Growing resistant crops and tolerant wheat varieties is the key for management of root-lesion nematodes (RLN).

**KEY POINTS**

- Test soil to monitor population changes in rotations and to determine RLN species and population density.
- Avoid consecutive susceptible crops in rotations to limit the build-up of RLN populations.
- RLN can multiply in cereal and legume crops and each nematode species can build up on different crops.
- Choose wheat varieties with tolerance to maximise yields when RLN are present.
- Choose rotation crops with high resistance ratings, so that fewer nematodes remain in the soil to infect subsequent crops.
- Two or more consecutive resistant crops may be needed to reduce damaging populations.

---

**About root-lesion nematodes**

Root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) are worm-like organisms, less than 1 mm in length, which feed inside plant roots. RLN use their head and a syringe-like stylet in their mouthpart to break open cell walls and feed on the contents of root cells (Figure 1).

Root-lesion nematodes can complete several generations during growth in a susceptible crop. RLN develop from an egg and pass through four juvenile stages to become an egg-laying female. The females are self-fertile and males are rarely found of *P. thornei* and *P. neglectus*. Under ideal conditions, the life cycle takes about 6 weeks for *P. thornei*, depending on the temperature. Populations of RLN increase with each generation; therefore, more plant roots are damaged, which in turns restricts the uptake of water and nutrients from the soil (see Figure 2).

**Natural enemies of root-lesion nematodes**

Biological suppression is a potential method of reducing populations of *P. thornei* and *P. neglectus*. Recent research has identified that northern grain-growing soils are capable of suppressing root-lesion nematodes, especially in the top layer (0-15 cm) of soil, and this capacity can be enhanced by increasing the biological activity of that soil, mainly through carbon inputs and minimising soil disturbance. Several key organisms that prey on nematodes have been found in northern soils, such as *Pasteuria* bacteria that infect and eventually kill *Pratylenchus* spp. Several species of fungi including some that trap nematodes and predatory nematodes have also been found, all of which have potential to reduce root-lesion nematode populations.

Research is continuing to develop methods of increasing biological activity to enhance suppressiveness deeper in the profile.
Intensive cropping of susceptible crops—particularly wheat—will lead to an increase in RLN levels in the soil, meaning that crop rotation is the key to reducing RLN and the damage caused by this pest. Studies have shown that the extent of yield loss caused by *P. thornei* and *P. neglectus* is related to the populations present at planting. In the northern grain region, *P. thornei* at two nematodes per gram of soil anywhere in the soil profile is considered a damaging population, causing yield loss of up to 70% in wheat and 20% in chickpeas.

In the northern grain region, RLN are found throughout northern New South Wales and Queensland. *Pratylenchus thornei* is more widespread and generally occurs in higher populations than *P. neglectus* (see Figure 3). Results from 600 samples tested in 2010–13 showed that 50% of paddocks had populations above 2 nematodes/g soil. A recent survey in Central Queensland found that 28% of paddocks had RLN, with 26% of those paddocks containing *P. thornei*. Populations were generally low, but in the Dawson–Callide region of Central Queensland, 5% of samples had populations above 2 nematodes/g soil.

At planting, damaging populations of RLN can be found deep in the soil. In some soils, peak numbers are as deep as 60 cm. This happens because the hot, dry conditions of the surface soil can cause nematode death, and RLN can migrate down the soil profile where cooler, moist conditions favour survival. Therefore, be aware that RLN populations in surface soil may not give a full picture of the population density at depth threatening crops, particularly after a long fallow. However, if RLN are detected in the surface soil, start actively managing for RLN.

![Disease cycle of root-lesion nematode](image)


<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. thornei</em></td>
<td>44%</td>
</tr>
<tr>
<td><em>P. neglectus</em></td>
<td>5%</td>
</tr>
<tr>
<td><em>P. thornei</em> and <em>P. neglectus</em></td>
<td>28%</td>
</tr>
<tr>
<td>No <em>Pratylenchus</em></td>
<td>23%</td>
</tr>
</tbody>
</table>

