NORTHERN
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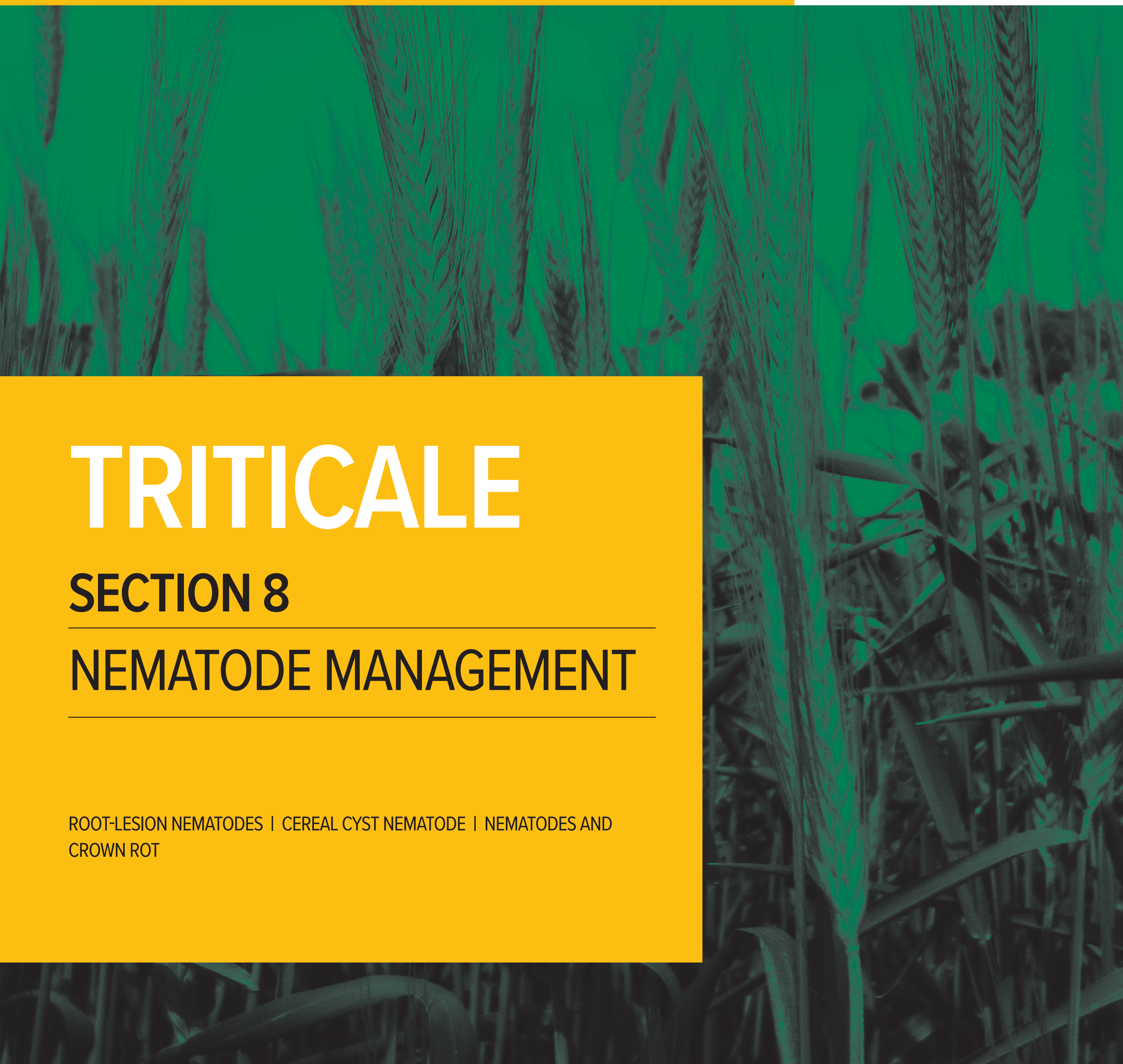


TRITICALE

SECTION 8

NEMATODE MANAGEMENT

ROOT-LESION NEMATODES | CEREAL CYST NEMATODE | NEMATODES AND CROWN ROT

Nematode management

Key messages

- Some varieties of triticale can reduce soil nematodes such as *Pratylenchus neglectus* and *P. thornei* (root-lesion nematodes) and *Heterodera avenae* (cereal cyst nematode). [1]
- Some varieties of Triticale have some resistant to *P. neglectus,* and *P. thornei*.
- Some varieties of triticale are thought to be resistant to cereal cyst nematode, a characteristic that is probably inherited from its parent crop, cereal rye.
- Root-lesion nematodes (*P. thornei* and *P. neglectus*) have been detected at potentially damaging levels in nearly 30% of paddocks in the northern part of the Northern Region, and can be common throughout the southern part of the Northern region.
- The most effective way to manage RLN populations and protect yields is to use rotations with resistant and tolerant crops and varieties, and good nutrition and early sowing.
- Soil testing (e.g. with PreDicta B) is the best way to diagnose nematode infestations and also to inform growers' management decisions.

Nematodes (or roundworms) are one of the most abundant life forms on earth. They are adapted to nearly all environments. In cropping situations they can range from being beneficial to detrimental to plant health.

Successful management of destructive nematodes relies on:

- Farm hygiene to keep paddocks free of root-lesion nematode (RLN).
- Growing tolerant varieties when root-lesion nematodes are present, to maximise yields.
- Rotating with resistant crops to keep root-lesion nematodes at low levels.
- Test soil to monitor population changes between crop rotations and to determine RLN species and population density.
- When rotating crops, avoid planting susceptible crops consecutively, so as to limit the build-up of RLN populations.
- Choose rotation crops with high resistance ratings, so that fewer nematodes remain in the soil to infect the next crop. [2]

Triticale has some resistance to *P. neglectus,* [3] and *P. thornei*. [4], and some varieties have resistance to cereal cyst nematode [5], a characteristic that is probably inherited from its parent crop, cereal rye. [6] Because of this, many growers use it as a disease break in their rotations and value the benefits of triticale for its contribution to soil conservation and reducing parasitic nematode populations in the soil. [7] [8]

1 GRDC (2009) Field Peas: The Ute Guide. GRDC, https://grdc.com.au/resources-and-publications/apps/field-peas-the-ute-guide. See also GRDC (2013) Field Peas: The Ute Guide. App. GRDC, https://grdc.com.au/Resources/Apps

2 K Owen, J Sheedy, N Seymour (2016) Root-lesion nematode, Queensland. Soilquality.org, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

3 M Williams (2013) Root out nematodes and get them tested. GRDC, https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested

4 A Wherrett, V Vanstone (2016) Root lesion nematode. Soilquality.org, http://soilquality.org.au/factsheets/root-lesion-nematode

5 M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, http://www.fao.org/docrep/009/y5553e/y5553e00.htm

6 R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to *Heterodera avenae* in the rye genome of triticale. Theoretical and Applied Genetics, 79 (3), 331–336.

7 Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

8 KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia–Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, http://www.fao.org/docrep/009/y5553e/y5553e00.htm

VIDEOS

WATCH: GCTV6: Root-lesion nematodes

WATCH: Understanding root-lesion nematodes

8.1 Root-lesion nematodes

Key points:

- *Pratylenchus neglectus* and *P. thornei* are the main root-lesion nematodes (RLNs) that cause yield loss in the northern agricultural region of Australia. They often occur together.
- Root-lesion nematodes cost Australian growers in excess of $250 million a year.
- Root-lesion nematodes reduce the development of lateral roots, and this decreases the ability of plants to extract water and nutrients.
- Wheat is the main host of RLN, although varieties vary in their resistance and tolerance. Traditional break crops can also be hosts, and the host range varies for each *Pratylenchus* species.
- Yield losses can be reduced by rotation with resistant and tolerant crops and varieties, good nutrition, sowing early and testing soil.

The root-lesion nematodes are a genus of soil-borne, microscopic plant parasites that are migratory. They are widely distributed in the wheat-growing regions of Australia, the two common species in the Northern Region being *Pratylenchus thornei* (*Pt*) and *P. neglectus (Pn)*. *P. thornei* is the most damaging species and occurs commonly in the northern part of the Northern region (Photo 1). [9] *P. neglectus* occurs less frequently in this area, but is common and can be damaging in the southern part of the Northern region.

