WESTERN

MAY 2018

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

TRITICALE

SECTION 8

NEMATODE MANAGEMENT

ROOT-LESION NEMATODE (RLN) | CEREAL CYST NEMATODE | NEMATODES AND CROWN ROT

Nematode management

Key messages

- Triticale is highly resistant to *P. neglectus,* [1] and resistant to *P. thornei*. [2]
- Triticale is thought to be resistant to Cereal cyst nematode (CCN) [3] likely owing to its parent crop, cereal rye. [4]
- Triticale can reduce soil nematodes such as *Pratylenchus neglectus* and *thornei* (root lesion nematodes) and *Heterodera avenae* (cereal cyst nematode). [5]
- Yield losses can be reduced by rotation with resistant and tolerant crops and varieties, good nutrition and sowing early. Variety choice is critical in managing nematode populations in the soil.
- Soil testing is the best way to diagnose nematodes infestations in paddocks and will subsequently inform management decisions.

Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its contribution to soil conservation (Table 1). Triticale assists in maintaining soil health by the reduction of nematodes, such as root-lesion nematodes and cereal cyst nematode. [6]

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

Variety	CCN resistance	*P. neglectus* resistance	*P. thornei* resistance
Astute⚘	R	RMR	MS
Berkshire⚘	-	MR	MS
Bison⚘	R	MR	RMR
Canobolas⚘	-	MR	MSS
Chopper⚘	R	MRMS	MSS
Endeavour⚘	-	MR	SVS
Fusion⚘	R	RMR	MS
Goanna	R	MRMS	SVS
KM10	-	MR	MSp
Rufus	R	MSS	MSS
Tahara	R	MR	S
Tobruk⚘	-	MR	SVS
Tuckerbox	-	MRMS	S
Yowie	R	MR	MSS

Maturity: E = early, M = mid season, L = late, VL = very late Height: M = medium, T = tall Colour: W = white, Br = brown Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS. p = provisional ratings - treat with caution. R = resistant, M = moderately, S = susceptible , V = very. # Varieties marked may be more susceptible if alternative strains are present.

Source: Agriculture Victoria

Successful management of cereal diseases and nematodes relies on:

- farm hygiene to keep fields free of root-lesion nematode (RLN).

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

2 Soilquality.org. (2016). Root lesion nematode. http://soilquality.org.au/factsheets/root-lesion-nematode

3 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org.

4 Asiedu, R., Fisher, J. M., & Driscoll, C. J. (1990). Resistance to Heterodera avenue in the rye genome of triticale. *Theoretical and applied genetics*, *79*(3), 331–336.

5 Cooper KV, Jessop RS, Darvey NL in Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org.http://www.fao.org/docrep/009/y5553e/y5553e00.htm

6 Cooper KV, Jessop RS, Darvey NL in Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org. http://www.fao.org/docrep/009/y5553e/y5553e00.htm

- 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 in rotations and to determine RLN species and population density.

- Avoid consecutive susceptible crops in rotations 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 subsequent crops.

8.1 Root-lesion nematode (RLN)

Key points:

- In WA, at least 65% of cropping paddocks (or around 5.7 million hectares) are infested with one or more of the *Pratylenchus* species.
- There are four damaging nematodes present in Western Australia; *Pratylenchus neglectus, P. thornei, P. penetrans,* and *P. quasitereoides* (formerly *P. teres*).
- Root-lesion nematodes cost Australian growers in excess of $250 million/annum.
- Root lesion nematodes reduce development of lateral roots, which decreases the ability of plants to extract water and nutrients.
- Currently, there are no practices that can be applied after a crop is sown, so RLN management is based on:
    - » Rotation with a resistant break crop or pasture to inhibit or reduce nematode reproduction.
    - » In the cropping year, use varieties which are tolerant to the RLN species in your paddock as these suffer little or no yield loss when low or moderate populations of RLN are present in the soil. However, tolerant varieties may still increase RLN numbers. [7]

Pratylenchus spp. are microscopic worm-like organisms less than one-millimetre in length which feed on root tissues. *P. neglectus* is the dominant RLN species in all of Australia's cropping regions. *P. neglectus* has a wide host range, infecting all cereals as well as crops grown in rotation with cereals (grain legumes, pasture legumes and oilseeds). However, nematode multiplication differs both between and within host species. Damage caused by *P. neglectus* impairs root function, limiting water and nutrient uptake, leading to poor growth and yield decline.

Glasshouse trials have been conducted to compare nematode multiplication on roots of triticale, wheat and rye varieties. Roots of triticale were found to contain fewer nematodes than the other cereals. Triticale is thus a useful rotational crop for areas infested with the root lesion nematode. [8]

Triticale is thought to be susceptible to *P. penetrans*, however, this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant laboratories. More research is needed. [9]

Root lesion nematodes emerged as potential problems in cereals (and other crops) after management strategies were implemented to control cereal cyst nematode and take-all. Yield losses are variable, but present estimates for intolerant varieties indicate a 1% yield loss per 2 nematodes per gram soil. *Pratylenchus thornei* (Photo 1) occurs throughout the root zone and is often more damaging than *P. neglectus*, which tends to be concentrated in the top 15 cm of the soil.