Figure 3. Occurrence of *Pratylenchus thornei* and *P. neglectus* from 2010 to 2013 in the northern grain region (604 paddocks); 50% of samples had root-lesion nematode populations above the wheat damage threshold of 2,000 nematodes/kg soil (or 2/g soil).
### Table 1: Comparison of the risk of build-up of *Pratylenchus thornei* and *P. neglectus* for crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th><em>P. thornei</em></th>
<th><em>P. neglectus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cereals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>Medium to high</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Canary seed</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Maize</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Millet</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Oats</td>
<td>Low</td>
<td>NT</td>
</tr>
<tr>
<td>Sorghum (grain)</td>
<td>Low</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Triticale</td>
<td>Medium to high</td>
<td>Low</td>
</tr>
<tr>
<td>Wheat</td>
<td>Low, medium to high</td>
<td>Low, medium to high</td>
</tr>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blackgram</td>
<td>High</td>
<td>Medium (p)</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>Medium to high</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>High</td>
<td>NT</td>
</tr>
<tr>
<td>Faba beans</td>
<td>Medium to high</td>
<td>Low</td>
</tr>
<tr>
<td>Field peas</td>
<td>Low to medium</td>
<td>NT</td>
</tr>
<tr>
<td>Navy beans</td>
<td>High</td>
<td>NT</td>
</tr>
<tr>
<td>Pigeon peas</td>
<td>Low</td>
<td>NT</td>
</tr>
<tr>
<td><strong>Oilseeds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola, mustard</td>
<td>Low to medium</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Cotton</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Linseed</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Soybeans</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Pastures, forage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brassica (forage)</td>
<td>Low to medium (p)</td>
<td>NT</td>
</tr>
<tr>
<td>Lablab</td>
<td>Low</td>
<td>NT</td>
</tr>
<tr>
<td>Sorghum (forage)</td>
<td>Low</td>
<td>Medium to high</td>
</tr>
</tbody>
</table>

Within some crops there is variation in the susceptibility and resistance of varieties, and this is indicated where a range of risk ratings is shown. New varieties or hybrids may differ in their risk ratings from the overall rating for a crop species. NT, Not tested; p, provisional rating.

### The symptoms

Testing soil is the only reliable way to determine whether RLN are present in a paddock.

Aboveground symptoms of RLN attack in wheat can include:
- stunting
- yellowing of lower leaves
- poor tillering and reduced biomass
- wilting, particularly when the season turns dry

If crown rot is also present, then RLN attack can increase the expression of whiteheads.

Many susceptible crops, other than wheat, do not show aboveground symptoms of RLN attack.

When roots are damaged by RLN, the plants become less efficient at taking up water and nutrients, and less able to tolerate stresses such as drought or nutrient deficiencies. RLN infection of intolerant wheat varieties restricts water and nutrient uptake early in the season, which limits aboveground plant development and yield potential. The impact of reduced root function is particularly noticeable around September–October in the northern grain region as the crop draws on subsoil moisture and nematode populations increase with the rising soil temperatures.

An examination of washed plant roots may provide some information, but symptoms can be difficult to see and roots are difficult to remove from heavy clay soils. Chickpea roots can show distinct dark-brown–orange lesions at very early stages of infection, and the lateral roots can be severely stunted and reduced in number. The root cortex (or outer root layer) is damaged and it may disintegrate.

### Management of RLN

#### Soil testing

The first step in management of RLN is to have soil tested to determine whether RLN are present in paddocks. If RLN are detected, the soil test will tell you which of the species is present and the population level in the field (see Figure 4).

If RLN are not detected, protect those paddocks from contamination by controlling movement of soil and water on the farm. Clean soil from machinery before planting or fertilising, and plant RLN-free paddocks first. Consider re-testing in 5 years, particularly if there has been flooding, because RLN can move in floodwaters and in soil.

When RLN are detected, rotations and variety choice are central to successfully reducing RLN populations. Only non-host crops or resistant varieties will minimise the build-up of RLN (see Table 1 and the Case Study). Tolerant crops will suffer less damage, but if these varieties are susceptible, RLN numbers can still increase. Aim to reduce populations to less than 2/g soil.

When very high populations of RLN are detected, it may take two or more resistant crops grown consecutively in rotation to reduce populations. Re-testing of soil after growing resistant crops is recommended, so that crop sequences can be adjusted if populations are still at damaging levels. Avoid very susceptible crops and varieties.
Resistant and tolerant varieties

Tolerant wheat varieties yield well when RLN are present, but tolerant varieties can be susceptible (numbers of RLN increase). See NVT Online for ratings of the tolerance and resistance of wheat varieties to P. thornei and P. neglectus. Grow varieties with the highest level of tolerance and resistance and avoid very susceptible varieties.

Among chickpea cultivars, PBA HatTrick\(^1\) and Boundary\(^2\) are more resistant than others and they present a medium risk for the build-up of P. thornei (see Figure 5). Other crops such as mungbeans and soybeans show differences in susceptibility to P. thornei between varieties (see Figure 6, Case Study). For sorghum, sunflowers and maize, no differences were detected among varieties with respect to P. thornei populations in a recent field experiment (Figure 6).

For P. thornei, resistant or partially resistant crops such as sorghum (grain and forage), cotton, millet, panicum, sunflowers, maize, lablab, pigeon peas, canola, canary seed and linseed can be grown in rotations to limit populations. For P. neglectus, resistant or partially resistant crops such as cotton, sunflowers, maize, mungbeans, soybeans, cowpeas, lablab, triticale and linseed, and faba beans can be grown.

Fertilisers

Ensure that adequate fertiliser is applied (especially nitrogen, phosphorus and zinc) so that tolerant varieties can reach their yield potential; high fertiliser rates do not lead to lower nematode reproduction.

Nematicides

No nematicides or seed dressings are registered for use on broadacre crops in Australia. Experiments with nematicides have shown that they provide poor control of RLN populations deep in the soil profile.

PreDicta B soil testing

Before planting soil tests can be carried out by PreDicta B\(^{TM}\) (SARDI Diagnostic Services) through accredited agronomists to establish whether crops are at risk and whether alternative crop types or varieties should be grown. Growing-season tests can be carried out on affected plants and associated soil; contact local state departments of agriculture and PreDicta B.
Case Study
Impact of summer crops or a weed-free fallow on the yield of the next wheat crop and on *Pratylenchus thornei* populations in Queensland

The experiments were set up at a *P. thornei*-infested site, in adjacent fields with differing cropping histories: (i) a low *P. thornei* site with a cropping history of five successive, resistant crops (cotton, sunflowers and maize) where *P. thornei* populations were 0.15 nematodes/g soil at 0–90 cm soil depth; and (ii) a damaging *P. thornei* site with a cropping history of only one resistant sorghum crop (wheat, sorghum, wheat) where *P. thornei* populations were 2.5/g soil at 0–90 cm soil depth.

A weed-free fallow and several varieties each of sorghum, maize, sunflowers, mungbeans and soybeans were planted; then after a 13-month fallow, tolerant and intolerant wheat varieties were planted.

**Low *P. thornei* site.** This experiment showed no differences in *P. thornei* populations after growing the summer crops. Populations remained very low 0.25 nematodes/g soil at 0–90 cm soil depth. The following tolerant wheat (cv. EGA Wylie) yielded 3.7 t/ha and the intolerant wheat (cv. Strzelecki) 3.6 t/ha (see Figure 7).

**Damaging *P. thornei* site.** Populations increased after growing most soybean and mungbean varieties. Mungbean cv. Emerald and soybean cv. Soya791 were moderately resistant compared with the other varieties. After growing sorghum, maize and sunflowers, populations of *P. thornei* were similar to those in the fallow and there were no significant differences between hybrids (see Figure 6). The following tolerant wheat (cv. EGA Wylie) yielded 3.7 t/ha and the intolerant wheat (cv. Strzelecki) 1.9 t/ha (see Figure 7).

At the low *Pt* site after summer crops, the yields of tolerant and intolerant wheat were similar and reached the yield potential for that site.

At the damaging *Pt* site, the intolerant wheat yielded 50% less than the tolerant wheat; the yield of the tolerant wheat was the same as at the low *Pt* site.
**Conclusion.** Crop rotation works exceptionally well to manage root-lesion nematodes. Achieving low populations requires multiple resistant crops when damaging populations are detected (Figure 8).

![Image of crops](image_url)

**Figure 8.** Top: wheat cv. Strzelecki after soybean and following five resistant crops; yield = 3.4 t/ha; 0.35 Pt/g soil P. thornei/kg soil at planting. Bottom: wheat cv. Strzelecki after soybean and following one resistant crop; yield = 1.6 t/ha; 12 Pt/g soil P. thornei/kg soil at planting.

**Take-home messages**

- Maintaining low *P. thornei* populations and growing a tolerant wheat variety was the key to successful management.
- Tolerant wheat cv. EGA Wylie produced high yields when *P. thornei* was present at up to 20 nematodes/g soil.
- The yield of intolerant wheat cv. Strzelecki was reduced by 50% when *P. thornei* was present at damaging levels BUT it delivered high yields when *P. thornei* was at very low levels (0.25 n/g soil).
- Sorghum, sunflowers and maize are resistant to *P. thornei* and will restrict increases in populations BUT damaging populations require more than one resistant crop to reduce levels.
- Soybeans and mungbeans are susceptible to *P. thornei* and should not be grown when there are high populations of *P. thornei*. 
**Frequently asked questions**

**Q. Can we breed wheat and chickpea with resistance to RLN?**

Combining tolerance and resistance into wheat is a goal of northern grain region researchers. Valuable sources of resistance have been identified in landrace varieties, which are varieties that have been grown by Middle Eastern farmers for millennia, from wild relatives of wheat and from synthetic hexaploid wheat. Several lines with combined resistance to *P. thornei* and *P. neglectus* and greater levels of tolerance than current commercial lines have been provided to breeding companies. Wild relatives of chickpeas that are found in Turkey are also valuable sources of resistance to *P. thornei* and *P. neglectus*.

**Q. What other plant-parasitic nematode species are found in the northern grain region?**

The stunt nematode (*Merlinius brevidens*) is found widely on northern grain region grain farms. In a survey of ~800 farms, it was found in 73% of paddocks. This nematode prefers similar soil conditions to *P. thornei* (alkaline soils with high clay content) and in 60% of paddocks it was found in soils that also contained *P. thornei* and/or *P. neglectus*. The stunt nematode grazes on the surface of plant roots which causes restricted damage to the surface cells, consequently it is regarded as less destructive than root-lesion nematode that cause extensive damage as they feed and migrate within the plant roots. Occasionally, very large populations of the stunt nematode are found in Northern Grain Region farms and although wheat yield loss has not been associated with this nematode, there is a suggestion that symptoms of infection by *P. thornei* were greater when the stunt nematode was also present. In lighter textured soils, the stubby-root nematode (*Paratrichodorus* sp.) and root-knot nematode (*Meloidogyne* sp.) have been found on cereals and grain legumes. Other RLN occurring away from traditional wheat areas are *Pratylenchus zeae* on maize and sugarcane and *Pratylenchus brachyurus* on peanuts. There have been isolated reports of cereal cyst nematode (*Heterodera avenae*) near Tamworth and Dubbo on lighter textured soils and friable black soils. If growers suspect CCN, they should contact a local agronomist. The reniform nematode (*Rotylenchulus reniformis*) has recently been detected in damaging populations on cotton in the Dawson and Callide Valleys in Central Queensland.

**Q. Does timing of sowing help?**

Planting wheat—within the window for each variety—so that roots develop in cooler soil (<15°C) can give the wheat a competitive advantage over RLN and reduce yield loss. *Pratylenchus thornei* has an optimum temperature for reproduction of 20°–25°C. Note that planting too early risks damage to heads from frosting later in the season.

Rotation remains a key strategy for managing nematodes.

Wild relatives of chickpeas found in Turkey are also valuable sources of resistance to *P. thornei* and *P. neglectus.*

Root development in cooler soil can give wheat a competitive advantage over RLN.
For more information on the interactions between specific crops and RLN, see the GRDC GrowNotes at www.grdc.com.au/GrowNotes.

Useful Resources

- Researchers:
  - Kirsty Owen, University of Southern Queensland, ph. 07 4639 888, email Kirsty.Owen@usq.qld.gov.au
  - Richard Daniel, Northern Grower Alliance, ph. 07 46 395 344, email Richard.daniel@nga.org.au
  - Steven Simpendorfer, NSW DPI, ph. 0439 581672, email steven.simpendorfer@dpi.nsw.gov.au
  - Nikki Seymour, Queensland Department of Agriculture, Fisheries and Forestry, ph. 07 4639 8837, email nikki.seymour@daff.qld.gov.au
  - Tim Clewett, ph. 0746398846, timothy.clewett@usq.edu.au

- National Variety Test (NVT) website (nvtonline.com.au). Wheat Variety Guides for Queensland and NSW can be downloaded from the NVT site.

- PreDicta B™: a DNA-based soil analysis service delivered by accredited agronomists. PreDicta B can detect *P. neglectus*, *P. thornei* and CCN. Contact your local agronomist, or to locate your nearest supplier, email your contact details and location to: predictab@saugov.sa.gov.au.

- Growing-season tests can be carried out on affected plants and associated soil through state departments and PreDicta B™ through accredited agronomists.

DISCLAIMER

Any recommendations, suggestions or opinions contained in this publication do not necessarily represent the policy or views of the Grains Research and Development Corporation. No person should act on the basis of the contents of this publication without first obtaining specific, independent, professional advice. The Corporation and contributors to this Fact Sheet may identify products by proprietary or trade names to help readers identify particular types of products. We do not endorse or recommend the products of any manufacturer referred to. Other products may perform as well as or better than those specifically referred to. The GRDC will not be liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information in this publication.

CAUTION: RESEARCH ON UNREGISTERED AGRICULTURAL CHEMICAL USE

Any research with unregistered agricultural chemicals or of unregistered products reported in this document does not constitute a recommendation for that particular use by the authors or the authors; organisations. All agricultural chemical applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Copyright © All material published in this Fact Sheet is copyright protected and may not be reproduced in any form without written permission from the GRDC.