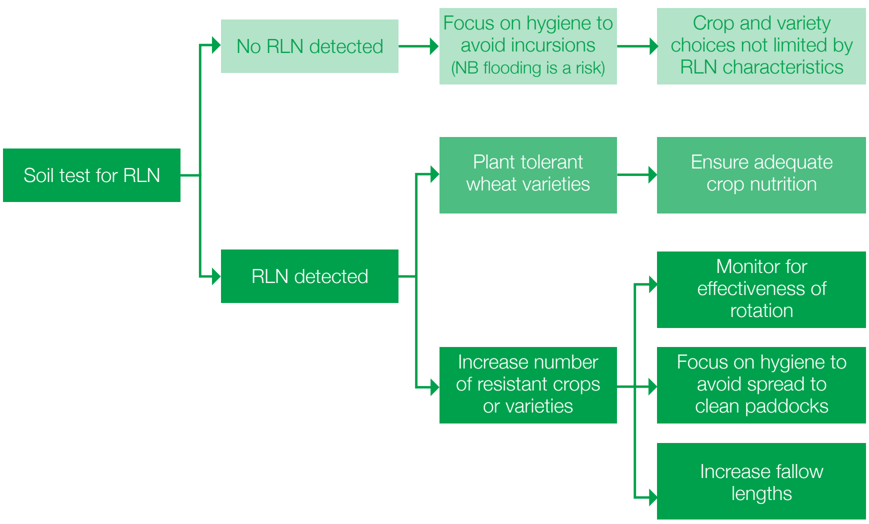

Figure 3: Root-lesion nematode management flow-chart.

[6] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

[7] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

Nematodes reduce yields in intolerant wheat cultivars and reduce the amount of water available for plant growth. They also impose early stress, which reduces yield potential despite the availability of water and nutrients.

In the Southern Region, *P. thornei* at 10 nematodes/g soil can cause grain yield losses of 10–15% in the intolerant wheat variety Derrimut, depending on seasonal conditions.

8.3.1 Crop rotation

The primary method of managing RLN populations is to focus on increasing the number of resistant crops in the rotation. Knowledge of the species of RLN present is critical, because crops that are resistant to *P. thornei* may be susceptible to *P. neglectus*. Key crops that are generally considered resistant or moderately resistant to *P. thornei* are sorghum, sunflower, maize, canola, canary seed, cotton, field peas and linseed.

Wheat, chickpeas, faba beans, mungbeans and soybeans are generally susceptible, although the level of susceptibility may vary between varieties.

8.3.2 Resistance differences between commercial wheat varieties

Resistance ratings for wheat varieties to RLN have been available for many years; however, the development of high-throughput DNA analysis has enabled an increased amount of testing to compare RLN build-up between varieties under field conditions. These data appear to be a very useful addition to our current knowledge on varietal resistance, with relative variety performance fairly consistent across sites. Figure 4 shows the relative performance of a range of varieties as a percentage of EGA Gregory ⒫ in a wide range of trials during 2009–2012.