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

7 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

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

9 Soilquality.org. (2016). Root lesion nematode. http://soilquality.org.au/factsheets/root-lesion-nematode

three generations of the nematodes are produced each season, with the highest multiplication in spring. [10]

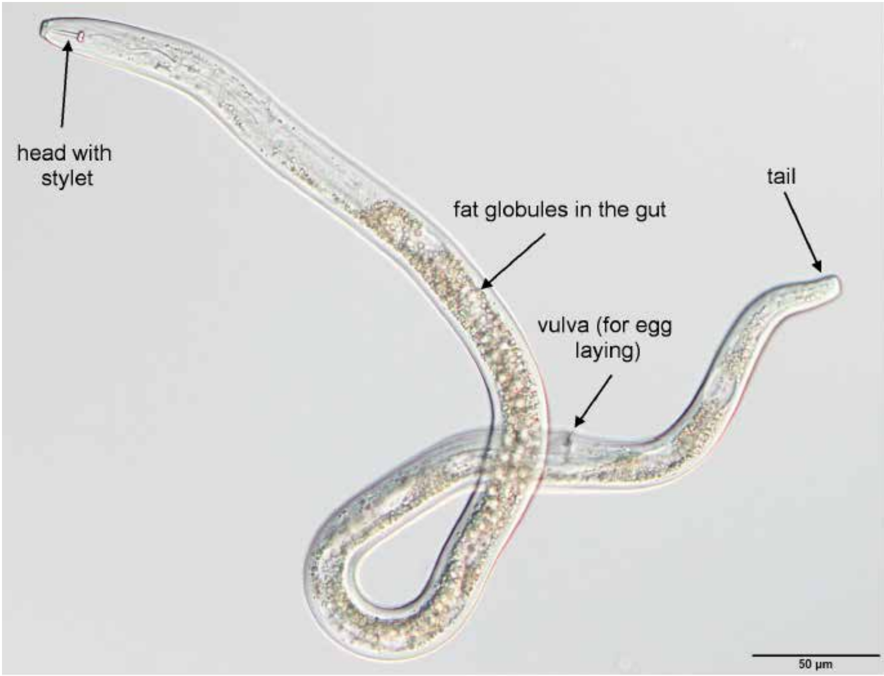


Photo 1: *A Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.*

Source: GRDC

In WA, at least 65% of cropping paddocks (or around 5.7 million hectares) are infested with one or more of the *Pratylenchus* species. In about 40% of cases the nematode is at levels capable of causing crop damage and yield loss of 5–15%. *P. neglectus, P. thornei, P. quasitereoides* and *P. penetrans* have been identified in WA and research is underway to learn more about these species and the rotations that will limit their populations in cropping soils. Forty per cent of RLN identified in WA is *P. neglectus*; 10% *P. quasitereoides* and 10% mixed species. *P. penetrans* is rare in WA but can cause severe damage to some crops. More than one RLN species can be found in the roots of an individual crop, although one species usually dominates. [11]

The extent of RLN occurrence across Australia has recently been estimated (Figure 1).

10 McKay A. (2016). Root lesion nematode – South Australia. http://www.soilquality.org.au/factsheets/root-lesion-nematode-south-australia

11 GRDC. (2009). Plant parasitic nematodes Fact sheet – Southern and western region. Managing cereal cyst and root lesion nematodes.

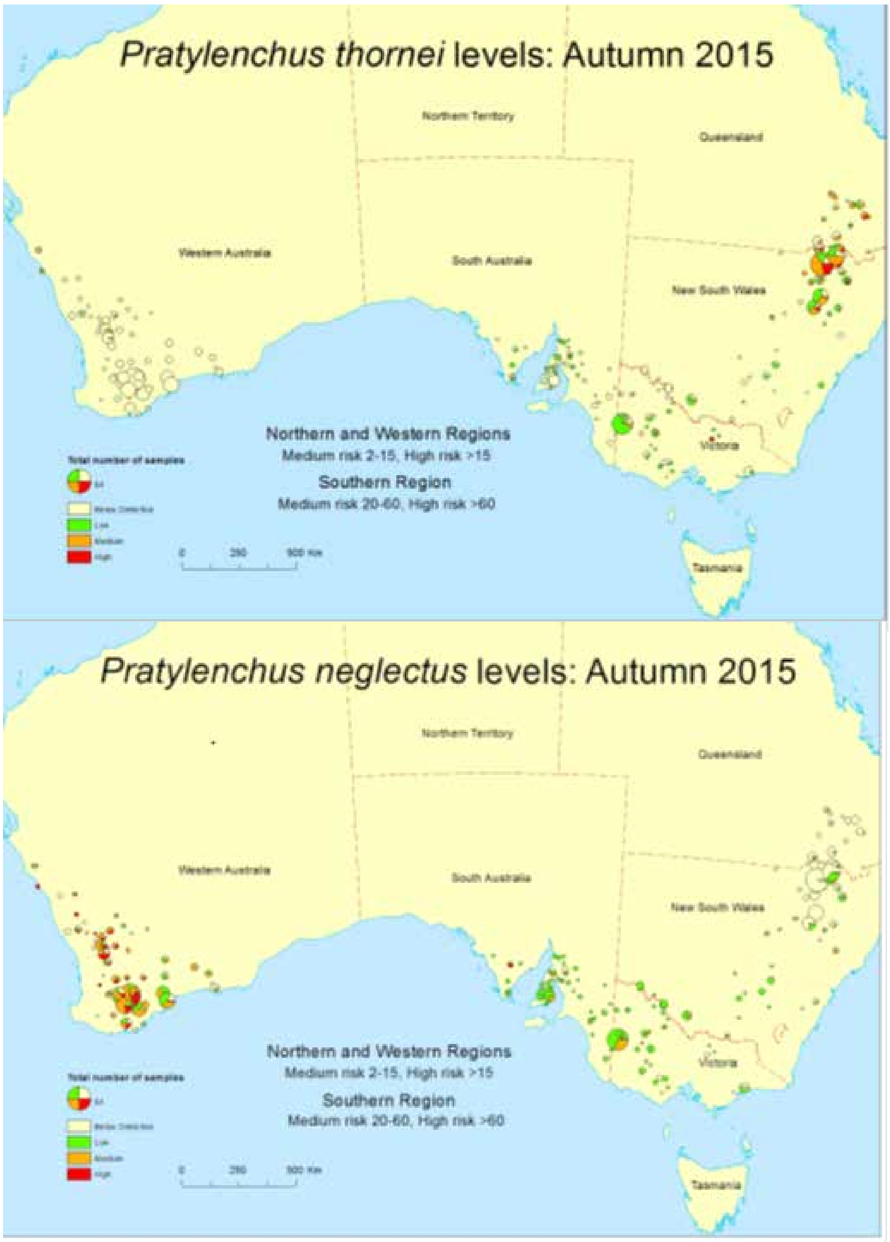


Figure 1: *The distribution and risk of causing yield loss of samples submitted to PreDictaB, SARDI in autumn 2015 for (top)* Pratylenchus thornei *and (bottom)* P. neglectus*.*

Maps are reproduced with permission from SARDI, Source: GRDC

IN FOCUS

Root lesion nematodes in WA

Key points:

- In 2013 RLN species were found in 90% of 130 paddocks surveyed in WA and RLN levels were high enough to cause between 15 and 50% yield loss in 48% of the paddocks assessed.
- This level of infestation may have been caused by a green bridge of volunteer crop species in some areas. Pasture and weeds after March rains may have allowed RLN numbers to increase before crops were sown. Plant stress from the prolonged dry spell in early winter may also have left crops more susceptible to RLN infestation.

RLN levels in a range of crops growing from Northampton in the north to Albany and Esperance in the south were assessed in 2013 at DAFWA trial sites. Data was also collected from Focus Paddocks (50 samples assessed by DAFWA, Nematology) and from samples sent to AGWEST Plant Laboratories. This data was summarised to determine the proportion of paddocks containing plant parasitic nematode species and the severity of infestations. In 2012, a trial site for *Pratylenchus quasitereoides* was identified in Esperance in response to grower observations of yellowing and poor growth in a 40 ha paddock of wheat. The paddock held high levels of *P. quasitereoides* (11,000/g root) which caused approximately 46% yield loss. The trial area was planted in 2013 with canola (cv. Cobbler) to increase *P. quasitereoides* and lupins (cv. Jennabillup) to decrease *P.quasitereoides* populations. The remainder of the paddock was sown with a soft seeded serradella (cv. Cadiz) known to be moderately resistant to *P. neglectus*. At the end of the cropping season, trial plots were sampled to determine if nematode levels had been successfully manipulated.

Results

RLN was identified across all cropping zones in 2013 (Figure 2). RLN species were found in 90% of the 130 paddocks surveyed. *Pratylenchus neglectus* and *P. quasitereoides* were the most common species in 68% and 24% of paddocks, respectively (Table 2). Two or three RLN species were found together in 18% of paddocks, with the most common combination being *P. neglectus* and *P. quasitereoides* (13%). RLN was not detected in 10% of paddocks. Of those infested with RLN, 48% had population densities with the potential to cause yield losses of between 15–50% in wheat. In 18% of paddocks, growers may not have seen visual effects in the crop, but RLN populations densities were sufficient to cause yield losses of up to 15%. Only 24% of the 130 paddocks tested contained a low level of RLN, which would not impact yield but could increase to damaging levels in susceptible cropping sequences.

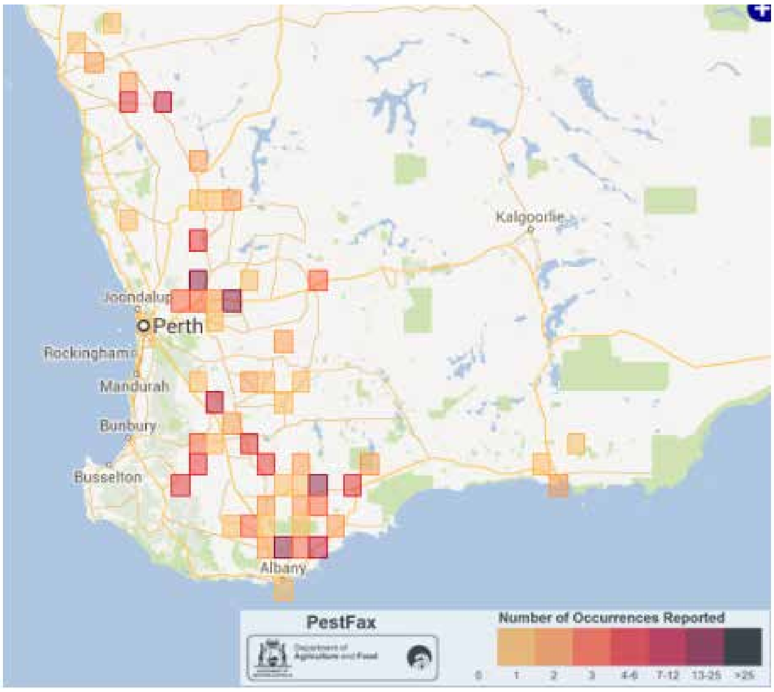


Figure 2: *Occurrence of root lesion nematodes in paddocks surveyed during 2013 in WA. Map adapted from Pestfax Database DAFWA.*

Source: DAFWA

Table 2: *Severity of infestation, total number of paddocks infested and number of paddocks infested with each Pratylenchus species in each severity category from samples taken across broadacre cropping zones of WA in 2013 (April-October, n = 130).*

Source: DAFWA

Severity of Infestation[1]	Total paddocks	P. neglectus[2]	P. quasitereoides	P. thornei	P. penetrans	spp.[3]	NO RLN
0	13 (10%)						13
1	31 (24%)	19	7	0	0	11	
2	24 (18%)	26	8	2	0	0	
3	53 (41%)	37	14	6	2	0	
4	9 (7%)	7	2	0	0	0	
Total with RLN	117 (90%)	89 (68%)	31 (24%)	8 (6%)	2 (2%)	11 (8%)	

1 Severity ratings; 0 = nil, 1 = < 0.2 /mL soil or 0- 200 /g dry root, 2 = 0.2–1 /mL soil or 200–1000 /g dry root, 3 = 1–10 /mL soil or 1000 - 10 000 /g dry root, 4 = > 10 /mL soil or > 10 000 /g dry root.
2 Number does not sum to total number of paddocks sampled as some paddocks contained more than one RLN species.
3 No adult Pratylenchus in sample, therefore species could not be confirmed.

A number of paddocks visited in 2013 for diagnostic assessment had both Rhizoctonia and RLN. These are commonly found together in WA and in combination may be synergistic in causing yield losses. [12]

Researcher's tip

MORE INFORMATION

Tips and tactics: Root-lesion nematodes Western region.

Plant parasitic nematodes factsheet

12 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

VIDEOS

WATCH: Root lesion nematode has a picnic 2013, WA – Sarah Collins.

WATCH: GCTV6: Root-lesion nematodes.

WATCH: Understanding root-lesion nematodes.

8.1.1 Symptoms

Paddock

- Crops appear patchy with uneven growth, and may appear nutrient deficient (Photo 2).
- Double sown and more fertile areas are often less affected.
- There may be stunted growth and waviness across the paddock.

Photo 2: *Poor vigour cereal in high RLN plot (left) compared to healthy plot with low RLN (right).*

Photo: Grant Hollaway) Source: Soilquality.org

Plant

- Affected plants stunted and poorly tillered and can wilt despite moist soil.
- Roots can have indistinct brown lesions or, more often, generalised root browning (Photo 3).
- 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 appearance. [13]
- Unlike the cereal cyst nematode, root lesion nematodes do not cause the roots to swell or knot and no cysts are produced. [14]

13 DAFWA. (2016). Diagnosing Root lesion nematode in cereals. https://www.agric.wa.gov.au/mycrop/diagnosing-root-lesion-nematode-cereals

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

VIDEOS

WATCH: How to diagnose root-lesion nematode.

WATCH: Root-Lesion Nematodes. Resistant cereal varieties have surprising impacts on RLN numbers.

MORE INFORMATION

Diagnosing root lesion nematode in cereals

GRDC Update Paper: Root-lesion nematodes; importance, impact and management.

Photo 3: *Discolouration and lack of lateral roots on cereals is caused by root lesion nematodes.*

Photo: Frank Henry. Source: Soilquality.org

8.1.2 Varietal resistance

Triticale is highly resistant to *P. neglectus,* [15] resistant to *P. thornei*. [16]

Triticale is thought to be susceptible to *P. penetrans*, however, this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant laboratories. More research is needed. [17]

See Table 1 for Triticale variety resistance ratings to nematodes, where known.

Limited information is available on the resistance of crops to *P. quasitereoides*. However, lupins are generally resistant, whilst cereals and canola are generally susceptible. Crops that are resistant to *P. penetrans* are often highly susceptible to *P. neglectus* or *P.quasitereoides* highlighting the importance of knowing which species of RLN is present, as management of one RLN species may be causing an increase in another. [18]

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

16 Soilquality.org. (2016). Root lesion nematode. http://soilquality.org.au/factsheets/root-lesion-nematode

17 Soilquality.org. (2016). Root lesion nematode. http://soilquality.org.au/factsheets/root-lesion-nematode

18 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

8.1.3 Thresholds for control

The damage threshold has been estimated at 2,000 nematodes/kg soil (or 2/g soil). Control is warranted for paddocks with populations over this density threshold. [19]

8.1.4 Conditions favouring development

Nematodes can spread through a district in surface water (e.g. floodwater) and can be moved from one area to another in soil adhering to vehicles and machinery. 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 subsequent crops can be significantly reduced.

8.1.5 Management of RLN

Key points:

- Know your enemy - soil test to determine whether RLN are an issue and which species are present
- Select wheat varieties with high tolerance ratings 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 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 (Figure 3).
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 (go to nvtonline.com.au). Tolerant varieties grow and yield well when RLN are present.
4. Rotate with resistant crops to prevent increases in root-lesion nematodes. 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.

19 GRDC. (2015). Tips and tactics: Root lesion nematodes Western region. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/03/tt-rootlesionnematodes

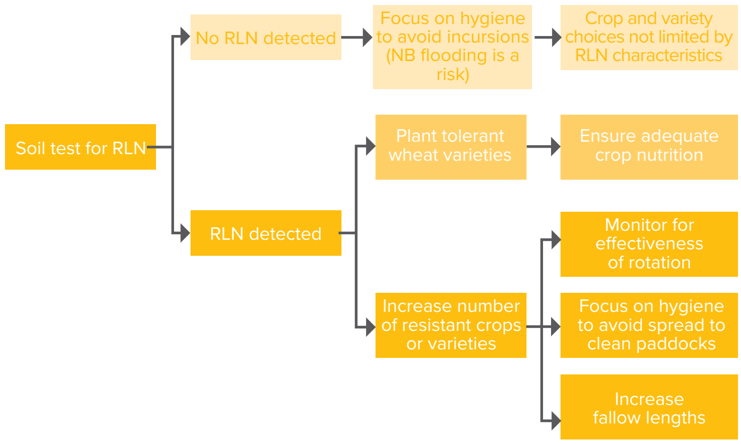


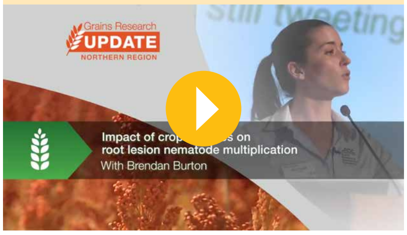
Figure 3: *RLN management flow chart - A simplified chart that highlights the critical first step in the management of RLN is to* **test your soil and determine whether or not you have an issue to manage**. *NB where RLN are present, growers should focus on both 1) planting tolerant wheat varieties and 2) increasing the number of resistant crops/varieties in the rotation.*

Source: GRDC

VIDEOS

WATCH: Root lesion nematodes – What can I do?

WATCH: Crop variety effect on nematode.



There are four major control strategies against RLN:

5. **Nutrition**: damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Under fertilising is likely to exacerbate RLN yield impacts however over fertilising is still unlikely to compensate for a poor variety choice.
6. **Variety choice and crop rotation:** *These are currently our most effective management tools for RLN.* However the focus is on two different characteristics - *Tolerance* (ability of the variety to yield under RLN pressure) and *Resistance* (impact of the variety on the build-up of RLN populations). NB varieties and crops often have varied tolerance and resistance levels to various *Pratylenchus* spp.
7. **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 Mycorrhizal (VAM) levels and create more cropping issues than they solve.
8. **Nematicides** (control in a drum): there are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted but RLN are a very difficult target with populations frequently deep in the soil profile. [20]

Soil testing

Make use of available testing services to determine nematode species and levels, but be aware that PreDicta-B™ cannot currently detect *P. quasitereoides* in WA crops. Paddocks can be sampled at the end of the season to determine if RLN populations have been sufficiently reduced. AGWEST Plant Laboratories can conduct in-season nematode diagnoses. [21]

PreDictaB

Cereal root diseases cost grain growers in excess of $200 million a year in lost production. Much of this can be prevented.

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

21 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

PreDicta B (B = broadacre) is a DNA-based soil testing service that identifies which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 4).

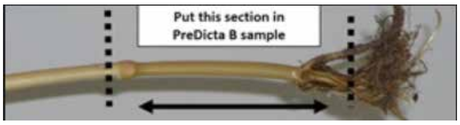


Photo 4: *Sampling for PreDicta B*

Source: GRDC

PreDicta B includes tests for:

- Take-all (*Gaeumannomyces graminis var tritici (Ggt)* and *G. graminis var avenae (Gga)*).
- Rhizoctonia barepatch (*Rhizoctonia solani AG8*).
- Crown rot (*Fusarium pseudograminearum and F. culmorum*).
- Blackspot of peas (*Mycosphaerella pinodes, Phoma medicaginis var pinodella* and *Phoma koolunga*).

Access PreDicta B testing service

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

SARDI processes PreDicta B samples weekly between February to mid-May (prior to crops being sown) every year.

These timeframes help assist growers with their cropping programs.

PreDicta B is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services.

DDLS – plant pathology services

DDLS - Plant pathology (formerly part of AGWEST Plant Laboratories) is a service area under the DAFWA Diagnostic Laboratory Services (DDLS) and an amalgamation of DAFWA plant and animal laboratory and inspection services.

DDLS provide critical disease diagnostics services for broadacre crops (cereals, canola and pulses), pastures and horticulture (ornamentals, nursery plants, amenity horticulture, turf, soil, fruits and vegetables).

Provides:

- routine plant disease diagnosis in plants, potting mix, soil and water
- nematode analysis of roots and soils for horticulture and broadacre crops
- plant virus identification
- specific disease testing for seed crops to meet export requirements
- plant pathogen testing to fulfil nursery accreditation and export requirements.

After diagnosis, DDLS can direct you to specialists to:

- Implement best practice pest and disease control.
- Reduce your use of incorrect or unnecessary chemicals.

MORE INFORMATION

DDLS – Plant pathology services.

Crop rotation

If there are high to very high RLN levels in a paddock, >10 nematodes/mL of soil or >10 000 nematodes/g dry root (severity score 3 & 4), DAFWA recommends growing a MR-R crop or pasture for one to two cropping seasons to reduce nematode numbers to a level that is not yield limiting (Table 3). Resistant crops reduce nematode numbers and may allow a tolerant varieties to be planted in the future. Do not sow susceptible crops where RLN populations are at damaging levels. Where there are low or moderate levels of RLN in a paddock then resistant crops, or tolerant cultivars of a susceptible or moderately resistant crop, may be suitable (refer to Crop Variety Sowing Guides). However, susceptible and moderately resistant crops are likely to increase RLN populations and adversely affect yield of subsequent crops. [22]

Table 3: *Reaction of major crop and pasture species to Pratylenchus neglectus, P. quasitereoides and P. penetrans.*

	P. neglectus		P. quasitereoides *	P. penetrans *
Susceptible	**Moderately susceptible**	**Resistant**	**Susceptible**	**Susceptible**
Wheat	Barley	Field Pea	Wheat	Wheat
Canola	Oat	Narrow-leafed lupin	Barley	Oat
Chickpea	Medic	Faba and Narbon bean	Oat	Field pea
Mustard	Durum wheat	Lentil	Canola	Faba bean
Biserulla	Common vetch	Lathyrus		Narrow-leafed lupin
	Trigonella	Triticale		Chickpea
		Rye		Durum wheat
		Safflower		Triticale
		Clover and Lotus	**Moderately susceptible**	**Moderately susceptible**
		Legume pastures**	Narrow-leafed lupin	Barley
			Field pea	Canola
				Triticale

Source: GRDC

Weed control

It is important when planting resistant crops to ensure that susceptible weeds and volunteers are completely removed as, even at low densities, these may provide enough roots for RLN to multiply and remain at damaging levels. [23]

8.2 Cereal Cyst Nematode

Key points:

- Triticale is thought to be resistant to Cereal cyst nematode (CCN) [24] likely owing to its parent crop, cereal rye. [25]
- CCN is a threat to cereals in the Western and Southern growing regions.
- CCN is most damaging in low rainfall districts/seasons, especially with late breaks.
- Rotations — use break crops to minimise carry-over of CCN host species (canola, lupins, chickpeas etc) 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 during your rotation. CCN levels can become damaging after only one or two seasons of a susceptible crop.

22 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

23 Collins S, Wilkinson C, Kelly S, Hunter H, DeBrincat L. (2014). Root lesion nematode has a picnic in 2013. DAFWA.

24 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org.

25 Asiedu, R., Fisher, J. M., & Driscoll, C. J. (1990). Resistance to Heterodera avenue in the rye genome of triticale. *Theoretical and applied genetics*, *79*(3), 331–336.

- Grow resistant cereal cultivars to limit levels of CCN in the soil.
- Control volunteer cereal hosts and grass weeds during late summer/early autumn and in break crops.
- Sow early where possible to ensure better root development.
- Maintain optimum soil fertility to 'get-ahead' of CCN infections.

Cereal Cyst Nematode is a pest of graminaceous crops worldwide. This nematode is found in the Northern and Central regions of Western Australia. CCN becomes more problematic in areas where intensive cereal cropping occurs. Cereal cyst nematode will only infect, feed and develop on cereals and other grasses (particularly wild oat). Non-cereal crops will 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.

CCN juveniles hatch from eggs contained in the cysts remaining from previous seasons 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 roots and begin feeding. Following mating, the females produce eggs within their body. As the season progresses the females remain feeding at the same infection site and begin to swell into the characteristic white spheres. This process takes 6 – 9 weeks, and the CCN females remain like this until the host plant begins to senesce. The females die and their cuticle hardens and turns brown to form a cyst. Cysts are particularly hardy, and remain in the soil over summer until temperatures fall and the autumn rains begin which stimulates hatching of the next generation. Cereal cyst nematodes have only one life cycle per year (Figure 4). However, each cyst contains several hundred eggs, so populations can increase rapidly on susceptible cereals. [26]

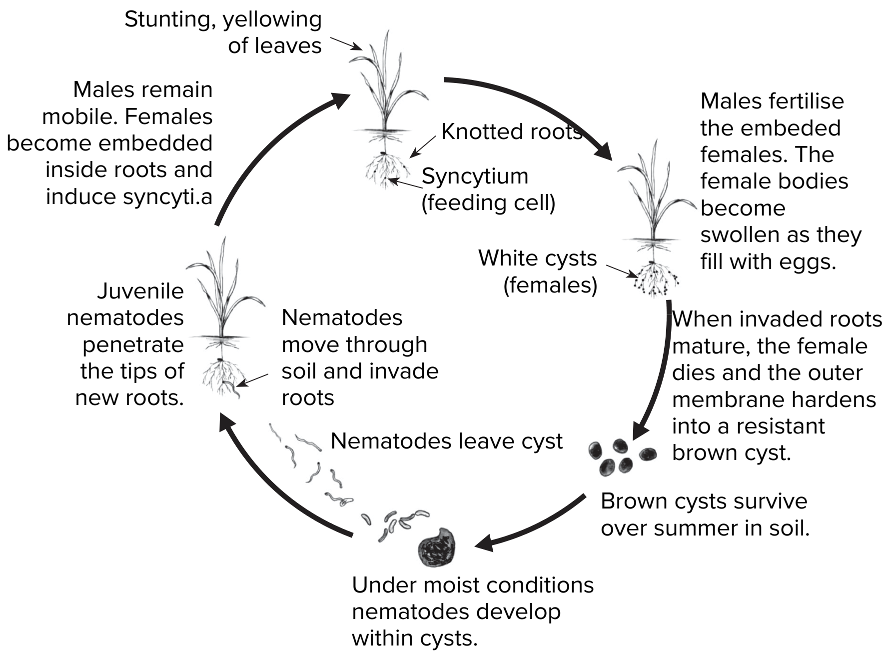


Figure 4: *Life cycle of the cereal cyst nematode.*

Source: Adapted from Kylie Fowler

CCN survives between susceptible cereal crops as eggs inside protective cysts that form on the roots of host plants. In the autumn, nematodes hatch from eggs in response to moisture and low temperatures (<15°C). Nematodes hatch over a period of several weeks, with the peak hatch occurring about six weeks after the autumn

26 Wherrett A and Vanstone V. Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

break. In a further eight weeks these nematodes will form viable eggs. Therefore, to prevent CCN multiplying, it is necessary to control host plants within 10 weeks of crop germination.

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 (drought) conditions up to 50% of nematodes remain dormant, and an extra year of 'break' crop is advisable. [27]

8.2.1 Symptoms and detection

Above ground, patches of unthrifty yellowed and stunted plants can be observed (Photo 5). Planting a susceptible crop in successive years will result in these patches becoming larger with time.
Closer examination of the roots will reveal symptoms that are typical of CCN. Below ground, cereal roots can appear 'knotted' (Photo 6), and 'ropey' or swollen (Photo 7). Development of 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 and washed free of soil. These are the swollen bodies of the female CCN, each containing several hundred eggs. [28]

Photo 5: *CCN will cause distinct patches of yellowed and stunted plants. Note the likeness of symptoms to poor nutrition or water stress. (Photo by Vivien Vanstone, DAFWA, Nematology).*

Source: Soilquality.org.

27 Hollaway G, Henry F. (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

28 Wherrett A and Vanstone V. Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

Photo 6: *CCN produce 'knotting' of cereal roots.*

Photo by Vivien Vanstone, DAFWA, Nematology, Source: Soilquality.org

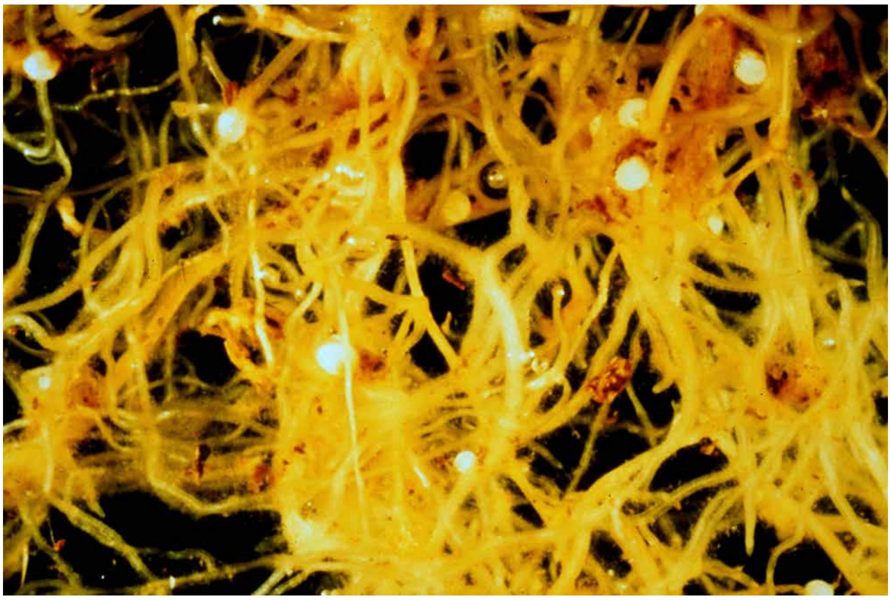


Photo 7: *Cereal roots infected with CCN appear 'ropey' and swollen.*

Source: CropPro

MORE INFORMATION

Diagnosing cereal cyst nematode

8.2.2 Varietal resistance or tolerance

Triticale is thought to be resistant to Cereal cyst nematode (CCN) [29] likely owing to its parent crop, cereal rye. [30]

8.2.3 Damage caused by CCN

CCN affects triticale, wheat, barley and oat varieties and can cause yield loss of up to 80% in intolerant varieties. [31] In serious outbreaks of CCN, it may be important to avoid cereals for two years to ensure an adequate reduction in the population. Just

29 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org.

30 Asiedu, R., Fisher, J. M., & Driscoll, C. J. (1990). Resistance to Heterodera avenue in the rye genome of triticale. *Theoretical and applied genetics*, *79*(3), 331–336.

31 GRDC. (2009). Plant parasitic nematodes Fact sheet – Southern and western region. Managing cereal cyst and root lesion nematodes.

two CCN eggs per of gram soil can cause significant economic loss to intolerant cereal crops. Levels of 1 – 5 eggs per gram of soil can reduce yield of intolerant cultivars by up to 20%. [32]

8.2.4 Management

Plan ahead and make sure there is at least a two-year disease break following susceptible cereals on paddocks infested with wild oats. Timing of host removal is critical when establishing a disease break. In calculating the critical date to chemical fallow or remove host species from break crops consideration should be given to the time taken for host plants to die after herbicide application. Nematodes will continue to feed until the plant is dead.

Host plants, particularly wild oats and susceptible self-sown cereals, must be controlled before the nematodes have completed the development of eggs. This is approximately 10 weeks after the autumn break (See Figure 8 above).

The use of resistant cereals and non-host crops, or fallow in rotations as part of a two-year break is an effective method to control CCN.

In areas prone to CCN, it is important to maintain a high proportion of CCN resistant cereals in the rotation.

Disease breaks for CCN

- Grass free pulse and oilseed crops or legume pasture.
- Resistant cereals (See local Cereal Diseases Guide for a list of CCN resistant cereal varieties).
- Chemical fallow prepared early in the season before nematodes have produced viable eggs.

As with other nematodes, there is no effective or economically feasible means of controlling CCN through chemical application. Chemical nematicides are expensive to use, toxic to humans and the success of applications are often 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 is important to realise that during a pasture phase in a rotation, the existence of cereal weeds will assist the development of a CCN population. Likewise, if there are grasses present following summer rains or around paddock borders it provides a carry over for the nematode population.

Ensuring optimum soil fertility is maintained 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 any 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 displaying CCN resistance. [33]

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

33 Wherrett A and Vanstone V. Cereal cyst nematode. Soilquality.org. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

8.3 Nematodes and crown rot

While all winter cereals host the crown rot fungus, yield loss due to infection varies with cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [34]

Many trials concentrate on crown rot, and it is becoming more important to build a picture of the interaction of crown rot with other factors, especially in combination with *P. thornei* levels. As well as reducing yield, *P. thornie* reduces grain quality and nitrogen use efficiency, and increases the severity of crown rot infections. [35]

There have been numerous field trials since 2007 evaluating the impact of crown rot on a range of winter-cereal crop types and varieties. This work has greatly improved the understanding of crown rot impact 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 that indicated *P. thornei* was having a frequent and large impact on crop yields. [36]

Where *P. thornei* 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 from Pt in a susceptible variety it could be 30–50% if crown rot is combined with a *P. thonei*-intolerant variety (Photo 8).

The research has also shown that not only does *P. thornei* cause high yield loss in susceptible varieties, but *P. thornei* numbers can increase much faster than in an area in which tolerant varieties are growing. These increased numbers can lead to even greater damage in future crops. [37]

Photo 8: *Grass plant showing both parasitic nematode damage to roots and crown rot in above ground tissues.*

Source: NCSU

VIDEOS

WATCH: GCTV9: Crown rot and root-lesion nematode.

34 GRDC. (2016). Tips and Tactics: Crown rot in winter cereals – Southern region.

35 Dixon T. (2013). Balancing Crown rot and Nematodes in wheat. Ground Cover Issue 104: May – June 2013. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat

36 R Daniel (2013) Managing root-lesion nematodes: how important are crop and variety choice? Northern Grower Alliance/GRDC Update Paper, 16/07/2013.

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

8.3.1 Management

Variety choice is the key management option when it comes to managing *P. thornei* 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. Root lesion nematodes, need to be taken far more seriously and better factored into crop rotation considerations as well as variety choice. [38]

Soil testing

PreDictaB

Cereal root diseases cost grain growers in excess of $200 million a year in lost production. Much of this can be prevented.

PreDicta B (B = broadacre) is a DNA-based soil testing service that identifies which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 9).

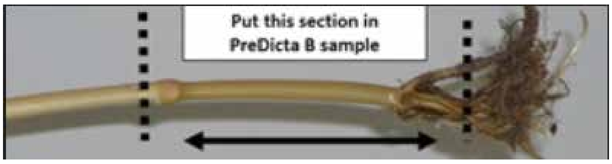


Photo 9: *Sampling for PreDicta B*

Source: GRDC

PreDicta B includes tests for:

- Take-all (*Gaeumannomyces graminis var tritici (Ggt)* and *G. graminis var avenae (Gga)*).
- Rhizoctonia barepatch (*Rhizoctonia solani AG8*).
- Crown rot (*Fusarium pseudograminearum and F. culmorum*).
- Blackspot of peas (*Mycosphaerella pinodes, Phoma medicaginis var pinodella* and *Phoma koolunga*).

Access PreDicta B testing service

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

SARDI processes PreDicta B samples weekly between February to mid-May (prior to crops being sown) every year.

These timeframes assist growers with their cropping program.

PreDicta B is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services.

Varietal choice

Crop rotation and variety choice are the important factors in protection against both diseases. Choosing a variety solely on crown rot resistance is not critical, especially if appropriate management techniques have been carried out, but choice of variety is crucial when it comes to *P. thornei* tolerance.

Further 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 *P. neglectus* versus *P. thornei* 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

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

for in the interaction between crown rot and varieties. Starting soil water, in-crop rainfall, relative biomass production, sowing date and resulting variety phenology in respect to moisture and/or temperature stress during grain-fill can all differentially influence the expression of crown rot in different varieties.

Growers still need to be aware that significant yield loss can occur in more tolerant varieties under high infection levels, particularly when plants suffer serious moisture/ temperature stressed during grain-fill. Some newer varieties have a measurable improvement in their tolerance to crown rot but current levels are still not a complete solution to crown rot. [39]

39 Simpfendorfer S, Gardner M, Brooke G, Jenkins L. (2014). GRDC Update Papers: Crown rot and nematodes – are you growing the right variety? https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes