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TRITICALE

SECTION 8

NEMATODE MANAGEMENT

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

Nematode management

Key messages

- The most important root and crown diseases of cereal crops in southern Australia are cereal cyst nematode (CCN), take-all, rhizoctonia root rot, crown rot and root-lesion nematode (RLN).
- Triticale is highly resistant to *Pratylenchus neglectus* [1] and resistant to *Pratylenchus thornei* [2].
- Triticale is thought to be resistant to cereal cyst nematode (CCN) [3], due to its cereal rye component [4].
- At least 20 % of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield [5], with more than 90 percent of paddocks in the Wimmera and Mallee regions having RLNs present [6].
- 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.
- Triticale can reduce soil nematodes such as *P. neglectus* and *P. thornei* (RLNs) and *Heterodera avenae* (CCN). [7]
- Soil testing is the best way to diagnose nematode infestations in paddocks, and to inform subsequent management decisions.

The most important root and crown diseases of cereal crops in southern Australia are cereal cyst nematode (CCN), take-all, rhizoctonia root rot, crown rot and root-lesion nematode (RLN). These diseases can cause significant yield loss in crops. Fortunately, they can be easily controlled with crop rotation and use of resistant varieties. [8]

Successful management relies on:

- farm hygiene to keep fields free of RLN;
- growing tolerant varieties when RLN are present, to maximise yields; and rotating with resistant crops to keep RLN 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.

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 reducing the presence of nematodes, such as root-lesion nematodes and cereal cyst nematodes. [9]

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1 M Williams (2013) Root out nematodes and get them tested. Grains and Research Development Corporation, 28/10/2013. https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested

2 A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

3 M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/y5553e00.pdf

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

5 G Holloway (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

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

7 KV Cooper, RS Jessop, NL Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/y5553e00.pdf

8 G Hollaway (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

9 KV Cooper, RS Jessop, NL Darvey 'Triticale in Australia' in M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/y5553e00.pdf

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

Variety	CCN resistance	*Pratylenchus neglectus* resistance	*Pratylenchus 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	MS*p*
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

Cereal root disease management in Victoria and southern Australia

Take home messages:

- Minimise losses associated with root diseases by inspection of plant roots in the previous crop or using a PreDicta B soil test prior to sowing to identify at risk paddocks.
- Crown rot will be an important disease during if the season finishes with a dry spring as inoculum levels are high from the previous season. Reduce risk by rotating to non-cereal crops.
- In paddocks with high numbers of root-lesion nematodes, yield losses can be minimised by selecting partially tolerant cultivars and avoiding late sowing. Resistant cultivars can reduce nematode densities and therefore reduce losses in subsequent intolerant crops.
- Cereal cyst nematodes are very damaging if numbers are allowed to increase by growing susceptible cereals.
- Rhizoctonia root rot will likely be a low risk if there is a wet summer with multiple rainfall events, provided summer weeds are controlled.
- Take-all will be a low risk if there is a dry spring, limiting inoculum build up.

Cereal root diseases can have serious impacts on grain yield in the absence of adequate control. The key to preventing root diseases is to identify paddocks at risk by inspecting the roots of previous cereal crops or taking a PreDicta B soil test prior to sowing. Knowledge of the potential root diseases in a paddock then enables the most appropriate control strategies to be implemented prior to and/or at sowing. Management must be implemented prior to sowing as there are no in-crop management options available for the control of root diseases, compared with many foliar diseases. [10]

10 G Hollaway, J Fanning, F Henry, A McKay (2015) GRDC Update Papers: Cereal root disease management in Victoria. Grains Research and Development Corporation, 24/02/2015. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria

8.1 Root-lesion nematodes (RLN)

Key points

- Root-lesion nematodes, *Pratylenchus neglectus* and *Pratylenchus thornei,* are the main root-lesion nematodes causing yield loss in the southern agricultural region of Australia. They often occur together.
- 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.
- Triticale is highly resistant to *P. neglectus,* [11] resistant to *P. thornei* [12].
- At least 20 % of cropping paddocks in south-eastern Australia have populations of RLNs high enough to reduce yield [13], with over 90 percent of paddocks in the Wimmera and Mallee regions having RLNs present [14].
- Wheat is the main host, but varieties vary in resistance and tolerance. Traditional break crops can also be hosts; the host range varies for each *Pratylenchus* species.
- 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.

Root-lesion nematodes (*Pratylenchus spp.*) occur throughout the cereal growing regions of South Australia. RLNs are a genus of microscopic plant parasitic nematode that are soil-borne, ~0.5 to 0.75 mm in length, and will feed and reproduce inside roots of susceptible crops or plants. RLNs are migratory root endoparasites that are widely distributed in the cereal-growing regions of Australia, and can reduce grain yield by up to 50% in many current varieties. There are two common species of RLN in the southern region: *Pratylenchus thornei* (*Pt*) and *Pratylenchus neglectus (Pn)*. They often occur together.

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. In preliminary experiments, a yield loss of 20% has been recorded for an intolerant wheat variety. Trials were conducted at infested sites to determine the ability of cereal species and varieties to multiply the nematode. Further tests were conducted in the glasshouse 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 nematodes. [15]

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. [16]

At least 20% of cropping paddocks in south eastern Australia have populations of RLNs high enough to reduce yield. [17]

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

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11 M Williams (2013) Root out nematodes and get them tested. Grains Research and Development Corporation, 28/10/2013. https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested

12 A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

13 G Hollaway (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

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

15 V Vanstone, M Farsi, T Rathjen, K Cooper (1996) Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow, 557–560 (H Guedes-Pinto, N Darvey, VP Carnide (ed.s)). Springer Netherlands.

16 A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

17 G Hollaway (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

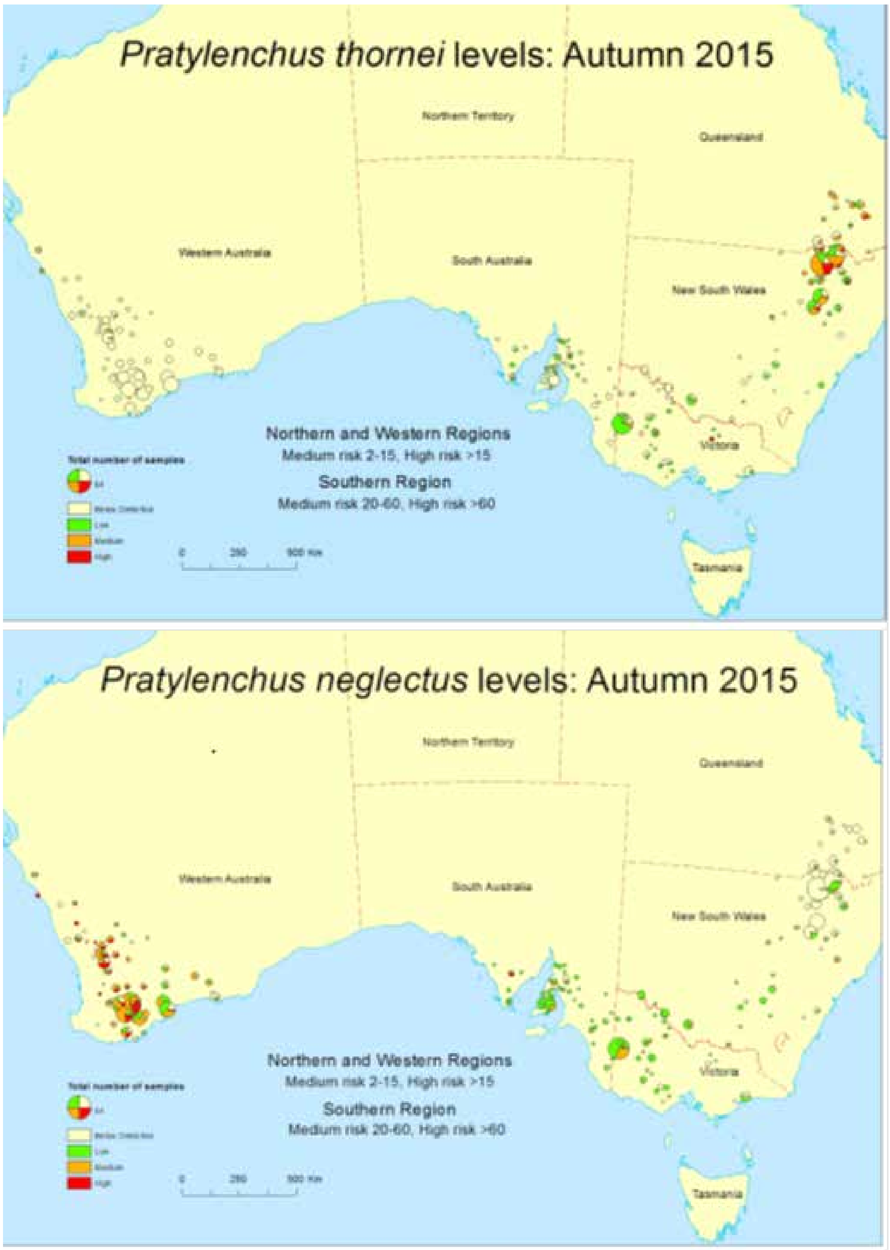


Figure 1: *The distribution of RLNs, based on samples submitted to PreDicta B, SARDI in autumn 2015 for (top) Pratylenchus thornei and (bottom) P. neglectus. These coloured areas may be at a higher risk to RLN infestation. Maps are reproduced with permission from SARDI.*

Source: GRDC

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 in the southern region are variable and currently under investigation, 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.

VIDEOS

WATCH: GCTV6: Root-lesion nematodes

WATCH: Understanding root-lesion nematodes

About three generations of nematodes are produced each season, with the highest multiplication in spring. [18]

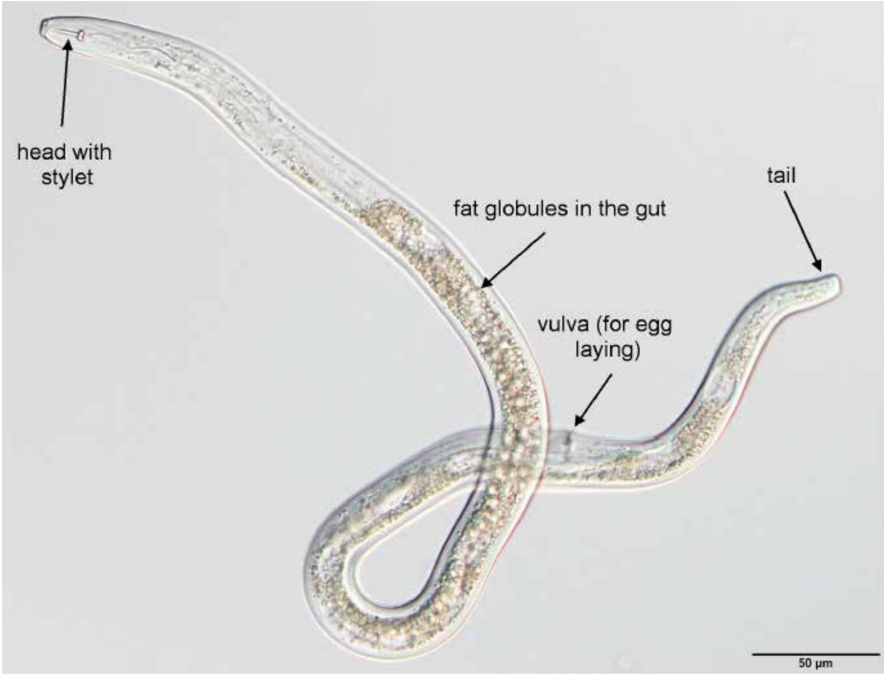


Photo 1: *A Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.*

Source: GRDC

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 with healthy plot with low RLN (right).*

Photo: Grant Hollaway. Source: Soil Quality

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

Plant

- Affected plants are stunted, 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. [19]
- Unlike cereal cyst nematodes, root-lesion nematodes do not cause the roots to swell or knot, and no cysts are produced. [20]

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

Photo: Frank Henry. Source: Soil Quality

VIDEOS

WATCH: How to diagnose root-lesion nematodes.

19 DAFWA (2016) Diagnosing root lesion nematode in cereals. Department of Agriculture and Food, Western Australia, 06/09/2016 https://agric.wa.gov.au/n/2166

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

Soil testing

PreDicta B

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 soil-borne pathogens that pose a significant risk to broadacre crops prior to seeding (Photo 4).

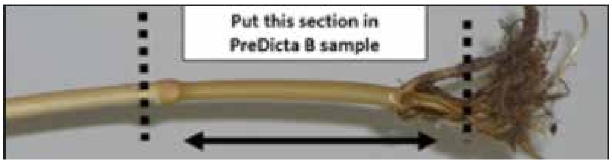


Photo 4: *Sampling for PreDicta B*

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

PreDicta B diagnostic testing services may be accessed through a SARDI-accredited agronomist. They will interpret the results, and provide advice on management options to reduce the risk of yield loss.

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

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

8.1.2 Varietal resistance or tolerance

Triticale is highly resistant to *P. neglectus* [21], and resistant to *P. thornei* [22].

Triticale is thought to be susceptible to *P. penetrans*, but this information is based on preliminary trials and from observations of samples submitted to AGWEST Plant laboratories. More research is needed. [23]

8.1.3 Damage caused by RLN

RLNs are more likely to be a problem when:

- susceptible varieties are grown sequentially, increasing nematode numbers
- an intolerant crop is sown
- sowing is delayed [24]

During recent years, the Department of Economic Development and SARDI have conducted field studies to quantify losses caused by root-lesion nematodes in the Southern cropping region. This work measured grain yield in the presence of

MORE INFORMATION

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

VIDEOS

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

21 M Williams (2013) Root out nematodes and get them tested. Grains Research and Development Corporation, 28/10/2013. https://grdc.com.au/Media-Centre/Media-News/West/2013/10/Root-out-nematodes-and-get-them-tested

22 A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

23 A Wherrett V Vanstone (2016) Root lesion nematode. Soil Quality. http://soilquality.org.au/factsheets/root-lesion-nematode

24 G Hollaway (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

high and low numbers of the target nematode. Table 2 shows the average yield loss caused by root-lesion nematodes in the five most intolerant cereal cultivars in Victorian field trials. There were large seasonal effects observed. The yield losses caused by *P. neglectus* were less than those caused by *P. thornei*.

Table 2: *Average yield loss due to root-lesion nematodes in the five most intolerant cereal cultivars across five growing seasons along with average rainfall.*

	P. thornei **(Banyena)**		***P. neglectus*** **(Dooen)**	
Year	**Yield loss (%)**	**Rainfall (mm)**	**Yield loss (%)**	**Rainfall (mm)**
2011	12.2	241	2.0	256
2012	9.9	268	6.7	254
2013	1.9	353	2.5	326
2014	4.3	253	6.7	215

Source: GRDC

8.1.4 Conditions favouring development

Nematodes can spread through a district in surface water (such as 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 following crops can be significantly reduced.

How long does it take to reduce P. thornei in soils?

Key points:

- *P. thornei* (Pt) populations greater than 40,000 per kg of soil at harvest will requires a double break of around 40 months free of a host to reduce the population below the accepted threshold of 2000 Pt/kg. *P. thornei* populations greater than 10,000 per kg at harvest will requires a single break of around 30 months free of a host to reduce the population below the accepted threshold of 2000 Pt/kg.
- Weeds can be a host, so fallows must be weed-free and free of volunteers.

Cereal cropping trials in the Northern region have highlighted the importance of the initial population when reducing nematode populations below the damage threshold. Over 30 months, the rate of decline in nematode populations with various starting populations and in a particular cropping sequence were monitored. High population of 80 nematodes/cm^3 (~80,000 Pt/kg) took four years to reduce below the threshold of two nematodes per cubic centimetre. This would require two non-host crops such as sorghum and fallows to reduce the population. A moderate initial population of 50 nematodes/cm^3 took three and a half years (Figure 2), requiring the equivalent of a single non-host summer crop and fallows. A population of 20 nematodes/cm^3 took 24 months.

The long survival mechanisms of root-lesion nematodes highlight the importance of knowing 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 time period will increase populations to higher levels that will take longer to reduce, thereby limiting cropping options, and potentially reducing the profitability of the overall farming system. As resistant wheat varieties are released they can be used to provide a winter decline option to increase non-host periods within the rotation. [25]

25 J Which, J Thompson (2016) GRDC Update Paper: How long does it take to reduce *Pt* populations in the soil? https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/how-long-does-it-take-to-reduce-Pratylenchus-thornei-populations-in-the-soil

MORE INFORMATION

How long does it take to reduce Pratylenchus thornei (Root-lesion nematode) population in the soil?

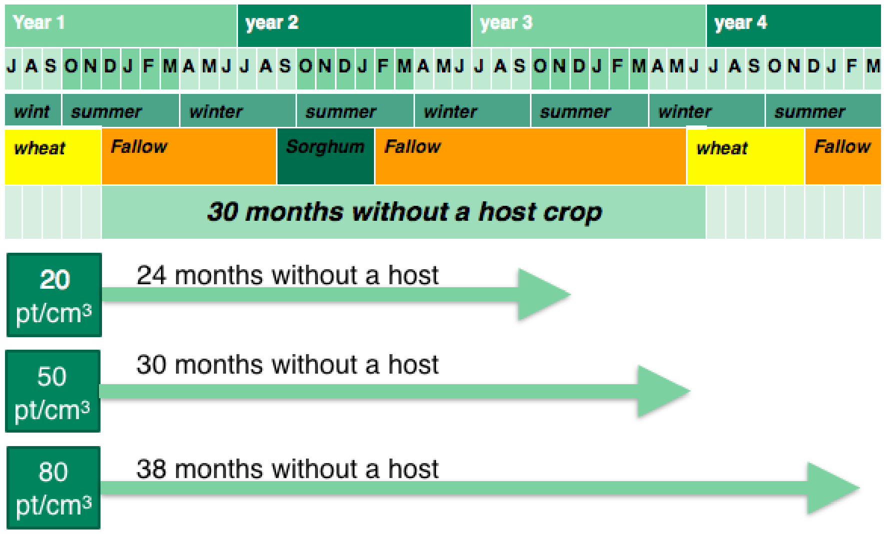


Figure 2: *An example of a non-host fallow showing the time required to reduce different starting populations of root-lesion nematodes.*

Source: GRDC

8.1.5 Thresholds for control

The damage threshold has been estimated at 2000 nematodes/kg soil (or 2/g soil). Control is warranted for paddocks with populations over this density threshold. [26]

8.1.6 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.
2. Protect paddocks that are free of nematodes by controlling soil and water run-off and cleaning machinery; plant nematode-free paddocks first.
3. Choose tolerant wheat varieties to maximise yields (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 (Figure 3, Table 3). 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 the yield potential of tolerant varieties is achieved.

26 GRDC (2015) Tips and tactics: Root lesion nematodes (Southern Region). Grains Research and Development Corporation, 03/03/2015. www.grdc.com.au/TT-RootLesionNematodes

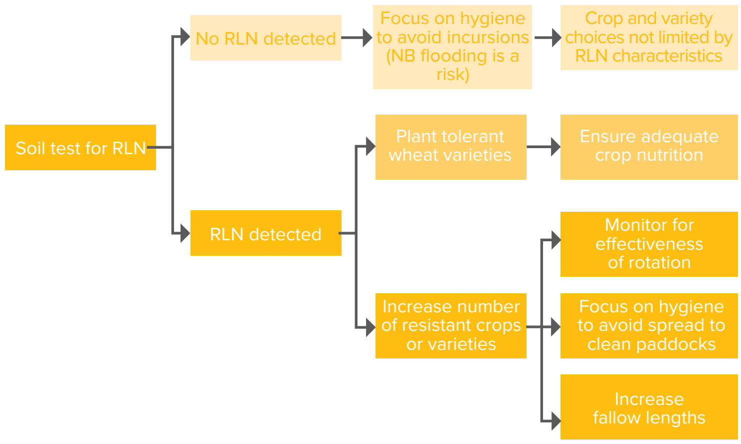


Figure 3: *RLN management flow chart. It highlights the critical first step in the management of RLN, which is to test the soil and determine whether there is an issue to manage. Where RLN are present, growers should focus on both planting tolerant wheat varieties and increasing the number of resistant crops/varieties in the rotation.*

Source: GRDC

Table 3: *Susceptibility of some non-cereal crop and pasture species to root-lesion nematode infection.*

RLN species	Susceptible	Moderately susceptible	Resistant
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—check classification of specific varieties.

MORE INFORMATION

GRDC Tips and tactics: Root-lesion nematodes Southern Region.

There are four major control strategies against RLN:

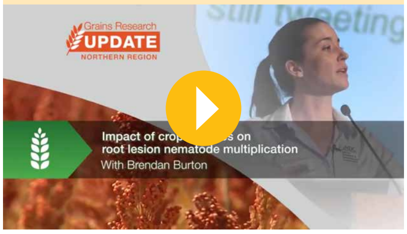
1. **Nematicides** (control in a drum). There are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted but RLN are a very difficult target with populations frequently deep in the soil profile.
2. **Nutrition**. Damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Underfertilising is likely to exacerbate RLN yield impacts, but overfertilising is still unlikely to compensate for a poor variety choice.
3. **Variety choice and crop rotation.** *These are currently our most effective management tools for RLN*, with 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). Varieties and crops often have varied tolerance and resistance levels to *Pt* and *Pn*.
4. **Fallow.** RLN populations will generally decrease during a 'clean' fallow but the process is slow and expensive in lost 'potential' income. Long fallows may also decrease Mycorrhizal (VAM) levels and create more cropping issues than they solve. [27]

27 B Burton, R Norton, R Daniel (2015) GRDC Update Paper: Root lesion nematode; importance, impact and management. Grains Research and Development Corporation, 03/08/2015. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

VIDEOS

WATCH: Root-lesion nematodes – What can I do?

WATCH: Crop variety effect on nematodes



8.2 Cereal cyst nematodes

Key points:

- Triticale is thought to be resistant to cereal cyst nematode (CCN) [28] likely owing to its parent crop, cereal rye [29].
- CCN is a threat to cereals in the Southern and Western 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 (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 during your rotation. CCN levels can become damaging after only one or two seasons of a susceptible crop.
- 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. It is a significant problem across eastern Australia, becoming more problematic in areas where intensive cereal cropping occurs. These nematodes will only infect, feed and develop on cereals and other grasses (particularly wild oat); non-cereal crops will not host CCN, so are useful in rotations to limit damage caused to cereals.

Cereal cyst nematodes usually occur 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 male nematodes remain free-living in the soil, females penetrate roots and begin feeding. After mating occurs, 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 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), but each cyst contains several hundred eggs, so populations can increase rapidly on susceptible cereals. [30]

28 M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/y5553e00.pdf

29 R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to Heterodera avenue in the rye genome of triticale. Theoretical and applied genetics 79(3), 331–336.

30 A Wherrett V Vanstone (2016) Cereal cyst nematode. Soil Quality. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

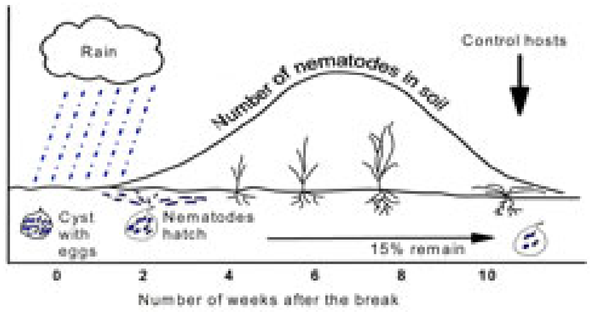


Figure 4: *Life cycle of the cereal cyst nematode.*

Source: AgVic

In the autumn, nematodes hatch in response to moisture and low temperatures (<15°C) over a period of several weeks, with the peak hatch occurring about six weeks after the autumn break. After 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. Under dry (drought) conditions, however, up to 50 % of nematodes remain dormant, and an extra year of 'break' crop is advisable. [31]

8.2.1 Symptoms and detection

The symptoms of CCN infection can be readily recognised. 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. [32]

31 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

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

Photo 5: *CCN will cause distinct patches of yellowed and stunted plants. Note the likeness of symptoms to poor nutrition or water stress.*

Photo: Vivien Vanstone, DAFWA, Nematology. Source: Soil Quality

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

Photo: Vivien Vanstone, DAFWA, Nematology. Source: Soil Quality

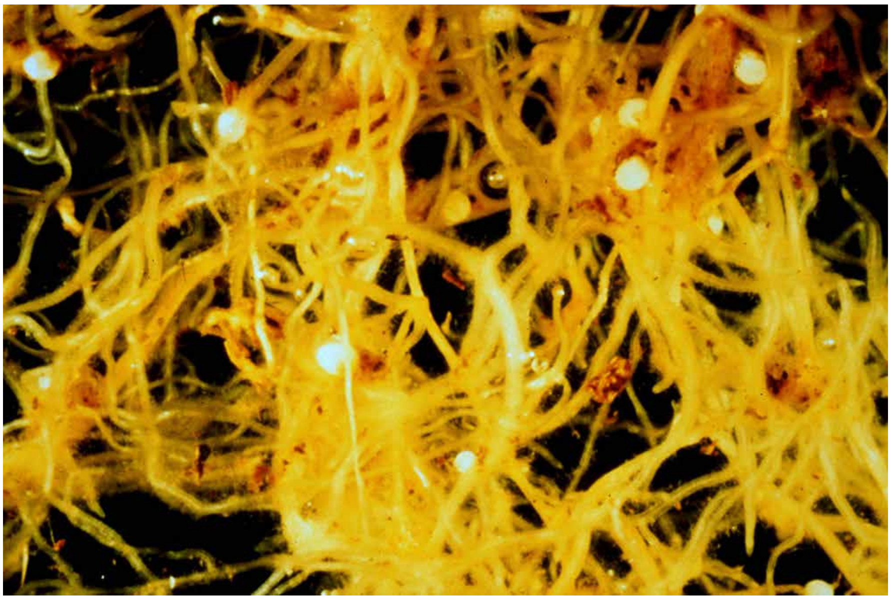


Photo 7: *Cereal roots infected with CCN appear 'ropey' and swollen.*

Source: CropPro

8.2.2 Varietal resistance or tolerance

Triticale is thought to be resistant to cereal cyst nematodes (CCN) [33] due to its cereal rye component [34].

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 per gram of soil can reduce yield of intolerant cultivars by up to 20%. [35]

8.2.4 Management

In general, cereal cyst nematodes (CCN) have been well managed in Victoria through the widespread use of resistant cultivars.

It is recommended to plan ahead for a disease break of at least two years 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).

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, such as the Wimmera and Mallee, it is important to maintain a high proportion of CCN resistant cereals in the rotation.

33 M Mergoum, H Gomez-Macpherson (2004) Triticale improvement and production. FAO Plan Production and Protection Paper 179. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-y5553e/y5553e00.pdf

34 R Asiedu, JM Fisher, CJ Driscoll (1990) Resistance to Heterodera avenue in the rye genome of triticale. Theoretical and applied genetics 79(3), 331–336.

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

Disease breaks for CCN

- grass-free pulse and oilseed crops or legume pasture
- resistant cereals (See the relevant 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 and toxic to humans, and the success of applications are often highly variable. Cereal cyst nematodes are 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 grasses are also good hosts for CCN, although reproduction rates may be lower than on the cropping species. For this reason, it is important to realise that during a pasture phase in a rotation, the existence of grass weeds will assist the development of a CCN population. Likewise, if there are also grasses present following summer rains or around paddock borders, it provides a carryover 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, where there is a known population of cereal cyst nematodes in a paddock, and the planting of a cereal cannot be avoided, it is important to choose cultivars displaying CCN tolerance and preferably resistance as well. [36]

8.3 Nematodes and crown rot

While all winter cereals host the crown rot fungus, the degree of yield loss due to infection will vary depending on cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [37]

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 *Pratylenchus thornei* (*Pt)* levels. As well as reducing yield, *Pt* reduces grain quality and nitrogen use efficiency, and increases the severity of crown rot infections. [38]

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 we may be suffering significant yield losses from another 'disease' that often goes unnoticed.

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

37 GRDC (2016) Tips and Tactics: Crown rot in winter cereals—Southern Region. https://grdc.com.au/~/media/Documents/Resources/Publications/Tips-and-Tactics/GRDC_Tips_and_Tactics_Crown_Rot_SOUTHERN_WEB.PDF

38 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover 104: May–June 2013. Grains Research and Development Corporation, 06/05/2013. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat

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 wheat variety yield. [39]

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 from *Pt* in a susceptible variety, a 30 to 50% loss could occur if crown rot is combined with a *Pt*-intolerant variety (Photo 8).

The research has also shown that not only does *Pt* cause high yield loss in susceptible varieties, but *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. [40]

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 nematodes.

8.3.1 Management

While variety choice is the key management option when it comes to managing *Pt* risk, rotation and stubble management are by far our most important management tools when it comes to crown rot management. Root-lesion nematodes, especially *Pt*, need to be taken far more seriously and better factored into crop rotation considerations as well as variety choice. [41]

Soil testing

PreDicta B

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

39 R Daniel (2013) GRDC Update Paper: Managing root lesion nematodes: how important are crop and variety choice? Grains Research and Development Corporation, 16/07/2013. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

40 B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover 91, March–April 2011. Grains Research and Development Corporation, 01/03/2011. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union

41 B Freebairn (2011) Nematodes and crown rot: a costly union. Ground Cover 91, March–April 2011. Grains Research and Development Corporation, 01/03/2011. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-91-March-April-2011/Nematodes-and-crown-rot-a-costly-union

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

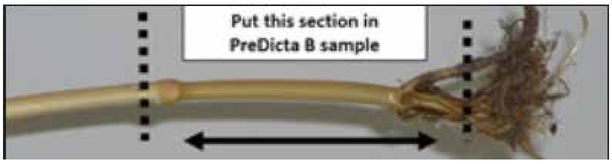


Photo 9: *Sampling for PreDicta B*

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

PreDicta B diagnostic testing services may be accessed through a SARDI-accredited agronomist. They will interpret the results, and provide advice on management options to reduce the risk of yield loss.

PreDicta B samples are processed weekly between February and mid-May (prior to crops being sown) every year.

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

8.3.2 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 RLN 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 *Pn* versus *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. Starting soil water, in-crop rainfall, relative biomass production, sowing date and resulting variety phenology in respect to moisture and/or temperature stress during grainfill can all differentially influence the expression of crown rot in different varieties. [42]

The approximate order of increasing yield loss to crown rot is: cereal rye, oats, barley, bread wheat, triticale and durum wheat. [43]

42 S Simpfendorfer, M Gardner, G Brooke, L Jenkins (2014) Crown rot and nematodes—are you growing the right variety? GRDC Update Papers 6 March 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Crown-rot-and-nematodes

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