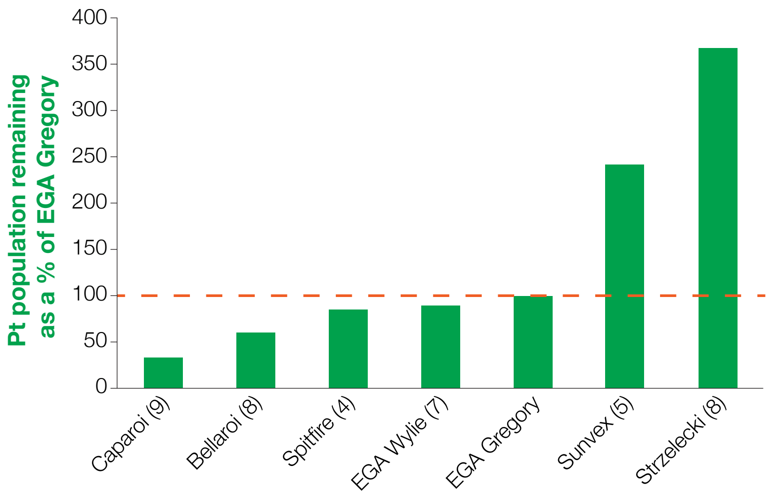

Figure 4: Comparison of P. thornei (Pt) population remaining as a percentage of EGA Gregory⒫, 2009–12. Values in parentheses are the number of trials in which the variety was compared with EGA Gregory⒫. The red broken line indicates the Pt level remaining after EGA Gregory⒫.

Bread wheats are generally susceptible to *P. thornei* but there are large differences between varieties in the level of susceptibility. Growers with *P. thornei* infestations must avoid 'sucker' varieties that result in very high levels of *P. thornei* multiplication. Although durum wheats generally restrict *P. thornei* multiplication compared with bread wheats, they are very susceptible to crown rot. [8]

Canola is now thought to have a 'biofumigation' potential to control nematodes, and a field experiment has compared canola with other winter crops or clean-fallow for

[8] R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Papers, 16 July 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

reducing *P. thornei* population densities and improving growth of *P. thornei*-intolerant wheat (cv. Batavia) in the following year.

Immediately after harvest of the first-year crops, populations of *P. thornei* were lowest following various canola cultivars or clean fallow and highest following susceptible wheat cultivars (1957–5200 *v.* 31,033–41,294 *P. thornei*/kg dry soil). Unexpectedly, at planting of the second-year wheat crop, nematode populations were at more uniform, lower levels (<5000/kg dry soil), regardless of the previous season's treatment, and remained that way during the growing season, which was quite dry.

Growth and grain yield of the second-year wheat crop were poorest on plots previously planted with canola or left fallow because of poor colonisation with arbuscular mycorrhizal (AM) fungi, with the exception of canola cv. Karoo, which had high AM fungal colonisation and low wheat yields. There were significant regressions between growth and yield parameters of the second-year wheat and levels of AM fungi following the pre-crop treatments.

Canola appears to be a good crop for reducing *P. thornei* populations, but the dependence of subsequent crops on AM fungi should be considered.

8.4 Symptoms and detection

Root-lesion nematodes are microscopic and cannot be seen with the naked eye in the soil or in plants. The most reliable way to confirm the presence of RLN is to have soil tested in a laboratory. Fee-for-service testing of soil offered by the PreDicta B root-disease testing service of the South Australian Research and Development Institute (SARDI) can determine levels of *P. thornei* and *P. neglectus* present. [9]

Similar results can be obtained by testing soil, either by manual counting (under microscopes) or by DNA analysis (PreDicta B), with commercial sampling generally at depths of 0–15 or 0–30 cm. [10]

Vertical distribution of *P. thornei* in soil is variable. Some paddocks have relatively uniform populations down to 30 cm or even 60 cm. Some will have highest *P. thornei* counts at 0–15 cm depth, whereas other paddocks will have *P. thornei* populations increasing at greater depths, e.g. 30–60 cm. Although detailed knowledge of the distribution may be helpful, the majority of on-farm management decisions will be based on the presence or absence of *P. thornei* confirmed by sampling at 0–15 or 0–30 cm depth.

Signs of nematode infection in roots include dark lesions or poor root structure. The damaged roots are inefficient at taking up water and nutrients—particularly nitrogen (N), phosphorus (P) and zinc (Zn)—causing symptoms of nutrient deficiency and wilting in the plant shoots. Intolerant wheat varieties may appear stunted, with yellowing of lower leaves and poor tillering (Figure 5). These symptoms may not be present in other susceptible crops such as barley and chickpeas. [11]

[9] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

[10] R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16 July 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

[11] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

Figure 5: Aboveground symptoms of root-lesion nematode are often indistinct and difficult to identify. Affected plants (centre) generally show poor vigour and are often stunted, and cereals tiller poorly.

8.4.1 What is seen in the paddock?

Although symptoms of RLN damage in wheat can be dramatic, they can easily be confused with nutritional deficiencies and/or moisture stress.

Damage from RLN is in the form of brown root lesions, but these can be difficult to see or can be caused by other organisms. Root systems are often compromised, with reduced branching, reduced quantities of root hairs and an inability to penetrate deeply into the soil profile. The RLN create an inefficient root system, which reduces the ability of the plant to access nutrition and soil water.

Visual aboveground damage from RLN is non-specific. Yellowing of lower leaves is often observed, together with reduced tillering and a reduction in crop biomass. Symptoms are more likely to be observed later in the season, particularly when the crop is reliant on moisture stored in the subsoil.

In the early stages of RLN infection, localised patches of poorly performing wheat may be observed. Soil testing of these patches may help to confirm or eliminate RLN as a possible issue. In paddocks where previous wheat production has been more uniform, a random soil-coring approach may be more suitable. Another useful indicator of RLN presence is low yield performance of RLN-intolerant wheat varieties.[12]

8.4.2 Belowground symptoms

Because aboveground symptoms of RLN damage are almost indistinguishable from other root diseases or nutrient constraints, it is necessary to examine plant roots for symptoms.

To inspect the root systems for diseases, they should be dug from the ground using a shovel, not pulled from the ground. Pulling from the ground leaves most of the diseased roots behind. The roots must be carefully washed to remove the soil. Roots can then be inspected for disease by floating them in a white tray containing water, and looking for symptoms of nematode damage.

In cereals, primary and secondary roots will show a general browning and discoloration. There will be fewer, shorter laterals branching from the main roots and a lack of root hairs (Figure 6). The root cortex (or outer root layer) will be damaged and it may disintegrate.

12 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16 July 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

Visual diagnosis is difficult and can be confirmed only with laboratory testing or by using a PreDicta B soil test.

Figure 6: Symptoms of root-lesion nematode on wheat roots include darkening of the cortex and lack of root hairs.

8.5 Nematodes and crown rot

The GRDC-funded Northern Grower Alliance has been involved in 22 field trials since 2007, in collaboration NSW Department of Primary Industries, evaluating the impact of crown rot on a range of winter-cereal crop types and varieties. This work has greatly improved the understanding of the impact of crown rot and variety tolerance, but also indicates that we may be suffering significant yield losses from another 'disease' that often goes unnoticed.

Although the trials were not designed to focus on nematodes, a convincing trend was apparent after 2008 indicating that *P. thornei* was having a frequent and large impact on wheat variety yield.

These trials were designed to evaluate the effect of crown rot on variety yield and quality. However, they strongly indicate that *P. thornei* is also having a significant impact on yield performance. The results do not compare the levels of yield loss from the two diseases but do indicate a greater range in variety of *P. thornei* tolerance than currently exists for crown rot tolerance. [13]

8.6 Testing for root-lesion nematodes

Growers are advised to check the roots of the host crops if they suspect RLN infestations. Carefully dig up roots, then wash the soil from the roots of an infected plant

13 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16 July 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

and inspect for symptoms (as above). If evidence of infestation in the roots is observed, then a laboratory analysis or a PreDicta B test can be used to determine species and density.

A DNA test, PreDicta B, is commercially available around Australia and growers should contact their state department of agriculture for advice. Grain producers can access PreDicta B via agronomists accredited by SARDI to interpret the results and provide advice on management options to reduce the risk of yield loss.

PreDicta B samples are processed weekly from February to mid May (prior to crops being sown) to assist with planning the cropping program.

Crop diagnosis is best achieved by sending samples of affected plants to your local plant pathology laboratory.

Postal Address for PreDicta B samples: C/- SARDI RDTS, Locked Bag 100 Glen Osmond, SA 5064.

Courier address: SARDI Molecular Diagnostics Group Plant Research Centre, Gate 2B Hartley Grove, Urrbrae, SA 5064.