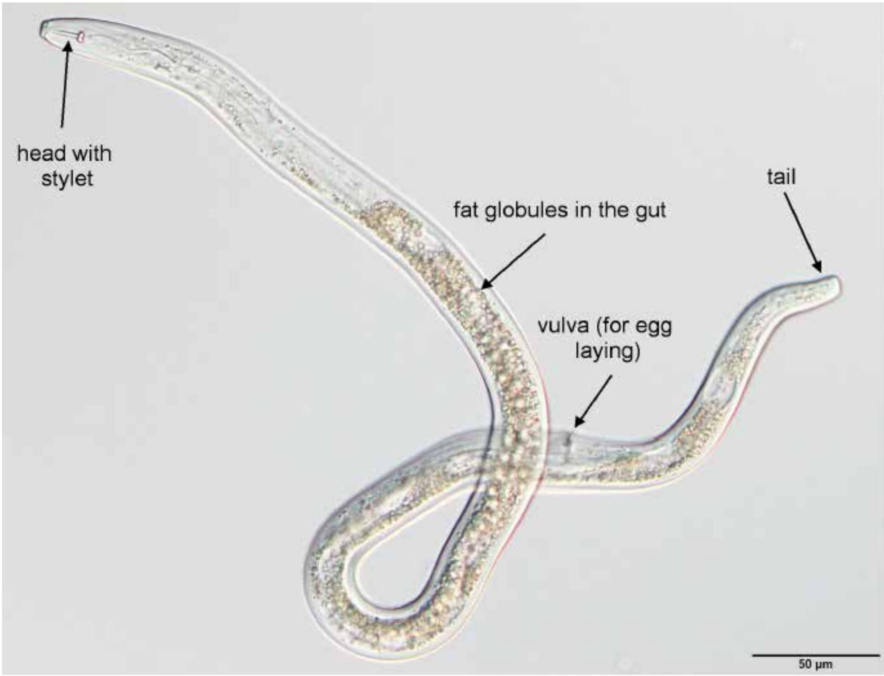


Photo 1: *A Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.*

Source: GRDC

Both species grow to ~0.5–0.75 mm in length and feed and reproduce inside the roots of susceptible crops (and other plants). They penetrate the plant root, digesting the cells' contents and laying eggs within the roots (Photo 2). [10] Nematode multiplication differs both between and within host species.

9 GRDC (2015) Root-lesion nematodes, Northern Region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/03/tt-rootlesionnematodes

10 J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. DAF Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

Pratylenchus thornei occurs throughout the root zone while *P. neglectus*, tends to be concentrated in the top 15 cm of the soil.

Big populations develop quickly following planting, so that the root systems quickly become inefficient in absorbing water and nutrients. [11]

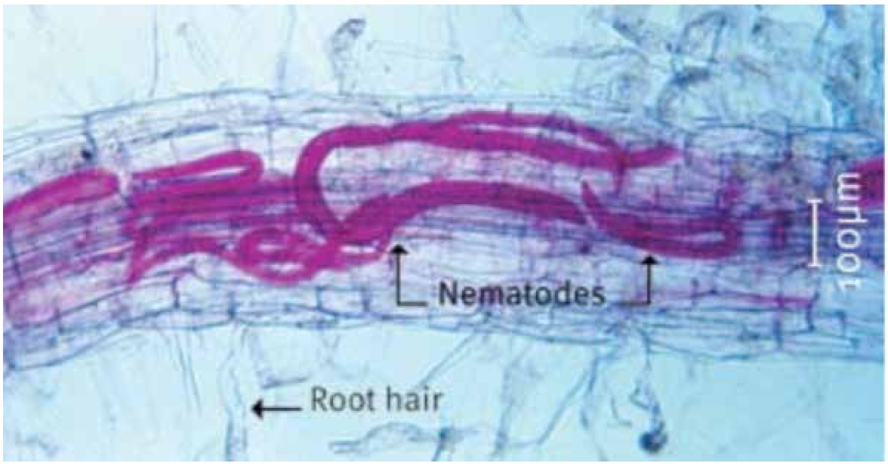


Photo 2: *Nematodes (stained to make them easy to see) in a cereal-plant root.*

Source: DAF Queensland

P. neglectus has a wide range of hosts, and infects all cereals as well as crops grown in rotation with cereals (e.g. grain legumes, pasture legumes and oilseeds). This species impairs root function, limiting water and nutrient uptake, and leading to poor growth and yield decline. Researchers conducted trials at infested sites to determine the ability of cereal species and varieties to promote the multiplication of the nematode. They also used glasshouse tests to compare nematode multiplication on roots of varieties of triticale, wheat and rye. The roots of triticale contained fewer nematodes than the other cereals. [12]

Triticale is thought to be susceptible to *P. penetrans*, a RLN common in WA, although this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant Laboratories (now called DDLS Seed Testing and Certification). More research is needed before this can be taken as fact. [13]

In 2015, SARDI generated maps of the distribution of *P. thornei* and *P. neglectus* from samples submitted for PreDicta B tests (Figure 1). [14] Results from the autumn samples show that in the northern part of the Northern Region, *P. thornei* (Pt) is more widely distributed and found in greater, more damaging populations than *P. neglectus* (Pn). In this region, paddocks with more than 15 *P. thornei*/g soil or 15,000/kg soil (ascertained by the PreDicta B test) are considered high risk for crops. However, populations of *P. thornei* classified as being of medium risk, that is 2–15/g soil or 2,000–15,000/kg soil, can cause substantial yield loss in intolerant varieties in the warm, wet growing seasons that are conducive to nematode reproduction. [15]

11 GRDC (2015) Root-lesion nematodes, Northern Region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/03/tt-rootlesionnematodes

12 V Vanstone, M Farsi, T Rathjen, K Cooper (1996) Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow, Springer Netherlands, pp. 557–560.

13 A Wherrett, V Vanstone (2016) Root lesion nematode. Soilquality.org, http://soilquality.org.au/factsheets/root-lesion-nematode

14 K Owen, T Clewett, J Sheedy, J Thompson (2016) Managing grain crops in nematode fields to minimize loss and optimise profit. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Managing-grain-crops-in-nematode-infested-fields-to-minimise-loss-and-optimise-profit

15 K Owen, T Clewett, J Sheedy, J Thompson (2016) Managing grain crops in nematode-infested fields to minimise loss and optimise profit. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Managing-grain-crops-in-nematode-infested-fields-to-minimise-loss-and-optimise-profit

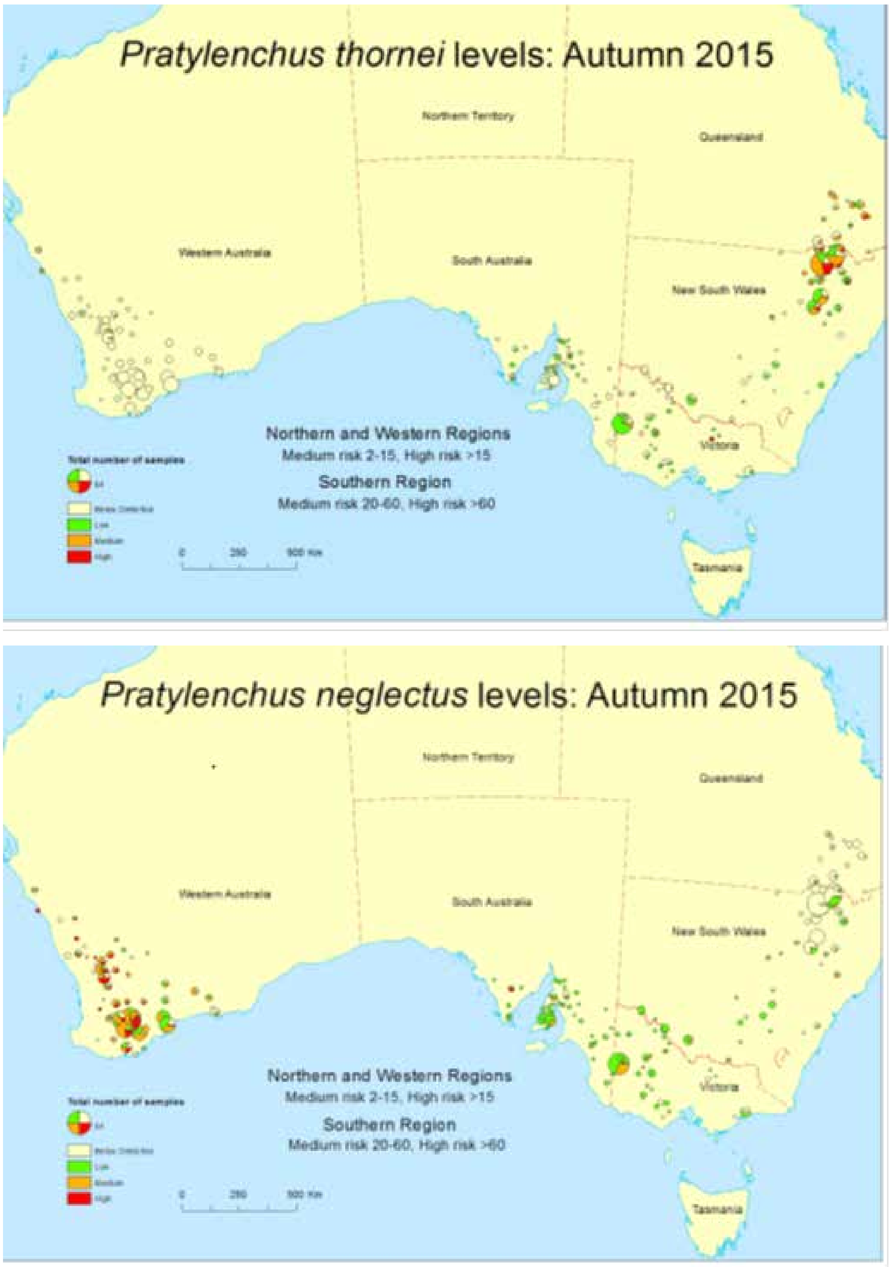


Figure 1: *The distribution of RLNs and risk of yield loss, from samples submitted for PreDicta B tests to SARDI in autumn 2015 for (top) Pratylenchus thornei and (bottom) P. neglectus.*

Source: GRDC

In a survey of soil samples from 596 paddocks in southern Queensland and northern New South Wales cropping areas consistently show *P. thornei* presence in ~60–70% of paddocks. *This nematode is* frequently present at concerning levels, detected at over 2 *Pt*/g soil in ~30–40% of paddocks. In this survey, it was found that 42% of paddocks tested had *P. thornei* alone, 27% had both species, 6% had *P. neglectus* alone, and 26% had neither species (Figure 2). [16]

MORE INFORMATION

[Managing grain crops in nematode infested fields]

16 J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. DAF Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

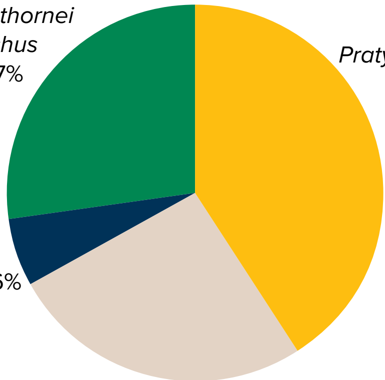


Figure 2: *A survey of nematodes in 596 paddocks in the Northern Region revealed that P. thornei is the most commonly found root-lesion nematode in the region (prior to recent region boundary changes) and that P. neglectus is also present.*

Source: DAF Queensland

8.1.1 Symptoms

What to look for in the paddock

- Crops appear patchy with uneven growth, and may appear nutrient-deficient (Photo 3).
- Double-sown and more fertile areas are often less affected.
- There may be stunted growth and 'waviness' across the paddock.

Photo 3: *Poor vigour cereal in high-RLN plot (left) compared to a healthy plot with low numbers of RLN (right).*

Photo: Grant Holloway

What to look for in the plant

- Affected plants are stunted and poorly tillered, and can wilt even in moist soil.
- Roots can have indistinct brown lesions or, more often, generalised root browning (Figure 6).
- Badly affected roots are thin and poorly branched, with fewer and shorter laterals.

- Roots may appear withered, with crown roots often less affected than primary roots.
- Roots can assume a 'noodle-like' root thickening. [17]
- The roots do not swell or knot and no cysts are produced, occurrences that indicate infection by cereal cyst nematodes. [18]
- Note that symptoms may not be as distinct in triticale as it has higher resistance levels to RLNs than wheat of which this symptomology is based upon.

Photo 4: *Discolouration and a lack of lateral roots on cereals is caused by root-lesion nematodes.*

Photo: Frank Henry

VIDEOS

WATCH: How to diagnose root-lesion nematode

8.1.2 Varietal resistance or tolerance

Some crops, varieties and plant types have different levels of resistance to different species of the *Pratylenchus* family. Triticale has varying levels of resistance and tolerance to *P. neglectus* and *P. thornei* (Table 1). Triticale is thought to be susceptible to *P. penetrans*, but this needs to be confirmed by research. [19]

Table 1: *Triticale variety resistance ratings to nematodes.*

17 DAFWA (2016) Diagnosing root lesion nematode in cereals. DAFWA, https://agric.wa.gov.au/n/2166

18 CropPro (2014) Root lesion nematode (RLN). GRDC, http://www.croppro.com.au/crop_disease_manual/ch03s07.php

19 A Wherret, V Vanstone (2016) Root lesion nematode. Soilquality.org, http://soilquality.org.au/factsheets/root-lesion-nematode

Variety	*Pratylenchus neglectus* resistance	*Pratylenchus thornei* resistance
Astute⚔	R–MR	MS
Berkshire⚔	MR	MS
Bison⚔	MR	R–MR
Canobolas⚔	MR	MS–S
Chopper⚔	R	MS–S
Endeavour⚔	MR	S–VS
Fusion⚔	R–MR	MS
Goanna	MR–MS	S–VS
KM10	MR	MSp
Rufus	MS–S	MS–S
Tahara	MR	S
Tobruk⚔	MR	S–VS
Tuckerbox	MR–MS	S
Yowie	MR	MS–S

Disease resistance order from best to worst: R > R–MR > MR > MR–MS > MS > MS–S > S > S–VS > VS
p = provisional ratings—treat with caution. R = resistant, M = moderately, S = susceptible, V = very

Source: Agriculture Victoria

8.1.3 What does resistance and tolerance mean?

Resistant varieties will result in fewer nematodes remaining in the soil to infect subsequent crops. Tolerant varieties are able to perform well in the presence of the nematode, but they may allow nematode populations to build up.

Nematode Resistance relates to the effect of the variety on the nematode density present within the paddock (Table 2).

Table 2: *Standard disease ratings.*

Uniform rating	Management option description	In the paddock	Management action
Resistant	Growing these varieties will reduce the density of the nematode in question and so reduce yield loss in subsequent intolerant crops.	There will be a reduction in nematode densities when these varieties are grown.	Use these varieties in rotation with non-host crops to reduce nematode infestations. If using R varieties in paddocks with high nematode infestations make sure variety is also tolerant to prevent significant yield loss.
Moderately resistant	Growing these varieties will, to a lesser degree than growing a resistant variety, reduce the density of the nematode in question and, therefore, reduce yield loss in subsequent intolerant crops.	There will be a reduction in nematode densities when these varieties are grown.	These varieties are suitable to be grown in paddocks with high nematode infestations as they reduce nematode densities. They will, however, not reduce nematode densities to the same degree as a resistant variety. Note that if nematode densities are high tolerant to minimise yield loss.
Moderately susceptible	Growing these varieties will result in a small increase in nematode densities during the season.	Growing these varieties will increase the nematode density. However, unless the season is exceptionally favourable, growing these varieties in paddocks with low level nematode densities will only increase densities to moderate levels. If nematode densities are already moderate these varieties may result in high densities that may cause substantial loss in a following intolerant variety.	These varieties are suitable to be grown in paddocks with low nematode densities. They will, however, increase nematode densities which may be a problem for a following intolerant crop.

Uniform rating	Management option description	In the paddock	Management action
Susceptible	Growing these varieties will increase nematode density which may then cause problems to a following intolerant crop.	Growing these varieties will result in increases in the density of the nematode in question. However, unless the season is exceptionally favourable, growing these varieties in paddocks with a low level will only result in moderate levels. If nematode densities are already moderate these varieties can result in high levels that may cause substantial loss in a following intolerant variety.	These varieties will increase the density of nematodes in a paddock that may be of concern to a following intolerant crop. If nematode densities are high following a susceptible crop, growers should avoid intolerant crops in the following year and select a resistant crop to reduce nematode densities.
Very susceptible	Growing these varieties will support large multiplication rates of the nematode. It may take more than one year of a resistant variety/ non-host crop to reduce the nematode densities to a level that will not affect the yield of an intolerant crop.	These varieties will support large increases in nematode numbers when grown in infested paddocks.	Growers should where possible avoid growing these varieties in infested paddocks. Also avoid growing intolerant varieties after VS varieties due to the potential for significant yield loss. A tolerant non-host crop/resistant variety should be used following VS varieties to reduce nematode densities. If nematode densities are very high it may take more than two years of non-host/resistant varieties to reduce nematode levels to low risk densities.

Source: NVT Online).

Nematode Tolerance relates to yield of the variety in the presence of the nematode (Table 3).

Table 3: *Standard disease ratings.*

Uniform rating	Management option description	In the paddock	Management action
Tolerant	Variety will not lose yield in the presence of the nematode, even at high nematode densities.	The crop will not be affected by the presence of the nematode.	No economic management decisions required.
Moderately tolerant	These varieties can generally be sown in paddocks with low to medium levels of nematode infestations without a significant effect on grain yield occurring. These varieties can suffer yield loss (up to 10%) in the presence of high nematode densities.	Minimal yield loss will occur in the presence of the nematode (i.e. < 5%), except when nematode densities are high when up to 10% yield loss may occur.	Do not grow these varieties in paddocks with high nematode densities present. Suggest follow management recommendations to minimise yield loss for the nematode of concern.
Moderately intolerant	These varieties should not be grown in paddocks with medium to high nematode densities. In the presence of high nematode densities in a paddock these varieties will lose up to 30% yield.	In the presence of the nematode and in seasons conducive to disease, these varieties will lose yield and may show symptoms consistent with root damage. The expression of symptoms will be greater in paddocks with higher nematode densities.	These varieties should not be grown in paddocks with medium to high nematode densities. In the presence of high nematode densities in a paddock these varieties can lose up to 30% yield. Suggest follow management recommendations to minimise yield loss for the nematode of concern.
Intolerant	These varieties are prone to yield loss even in the presence of low nematode densities. Such varieties should not be grown in paddocks where nematodes are known to be present. In the presence of high nematode densities yield loss of up to 50% can occur.	In the presence of the nematode symptoms of root disease will often be easily found in the crop.	Do not grow these varieties in paddocks where the nematode is present at medium to high levels. Even paddocks with low nematode densities should be avoided when possible. Suggest follow management recommendations to minimise yield loss for the nematode of concern.

Uniform rating	Management option description	In the paddock	Management action
Very intolerant	Do not grow this variety unless the paddock is known to be nematode free or present at very low densities. High nematode densities could cause yield losses of greater than 50% to occur.	Symptoms of nematode damage will be present in these varieties even in the presence of low nematode densities.	Do not grow these varieties in paddocks where the nematode is present, even at low levels. If the variety is to be grown a soil test should be conducted prior to sowing to ensure that the paddock is free from the nematode in question. Suggest follow management recommendations to minimise yield loss for the nematode of concern.

Source: NVT Online

VIDEOS

WATCH: GCTV19: Root-lesion nematodes—Resistant cereal varieties have surprising impacts on RLN numbers

8.1.4 Damage caused by RLN

Root-lesion nematode numbers build up rapidly when susceptible crops are planted, and the build-up causes decreasing yields over several years. The amount of damage caused will depend on; the numbers of nematodes in the soil at sowing, the tolerance of the variety of crop being grown, and environmental conditions.

Field trials in areas infested with *P. neglectus* have shown yield losses for intolerant wheat ranged from 12–33%. [20] In the southern part of the northern region *P. neglectus* can cause major losses to susceptible crops. In southern Australia *P. neglectus* has been known to reduce grain yield by 10–20% and in Western Australia is has been reported to cause losses of up to 15%. [21]

In the northern part of the Northern region, intolerant varieties can lose more than 50% in yield when *P. thornei* populations are high (Figure 3). [22]

20 B Burton, R Norton, R Daniel (2015) Root-lesion nematode; importance, impact and management. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

21 V Vanstone, J Lewis (2009) Plant parasitic nematodes Factsheet. GRDC. https://grdc.com.au/resources-and-publications/all-publications/bookshop/2010/10/plant-parasitic-nematodes-fact-sheet-southern-western-region

22 B Burton, R Norton, R Daniel (2015) Root-lesion nematode: importance, impact and management. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

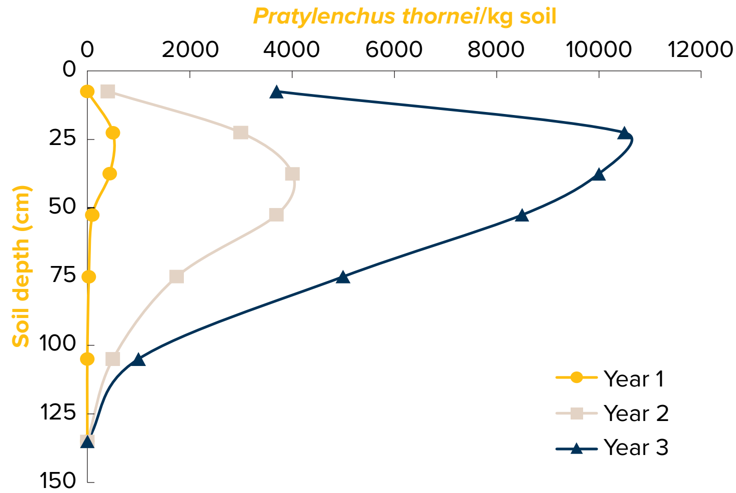


Figure 3: *During three years of continuous wheat cropping at Wellcamp (Queensland), numbers of Pt increased from low levels to levels that would reduce yields of intolerant crops. The graph shows numbers in the soil sampled before sowing each year.*

Source: DAF Queensland

8.1.5 Conditions favouring development

Root lesion nematodes survive summer as dormant individuals in dry soil and roots, and become active after rain. They can survive several wetting/drying cycles. About three generations of the nematodes are produced each season, with the highest multiplication in spring.

Nematodes can spread through a district in surface water (e.g. floodwater) and can be moved from one area to another in soil that adheres to vehicles and machinery. They can also move via soil adhering to vehicles and farm machinery. In uninfested areas, good hygiene should be adopted. Nematodes can be spread in dust when they are in a dehydrated state over summer.

They have the ability to quickly build up populations in the roots of susceptible crops, and remain in the soil during fallow. As a result, the yield of following crops can be significantly reduced.

IN FOCUS

How long does it take to reduce Pt in soils?

Key points:

- Paddocks that host *P. thornei* populations greater than 40,000 per kg of soil at harvest will require a double break of around 40 months free of a host plant in order to reduce the population.
- Paddocks that host *P. thornei* populations greater than 10,000 per kg at harvest will require a single break of around 30 months free of a host plant in order to reduce the population below the accepted threshold.
- Weeds can be hosts, so fallows must be free of weeds and volunteers.

Researchers explored how long it takes to reduce Pt populations in infected soils. Using wheat cultivars with different levels of tolerance and resistance, they created a range of nematode populations in the soil. At the harvest of the second wheat crop, the nematode population in each plot was recorded and defined as high (H, >20,000Pt/cm^2/1.2 m soil profile), medium (M, >10,000Pt/cm^2/1.2 m profile), low (L, >5,000Pt/cm^2/1.2 m profile) or very low (VL, <5,000Pt/cm^2/1.2 m profile), and calculated as the sum of nematodes across the whole profile. Over the next 30 months soil samples were collected from the plots to monitor the change in nematode populations over time.

The rotation over the 30 months was wheat, followed by a long fallow to sorghum, then a long fallow to wheat. In the fallow that commenced in 2011, no sorghum was sown due to drought.

A paddock with a high initial number of nematodes (80 nematodes per cm3, ~80,000 Pt/kg) took four years to reduce below the threshold. This required two non-host crops such as sorghum and fallows to reduce the population. A paddock with an initially medium level of nematodes (50 nematodes per cm3) took 3.5 years to drop below the threshold (Figure 4), [23] and required the equivalent of a single non-host summer crop and fallows. A low nematode population paddock (20 nematodes per cm3) took 24 months to drop below the threshold. [24]

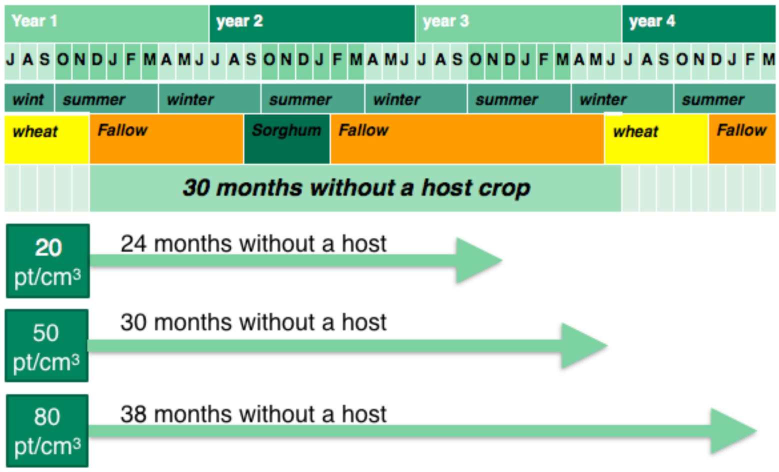


Figure 4: *An example of a non-host fallow showing the time required to reduce different starting populations of root-lesion nematode.*

Source: GRDC

MORE INFORMATION

[How long does it take to reduce Pratylenchus thornei (root lesion nematode) population in the soil?]

[Impact from *Pratylenchus thornei*, Macalister 2015]

8.1.6 Thresholds for control

The damage threshold for both RLNs has been estimated at 2,000 nematodes/kg soil (or 2/g soil). Control is warranted for paddocks with populations over this density. [25]

In the Northern region, paddocks with more than 15 *P. thornei*/g soil or 15,000/kg soil are considered high risk for crops. However, populations of *P. thornei* classified as being of medium risk, that is 2–15/g soil or 2,000–15,000/kg soil, can cause

23 J Whish, J Thompson (2016) How long does it take to reduce Pratylenchus thornei (root lesion nematode) population in the soil? GRDC Update Paper. GRDC, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/how-long-does-it-take-to-reduce-pratylenchus-thornei-populations-in-the-soil

24 J Whish, J Thompson (2016) How long does it take to reduce Pratylenchus thornei (root lesion nematode) population in the soil? GRDC Update Paper. GRDC, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/how-long-does-it-take-to-reduce-pratylenchus-thornei-populations-in-the-soil

25 GRDC (2015) Root lesion nematodes. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/03/tt-rootlesionnematodes

substantial yield loss in intolerant varieties in the warm, wet growing seasons that are conducive to nematode reproduction. [26]

The number of nematodes in the soil can be determined by conducting soil testing, for example with a PreDicta B test.

8.1.7 Management of RLN

Key points:

- Know your enemy—test soil to determine whether RLN are a problem and which species are present.
- Select wheat varieties rated as having a high tolerance to minimise yield losses in RLN-infected paddocks.
- To manage RLN populations, it is important to increase the frequency of RLN-resistant crops in the rotation.
- Multiple resistant crops in a rotation will be necessary for the long-term management of RLN populations.
- There are consistent varietal differences in Pt resistance within wheat and chickpea varieties.
- Avoid crops or varieties that allow the build-up of large populations of RLN in infected paddocks.
- Monitor the impact of your rotation.

There are four key strategies in reducing the risk of root-lesion nematodes:

1. Have soil tested for nematodes in a laboratory (For more information, see Section 8.1.8 Soil testing).
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 varieties to maximise yields; National Variety Trials online is a useful resource. Tolerant varieties grow and yield well when RLN are present.
4. Rotate with resistant crops to prevent increases in root-lesion nematodes (Figure 5 [27]). When high 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 to ensure that the yield potential of tolerant varieties is achieved. Crop rotation with resistant crops such as grain sorghum, millet, sunflower and lupins will reduce the numbers of nematodes in the soil to a level where susceptible varieties can be grown. However, it will not eliminate them completely. [28]

26 K Owen, T Clewett, J Sheedy, J Thompson (2016) Managing grain crops in nematode-infested fields to minimise loss and optimise profit. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Managing-grain-crops-in-nematode-infested-fields-to-minimise-loss-and-optimise-profit

27 B Burton, R Norton, R Daniel (2015) Root lesion nematodes: importance, impact and management. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

28 DAF Qld (2015) Wheat: diseases, physiological disorders and frost. DAF Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

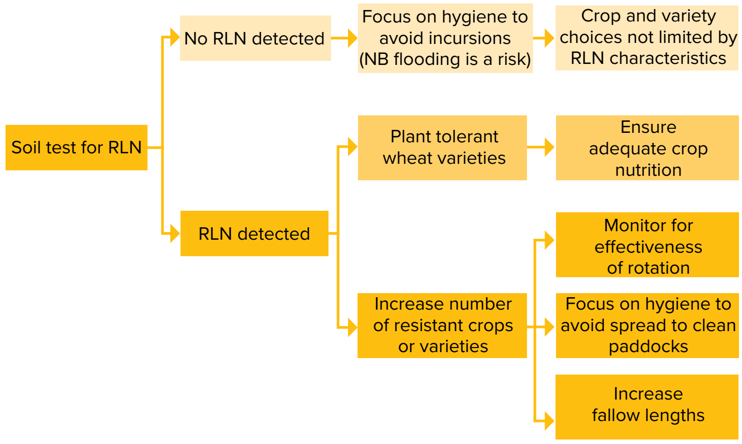


Figure 5: *The simplified RLN management flow chart. It highlights the critical first step in the management of RLN is to test soil to determine whether you have a problem to manage. Where RLN are present, growers should focus on both planting tolerant wheat varieties and increasing the number of resistant crops and varieties in the rotation.*

Source: GRDC

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. 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.

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 (Tables 4 and 5). Aim to reduce populations to less than 2/g soil. 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. [29] Consider re-testing in five years, particularly if there has been flooding, because RLN can move in floodwaters and in soil.

Table 4: *Susceptibility of some non-cereal crop and pasture species to root lesion nematode infection.*

RLN species	Susceptible crops	Moderately susceptible crops	Resistant crops
Pratylenchus neglectus	Canola, chickpeas, mustard	Common vetch, lentils	Field peas, narrow leaf lupins, faba beans, triticale, safflower, cereal rye, medic, clover
Pratylenchus thornei	Chickpeas, vetch, faba beans	Canola, mustard, field peas*, lentils	Field peas*, lupins

* New field pea varieties are more susceptible to *P. Thornei* than older varieties, so check the classification of each variety.

Source: GRDC

29 GRDC (2015) Root-lesion nematodes, Northern Region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/03/tt-rootlesionnematodes

Table 5: *Comparison of the risk of build-up of Pratylenchus thornei and P. neglectus in crops.*

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

Source: GRDC

Fallow

RLN populations will generally decrease during a 'clean' fallow but the process is slow and expensive in lost potential income. Additionally, long fallows may decrease arbuscular mycorrhizae (AM) levels and create more cropping problems than they solve.

Weed control

Weeds can play an important role in the increase or persistence of nematodes in cropping soils. Thus, poor control of susceptible weeds compromises the use of crop rotations for RLN management. Wild oat, barley grass, brome grass and wild radish are susceptible to *P. neglectus*. When a pasture is included in the cropping rotation, weeds strongly influence nematode populations at the end of the pasture phase. Manage volunteer susceptible crop plants that can harbour nematodes. [30]

Nutrition

Damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture, and can induce nutrient deficiencies. Although under-fertilising is likely to exacerbate the impact of RLN-affected yields, over-fertilising is unlikely to *compensate* for a poor variety choice.

Adequate nutrition (especially nitrogen, phosphorus and zinc) normally allows plants to better tolerate plant parasitic nematodes, although this does not necessarily lead to lower nematode reproduction.

Field trials in areas infested with *P. neglectus* have shown yield losses for intolerant wheat ranged from 12–33% when minimal levels of phosphorus were applied but losses were reduced to only 5% with a high (50 kg/ha) rate of phosphorus.

Nematicides (control in a drum)

There are no nematicides registered for use against RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted, but RLN are very difficult to target because populations are frequently deep in the soil profile. [31]

Natural enemies

Biological suppression is a potential method of reducing populations of *P. thornei* and *P. neglectus*. Recent research has identified that Northern Region soils are capable of suppressing root-lesion nematodes, especially in the top layer (0–15 cm), and this capacity can be enhanced by increasing the biological activity of that soil, mainly through carbon inputs and minimising soil disturbance.

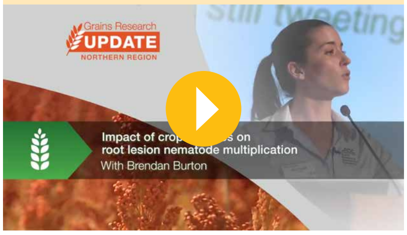
Several organisms that prey on nematodes have been found in northern soils that have the potential to reduce root-lesion nematode populations. They include the *Pasteuria* bacteria that infect and eventually kill *Pratylenchus* spp. Several species of fungi, including some that trap nematodes, and predatory nematodes have also been found.

Research is continuing to develop methods of increasing biological activity to enhance natural suppression of nematodes deeper in the soil profile.

VIDEOS

WATCH: Root lesion nematodes part 3: What can I do?

WATCH: Crop variety effect on nematodes



MORE INFORMATION

National Variety Trials

GRDC Tips and Tactics, Root-lesion nematodes, Northern Region

30 V Vanstone, J Lewis (2009) Plant parasitic nematodes Factsheet. GRDC. https://grdc.com.au/resources-and-publications/all-publications/bookshop/2010/10/plant-parasitic-nematodes-fact-sheet-southern-western-region

31 B Burton, R Norton, R Daniel (2015) Root-lesion nematode; importance, impact and management. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

IN FOCUS

Biological suppression of RLN in northern soils

Key points:

- In one study, biological suppression occurred in most soils tested in the northern grain-growing region, showing that populations of *RLN* are reduced by parasites and predators.
- Suppression was found to be greater in the top 10 cm of soil than at deeper layers (e.g. 30–45 cm). Practices such as zero tillage with stubble retention enhanced suppression. In the absence of these, it is estimated that RLN multiplication would be significantly greater, especially in topsoils, and that this would result in much greater losses in the productivity of susceptible crops.
- Several antagonists of *Pratylenchus* spp. were found in northern grain-growing soils that enhance the plant's resistance to nematodes: nematode-trapping fungi, predatory nematodes, parasitic bacteria, and root-colonising fungi. Further research is focussing on these organisms as they are likely to contribute to the ability of natural subsoil systems to suppress RLN.

Actively enhancing the ability of soils to suppress root-lesion nematodes is a control option that deserves some consideration. In regard to RLN, disease suppression can be defined as the ability of a soil and its organisms to suppress the incidence or severity of disease even in the presence of the pathogen, host plants and favourable environmental conditions. The vast array of organisms in the soil can provide a degree of biological buffering against pathogens. Disease reduction results from the combined effects of many antagonists acting collectively and mediated through inputs of organic matter (general suppression) and direct antagonism by a limited number of organisms (specific suppression).

A recent GRDC-funded project aimed to better understand the suppressive nature of grain-growing soil environments and provide growers with methods to enhance the soils' ability to suppress root-lesion nematodes.

Over four years, researchers sampled 24 sites to test the suppressive nature of the soils. The sites were located in several farmers' paddocks and three long-term farm-management trial sites. The soils were given several fertiliser or tillage treatments. Also, seven of the sites were comparisons of cropped/pasture or native/scrub remnant soils that were close by to gain an understanding of the impact cropping may have on any natural ability of soils to suppress RLNs.

Repeated studies over four years of multiple soils from northern NSW and southern Queensland consistently showed that some soil environments have a natural ability to suppress root-lesion nematodes. In glasshouse tests, the researchers also found that a 10% addition of suppressive field soil to a sterilised soil (heated at 60°C for 45 mins) is sufficient to reduce RLN multiplication by 60–90%, showing that the suppressive effect was biological and could be transferred or added to a less suppressive soil.

Implications:

- Suppression does occur in most of the soils tested, as populations of *P. thornei* were reduced due to biological activity. Suppression was greater in the top 10 cm of soil than at deeper layers, and practices such as zero tillage with stubble retention enhanced the effect.
- Maintenance of a healthy topsoil through diverse organic matter inputs will preserve the potential of soils to naturally suppress RLNs.

MORE INFORMATION

Biological suppression of RLN in northern region

- Heavy rates of stubble (up to 20 t/ha) increased general suppression of RLN in the short term. This coincided with high levels of microbial activity.
- The presence of a crop for longer periods of time and the associated input of root exudates may have provided a better environment for sustained microbial activity and, hence, suppression of RLN.
- Growers using no-till, stubble-retention practices and cropping when soil moisture allows are probably doing a great deal toward enhancing the suppressive ability of their topsoils. Without these practices, RLN multiplication would probably be significantly greater, especially in topsoils, and therefore lead to much greater losses in productivity of susceptible crops.

More work is required to confirm the biological-control agents found to be present in grain-growing soils can have a significant impact on RLN populations on a broad scale. [32]

8.1.8 Soil testing

Soil testing is the best way to diagnose nematode infestations and also to inform growers' management decisions. It is important to know whether nematodes are on your farm and which species are present. This is important because varietal tolerance information for *P. thornei* does not hold true for *P. neglectus*, so proper species identification can help minimise losses that arise from planting intolerant varieties in nematode-infested land.

RLN populations can persist in the soil for a long time, so it is important to know the size of the population at the end of each season. Once a population increases, non-host, resistant crops or fallows are required to reduce the population below the damage threshold. Planting susceptible or tolerant crops within this period will enable the rapid increase in populations to higher levels. [33]

There are two services available to test for RLNs.

Leslie Research Centre tests

The Leslie Research Centre of the Department of Agriculture and Fisheries Queensland offers a commercial test for their the presence of nematodes in soil.

Since nematodes may not be evenly spread across a paddock, particularly when there are new infestations, it is important to take samples from several locations within a paddock. It is suggested that growers take nine cores in groups of three.

Nematodes are often more numerous in the subsoil than in the topsoil. Although you can have soil to a depth of 120 cm analysed, this isn't necessary. As long as soil is sampled in two layers, topsoil at 0–15 cm and subsoil at 15–30 cm, a useful result can be achieved. Use a hand corer (or a mattock if no corer is available). Topsoil-only samples can give inaccurate results and should always be accompanied by a subsoil sample. If deeper samples are already being taken for other analysis (e.g. nitrate), a nematode assessment can be made from the depths 0–30 cm, 30–60 cm and 60–90 cm.

32 N Seymour, G Stirling, J Li (2016) Biological suppression of RLN in northern grain growing soils. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Biological-suppression-of-root-lesion-nematodes-in-northern-grain-growing-soils

33 J Whish, J Thompson (2016) How long does it take to reduce Pratylenchus thornei (root lesion nematode) population in the soil? GRDC Update Paper. GRDC, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/how-long-does-it-take-to-reduce-pratylenchus-thornei-populations-in-the-soil

MORE INFORMATION

Leslie Research Centre, Test your farm for nematodes

Send samples to: Soil Microbiology Section
Leslie Research Centre
PO Box 2282 Toowoomba, QLD 4350
13 Holberton Street v
Toowoomba
Phone: (07) 4639 8888
Fax: (07) 4639 8800

MORE INFORMATION:

Leslie Research Centre, Test your farm for nematodes

PreDicta B tests

PreDicta B is a DNA-based soil-testing service that was developed by the South Australian Research and Development Institute (SARDI) (The B in the name stands for broadacre). The test identifies which soil-borne pathogens pose a significant risk to broadacre crops before paddocks are planted (Photo 5). [34]

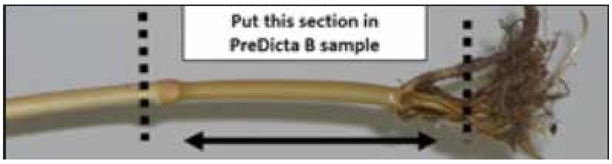


Photo 5: *It is important to follow the PreDicta B sampling instructions closely.*

Source: GRDC

PreDicta B can be used to test for:

- Root-lesion nematodes including *P. neglectus* and *P. thornei*
- take-all (*Gaeumannomyces graminis var. tritici (Ggt)* and *G. graminis var. avenae (Gga)*).
- Rhizoctonia root rot (*Rhizoctonia solani AG8*).
- crown rot (*Fusarium pseudograminearum and F. culmorum*).
- blackspot of peas (*Mycosphaerella pinodes, P. medicaginis var. pinodella* and *P. koolunga*).

Testing service

You can access PreDicta B diagnostic testing services through a SARDI accredited agronomist, who will interpret the results and give you advice on management options to reduce your risk of yield loss.

Samples are processed weekly between February and mid-May (prior to crops being sown).

PreDicta B is not intended for in-crop diagnosis.

8.2 Cereal cyst nematode

Key points:

- Cereal cyst nematode (CCN) can cause major yield loss to crops in the southern part of the Northern growing region. CCN is rarely found in northern NSW and Queensland
- Some varieties of triticale are thought to be resistant to cereal cyst nematode, a characteristic that is probably inherited from its parent crop, cereal rye.
- CCN is most damaging in low rainfall districts and seasons, especially with late breaks.

34 D Lush (2014) PreDicta B sampling strategy. GRDC, https://grdc.com.au/Media-Centre/Media-News/South/2014/04/PreDicta-B-sampling-strategy

- Rotations using break crops minimise the carryover of CCN host species (e.g. canola, lupins, chickpeas) as non-host crops are more effective than resistant cereals in reducing levels of CCN.
- Be aware of and try to minimise consecutive cereal hosts in rotations. CCN levels can become damaging after growing a susceptible crop for only one or two seasons.
- Grow resistant cereal cultivars to limit levels of CCN in the soil.
- Control volunteer cereal hosts and grass weeds during late summer and early autumn and in break crops.
- Sow early where possible to ensure better root development.
- Maintain optimum soil fertility to help crops get ahead of CCN infections.

Cereal cyst nematode is a pest of graminaceous crops worldwide. It is a significant problem across south-eastern Australia, including the southern part of the Northern region. CCN becomes more problematic in areas where intensive cereal cropping occurs.

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. [35]

Cereal cyst nematode only infects, feeds on and develops on cereals and other grasses (particularly wild oats). Non-cereal crops do not host the nematode, so are useful in rotations to limit damage caused to cereals.

CCN usually occurs early in the season and can occur on heavy or light soils.

The nematodes hatch over a period of several weeks, with the peak hatch occurring about six weeks after the autumn break. The eggs are contained in cysts that remain from previous seasons and hatch in response to lower temperatures and autumn rains. Hatching is delayed by late breaks or dry autumns, and this increases the risk of crop damage. Once hatched, the young nematodes seek out the roots of host plants. While the male nematodes remain free-living in the soil, the females penetrate the roots and begin feeding. Therefore, to prevent CCN multiplying, it is necessary to control host plants within 10 weeks of crop germination.

Following mating, the female produces eggs within its body. As the season progresses she remains feeding at the same infection site, and begins to swell into a characteristic white sphere. This process takes 6–9 weeks, and the CCN female remains like this until the host plant begins to senesce. The female dies and its cuticle hardens and turns brown to form a cyst. The cysts are particularly hardy, and remain in the soil over summer until temperatures fall and the autumn rains begin. Temperatures below 15°C and moist soil stimulate the hatching of the next generation. Cereal cyst nematodes have only one life cycle a year (Figure 6). [36] However, each cyst contains several hundred eggs, so populations can increase rapidly on susceptible cereals. [37]

35 GRDC (2009) Plant parasitic nematodes, Northern Region. Factsheet. GRDC, https://grdc.com.au/resources-and-publications/all-publications/bookshop/2010/10/plant-parasitic-nematodes-fact-sheet-northern-region

36 G Hollaway (2013) Cereal root diseases. Note AG0562. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

37 A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

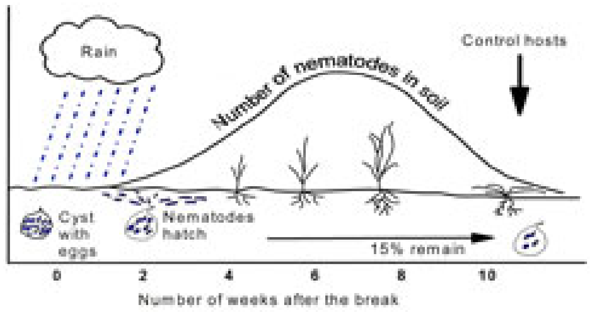


Figure 6: *Life cycle of the cereal cyst nematode.*

Source: Agriculture Victoria

Each year approximately 80% of nematodes hatch from cysts after the autumn break, while the remaining 20% stay dormant until the following season. This is why it will take at least two years with break crops to control CCN. However, under dry conditions or drought up to 50% of nematodes remain dormant, and an extra year of break crop is advisable. [38]

8.2.1 Symptoms and detection

The symptoms of CCN infection can be readily recognised. Above ground, patches of yellowed and stunted plants that fail to thrive can be observed (Photo 6). [39] Planting a susceptible crop in successive years will result in these patches becoming larger.

Below ground, close examination of the roots will reveal symptoms that are typical of CCN. Below ground, cereal roots can appear knotted (Photo 7), and 'ropey' or swollen (Photo 8). [40] Development of the root systems is retarded and shallow. In spring, characteristic white cysts about the size of a pin head can be seen with the naked eye if roots are carefully dug out and washed free of soil. These are the swollen bodies of the female CCN, each containing several hundred eggs. [41]

Photo 6: *CCN will cause distinct patches of yellowed and stunted plants. Note the likeness of symptoms to poor nutrition or water stress.*

Photo: Vivien Vanstone. Source: Soilquality.org

38 G Hollaway, F Henry (2013) Cereal root diseases. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-root-diseases

39 A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

40 CropPro (2014) Cereal cyst nematode (CCN). GRDC, http://www.croppro.com.au/crop_disease_manual/ch03s03.php

41 A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

Photo 7: *CCN produce knotting of cereal roots.*

Photo: Vivien Vanstone. Source: Soilquality.org

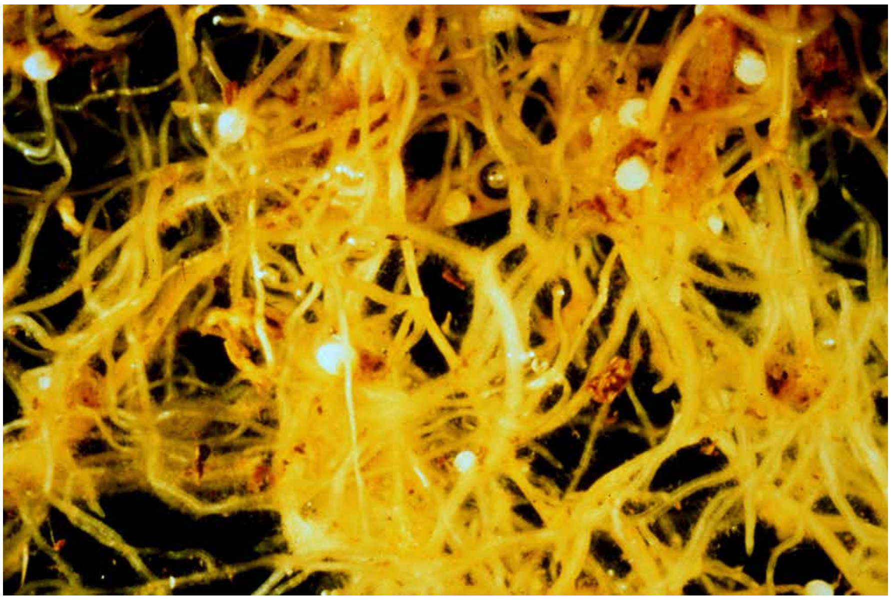


Photo 8: *Cereal roots infected with CCN appear 'ropey' and swollen.*

Source: CropPro

8.2.2 Varietal resistance or tolerance

Some varieties of triticale are thought to be resistant to cereal cyst nematode (Table 6) a characteristic that is probably inherited from its parent crop, cereal rye. Good resistance can be found in varieties such as Chopper⧉, Endeavour⧉, and Tuckerbox, however some varieties such as KM10 are susceptible to the nematode.

Table 6: *Triticale variety resistance ratings to nematodes.*

Variety	CCN resistance
Astute⚖	R
Berkshire⚖	–
Bison⚖	R
Canobolas⚖	–
Chopper⚖	R
Endeavour⚖	R
Fusion⚖	R
Goanna	R
KM10	S
Rufus	R
Tahara	R
Tobruk⚖	–
Tuckerbox	R
Yowie	R

Disease resistance order from best to worst: R > R–MR > MR > MR–MS > MS > MS–S > S > S–VS > VS

Source: Agriculture Victoria

8.2.3 Damage caused by CCN

In serious outbreaks of CCN, it may be important to avoid cereals for two years to ensure an adequate reduction in the population. Just two CCN eggs per of gram soil can cause significant economic loss to intolerant cereal crops. Levels of 1–5 eggs/g soil can reduce yield of intolerant cultivars by up to 20% (Photo 9). [42]

Photo 9: *Yield loss in a cereal crop due to CCN.*

Photo: Vivien Vanstone. Source: Soilqaulity.org

42 A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soilquality.org, http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

8.2.4 Management

As with other nematodes, there is no effective or economically feasible means of controlling CCN through the application of chemicals. Chemical nematicides are expensive to use and toxic to humans, and the success of applications is highly variable.

Cereal cyst nematode is best controlled through effective rotation management. Only 70–80% of eggs hatch each season, regardless of the crop host. As a result, it can take several years for high CCN levels to be reduced by rotation with resistant or non-host crops. The use of a break crop (e.g. canola, lupins, chickpeas) ensures a large proportion of the CCN population is removed. In serious outbreaks of CCN, it may be important to avoid cereals for two years to ensure an adequate reduction in the population.

Ryegrass, wild oats and other grass are also good hosts for CCN, although reproduction rates may be lower than on the cropping species. For this reason, during a pasture phase in a rotation, it is important to control cereal weeds in the crop so as to contain the development of a CCN population. Likewise, any grasses present following summer rains or around paddock borders, it provides a carryover for the nematode population.

Maintaining optimum soil fertility also helps to minimise the effects of CCN. Allowing the emerging crop access to adequate nutrition allows the root systems to establish and get ahead of potential nematode infections. Although this does not decrease the nematode population, losses associated with CCN infections will be minimised.

Finally, in paddocks where there is a known population of cereal cyst nematode and the planting of a cereal cannot be avoided, it is important to choose cultivars that have CCN resistance. [43]

Disease breaks for CCN

The best disease breaks against CCN are:

- grass-free pulse and oilseed crops or legume pasture;
- resistant cereals; and
- chemical fallow prepared early in the season before nematodes have produced viable eggs. [44]

8.3 Nematodes and crown rot

While all winter cereals host the crown rot fungus, the degree of yield loss due to infection varies with the cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [45]

Many trials concentrate on crown rot alone, but in the Northern Region, it is becoming more important to build a picture of the interaction of crown rot with other factors, especially in combination with *Pt* levels. As well as reducing yield, *Pt* reduces grain quality and nitrogen-use efficiency, and increases the severity of crown-rot infections. [46]

The Northern Grower Alliance has been involved in numerous field trials since 2007, and in collaboration with NSW DPI, has evaluated the impact of crown rot on a range of winter-cereal crop types and varieties.

This work has greatly improved understanding of the impact of crown rot and of variety tolerance, and has also indicated that growers may be suffering significant yield losses from another ‘disease’ that often goes unnoticed. This appears to be Pt.

43 A Wherrett, V Vanstone (2016) Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

44 CropPro. Cereal cyst nematode. GRDC, http://www.croppro.com.au/crop_disease_manual/ch03s03.php

45 GRDC (2016) Crown rot in winter cereals—Southern region. Tips and Tactics. GRDC, https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals

46 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. Issue 104, May–June 2013. GRDC, https://grdc.com.au/resources-and-publications/groundcover/gc104/balancing-crown-rot-and-nematodes-in-wheat

Although the trials had not been designed to focus on nematodes, a convincing trend was apparent after 2008 that *P. thornei* was having a frequent and large impact on wheat variety yield. [47]

Where Pt combines with high levels of crown rot, a common scenario, yield losses can be exacerbated if varieties are susceptible to Pt. Instead of a 10% yield loss in a susceptible variety from Pt alone, losses could amount to 30–50% if crown rot is combined with a Pt-intolerant variety (Photo 10). The research has shown that Pt numbers can increase much faster than in an area in which tolerant varieties are growing. These increased Pt numbers can lead to even greater damage in future crops. [48]

Photo 10: *Grass plant showing both parasitic nematode damage to roots and crown rot in above-ground tissues.*

Source: North Carolina State University

VIDEOS

WATCH: GCTV9: Crown rot and root-lesion nematodes

WATCH: Over the Fence North: Drew Penberthy

8.3.1 Management

Variety choice is the key management option when it comes to managing Pt risk. However, when it comes to crown rot management, although varieties have some impact, rotation and stubble management are by far our most important management tools. [49]

Soil testing

Crown Analytical Services has the first Australian commercial test for crown rot. It is based on five years of laboratory research.

Crown rot causes significant yield losses. The frequency of the disease has increased in recent years due to continuous cropping of wheat. Some of the current strategies for managing it are to control grass hosts prior to cropping, rotate susceptible cereals with non-host break crops, burn infected stubble, and grow tolerant wheat varieties. Therefore, it is very important for crown-rot testing to be carried out on a paddock. It

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

48 B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover. Issue 91, March–April 2011. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union

49 B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover. Issue 91, March–April 2011. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union

allows for growers and consultants to determine if it is present and how severe it is. An informed decision can then be made regarding crop choice and farming system.

Testing involves carrying out a visual assessment on stubble followed by a precise plating test. This is the only way of accurately testing for the disease. Results are provided to the grower and consultant within approximately four weeks of receiving the sample.

Crown Analytical Services provides sample bags and postage paid packs. Go to service's protocol web page to better understand the process.

For more on crown rot, see Section 9. Diseases.

Varietal choice

Research into varietal tolerance to crown rot and nematodes has revealed that choosing a variety is difficult. Determining the relative tolerance of varieties to crown rot is complex, as it can be significantly influenced by background inoculum levels, RLN populations, differential variety tolerance to *Pn* and *Pt,* and varietal interaction with the expression of crown rot. Other soil-borne pathogens such as *Bipolaris sorokiniana*, which causes common root rot, also need to be accounted for in the interaction between crown rot and varieties. Other factors that influence the expression of crown rot in different varieties are starting soil water, rain while the crop is growing, relative biomass production, sowing date and how moisture or temperature stress affect the variety during grainfill.

Growers should consider switching to varieties that can tolerate crown rot. Growers still need to be aware that significant yield loss can occur in the more tolerant varieties when infection levels are high, particularly when plants suffer serious moisture or temperature stressed during grainfill. Current levels of tolerance in varieties are still not a complete solution to crown rot. [50]

50 S Simpfendorfer, M Gardner, G Brooke, L Jenkins (2014) Crown rot and nematodes. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes