NORTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CEREAL RYE

SECTION 8

NEMATODE MANAGEMENT

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

Nematode management

Key messages:

- Rye is resistant to cereal cyst nematodes (CCN) and is a poor host to the root-lesion nematode (*Pratylenchus neglectus*) providing an alternative management approach for these diseases. [1]
- Rye can reduce the amount of CCN in a paddock. In one study, the biggest reduction in CCN numbers occurred in cereal rye (cv. South Australia), which reduced populations by 92% in the first year. [2]
- Root-lesion nematodes (RLN) (*Pratylenchus thorne*i and *P. neglectus*) cost Australian growers in excess of $250 million/annum.
- Rye is a poor host to the RLN (*Pratylenchus neglectus*) providing a break crop for this nematode.
- Variety choice is critical in managing nematode populations in the soil.
- Soil testing is the best way to diagnose nematode infestations in paddocks and will subsequently inform 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.

8.1 Root-lesion nematode (RLN)

Key points:

- Root-lesion nematodes (*Pratylenchus* spp.) are microscopic worm-like animals that extract nutrients from plants, causing yield loss.
- In the Northern Grains Region, the RLNs are found in three-quarters of fields tested—*Pratylenchus thornei* predominates but *P. neglectus* is also found.
- Intolerant crops such as wheat and chickpea can lose 20–50% in yield when nematode populations are high.
- Resistance and susceptibility of crops can differ for each RLN species.
- Rye is a poor host to the RLN (*Pratylenchus neglectus*) providing an alternative management approach for this nematode. [3]
- Successful management relies on:
- farm hygiene to keep fields free of RLN
- growing tolerant varieties when RLNs are present, to maximise yields
- rotating with resistant crops to keep RLNs 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.

Root-lesion nematode are a genus of microscopic plant parasitic nematode that are soil-borne, ~0.5–0.75 mm in length and will feed and reproduce inside roots of susceptible crops or plants. There are two common species of RLN in the Northern Grains Region; *Pratylenchus thornei* (*Pt*) and *Pratylenchus neglectus (Pn)*.

1 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

2 JM Fisher, TW Hancock (1991) Population dynamics of *Heterodera avenae* Woll. in South Australia. Crop and Pasture Science, 42(1), 53–68.

3 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

Root-lesion nematode are migratory root endoparasites that are widely distributed in the wheat-growing regions of Australia and can reduce grain yield by up to 50% in many current wheat varieties.

Rye is a poor host to the RLN (*Pratylenchus neglectus*) providing an alternative management approach for this nematode, [4] especially in southern NSW where this nematode commonly occurs.

P. thornei is the most damaging species and occurs commonly in the Northern Grains Region (Photo 1). *P. neglectus* occurs less frequently than *P. thornei* but is still quite common.

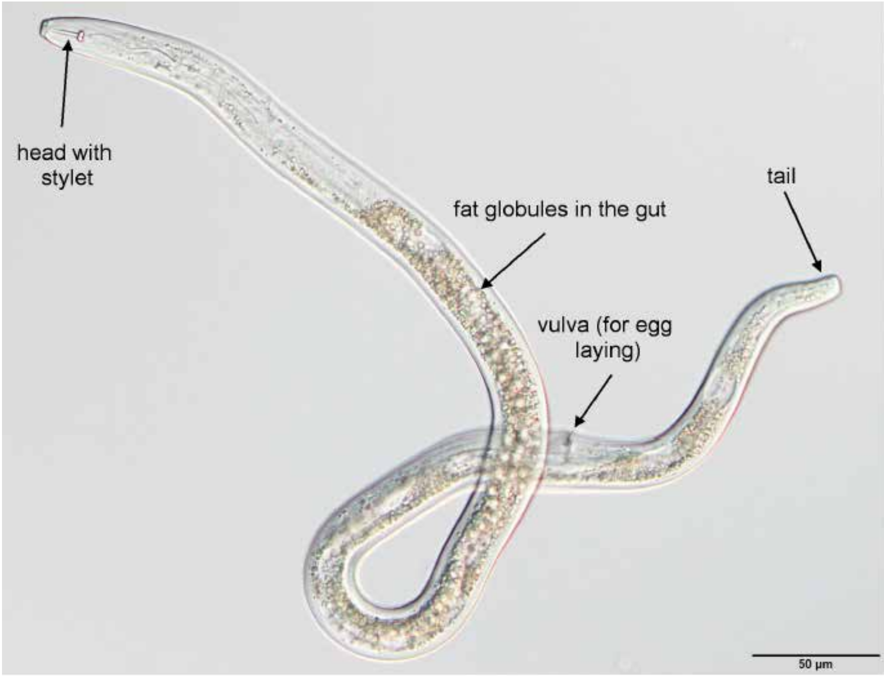


Photo 1: *A Pratylenchus thornei adult female viewed under the microscope. The nematode is approximately 0.65 mm long.*

Source: GRDC

The two species of RLNs occur in the soils of southern Queensland and New South Wales (NSW). In a survey of soil samples from 596 paddocks in this region, 42% had *P. thornei* alone, 27% had both *P. thornei* and *P. neglectus*, 5% had *P. neglectus* alone, while 26% had neither species.

Maps of the distribution of *P. thornei* and *P. neglectus* from samples submitted to PreDicta B™ have been recently generated (Figure 1). Results from autumn 2015 show that *Pratylenchus thornei* is more widely distributed and found in greater, more damaging populations than *P. neglectus* in the Northern Grains Region. In the Northern Region, paddocks with more than 15 *P.* thornei/g soil or 15,000/kg soil by the PreDicta B™ test are considered high risk for crops. However, in the Northern Region, even populations of *P. thornei* classified as medium risk by PreDicta B™, that is 2–15/g soil or 2,000–15,000/kg soil, can cause substantial yield loss of intolerant wheat varieties in warm wet growing seasons conducive to nematode reproduction in the roots. [5]

4 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

5 K Owen, T Clewett, J Sheedy, J Thompson (2016) Managing grain crops in nematode infested fields to minimise loss and optimise profit. GRDC Update Papers 2 March 2016, 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

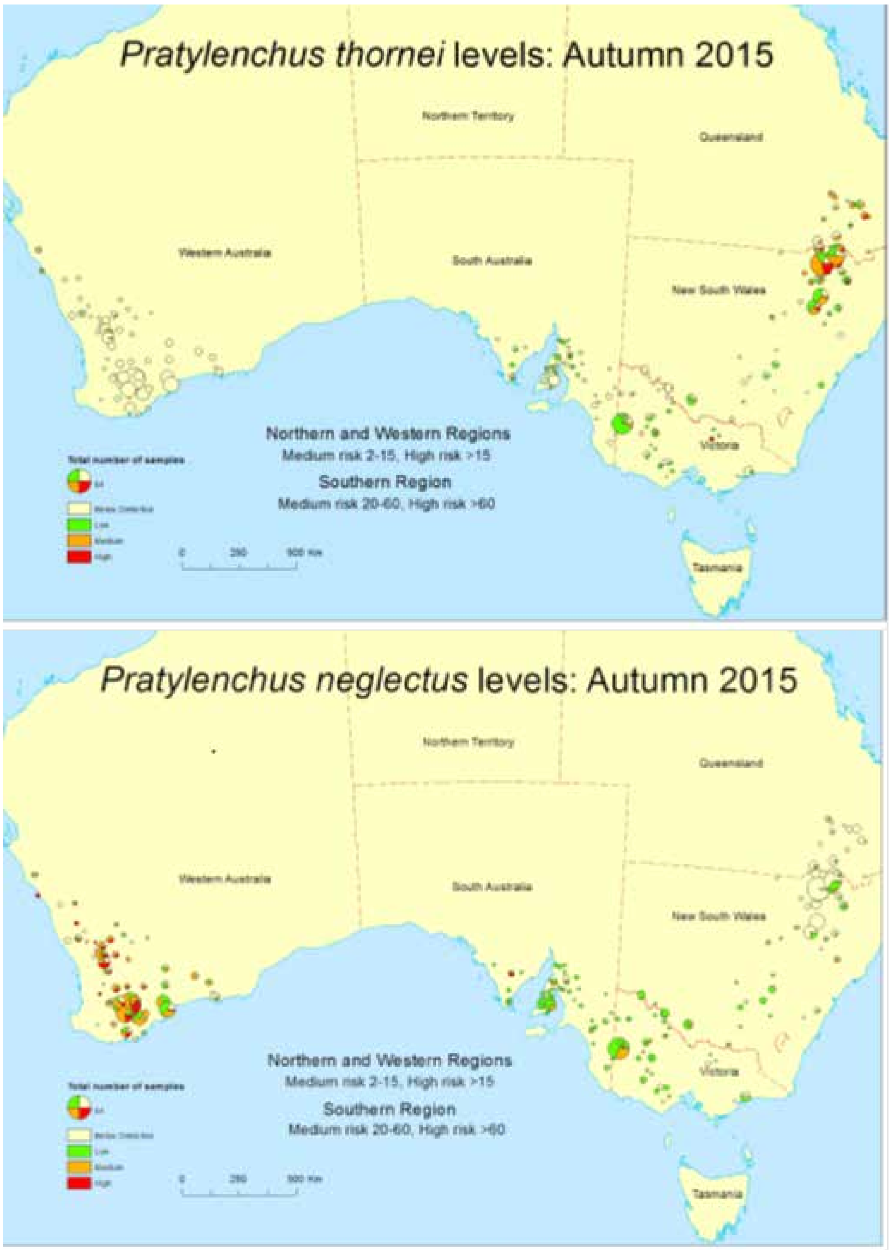


Figure 1: *The distribution and risk of causing yield loss of samples submitted to PreDicta B™, SARDI in autumn 2015 for (top) Pratylenchus thornei and (bottom) P. neglectus.*

Maps are reproduced with permission from SARDI.

Source: GRDC

Other crop species are also hosts of RLNs and care should be taken in sowing susceptible varieties after crops such as black gram and chickpeas in nematode-infested paddocks.

Nematodes penetrate the plant root, digesting the cells' contents and laying eggs within the roots. High populations develop quickly following planting, so that the root systems become inefficient in absorbing water and nutrients. [6]

MORE INFORMATION

Managing grain crops in nematode-infested fields.

VIDEOS

WATCH: GCTV6: Root-lesion nematodes

WATCH: Understanding root-lesion nematodes

6 GRDC (2015) Root-lesion nematodes Northern Region. GRDC Tips and Tactics February 2015, www.grdc.com.au/TT-RootLesionNematodes

Why the focus on Pt?

Pratylenchus neglectus occurs more commonly in southern NSW whereas, *Pratylenchus thornei* (*Pt*) is the most commonly occurring RLN in Queensland and northern NSW.

- *Pt* are widespread in the Northern grains Region. Surveys conducted within NSW and southern Queensland cropping areas consistently show *Pt* presence in ~60–70% of paddocks
- *Pt* are frequently at concerning levels. Found at >2 *Pt*/g soil in ~30–40% of paddocks
- Yield losses in wheat of up to 50% are not uncommon when *Pt*-intolerant wheat varieties are grown in paddocks infested with *Pt*
- Yield losses in chickpeas of up to 20% have also been measured in QDAF trials
- There is no easy solution to RLN infestation. Variety and crop rotation are currently our major management tools [7]

Impact of Pratylenchus thornei, Macalister 2015

Take home messages:

- Multi-crop and variety trials were conducted over strips of 'medium' and 'high' *Pratylenchus thornei* (*Pt*) pressure.
- Site characterised by generally high crop yields (cereals ~4–5.5 t/ha, chickpeas ~3.5–4.0 t/ha) combined with lower levels of *Pt* yield impact.
- Negligible decline in *Pt* population during the 21-month fallow leading up to the winter trials being planted.
- No evidence of yield impact from *Pt* in the brassica, faba bean, chickpea and barley trials.
- Greater yield loss observed in the wheat trials compared to the barley and broadleaf crops at this site.
- Addition of crown rot inoculum together with 'high' *Pt* pressure significantly increased mean yield loss (~30%) over a set of six wheat varieties compared to either the effect from crown rot inoculum alone (~13%) or *Pt* alone (~8%).

This trial was conducted to allow a sound scientific evaluation of the impact of *Pt* on the yield of a broad range of winter crops and varieties and subsequently to measure the crop impact on *Pt* population (i.e. rotational impact and fit). Trial results indicate that there was no significant difference in yield within varieties of canola, faba bean, chickpea and barley between low versus high nematode populations. However, significant yield reductions were recorded for varieties in the early wheat, main wheat and durum National Variety Trials (NVTs). In addition, significant yield losses were also recorded in the CR × RLN interaction trial.

MORE INFORMATION

GRDC Update Paper: Impact from Pratylenchus thornei, Macalister 2015.

8.1.1 Symptoms and detection

Signs of nematode infection in roots include dark lesions or poor root structure. The damaged roots are inefficient at taking-up water and nutrients (particularly nitrogen (N), phosphorus and zinc) causing symptoms of nutrient deficiency and wilting in the plant tops. Intolerant wheat varieties may appear stunted, with lower leaf yellowing and poor tillering (Photo 2).

7 B Burton, R Norton, R Daniel (2015) Root-lesion nematodes: importance, impact and management. GRDC Update Paper 3 August 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

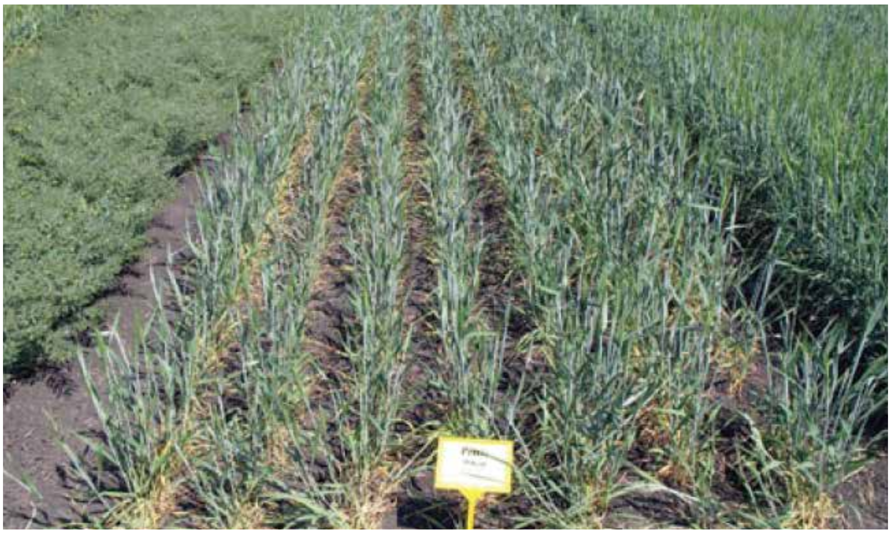


Photo 2: *Symptoms of RLN infection of an intolerant cereal variety include lower leaf yellowing, decreased tillers and wilting. There are no obvious symptoms in the susceptible chickpea and faba bean plots on either side of the wheat.*

Photo: Kirsty Owen, QDAF, Source: Soilquality.org

Crops are patchy, show lower leaf yellowing and appear drought affected and nutrient deficient. As peak nematode numbers often occur at depths in the soil of 30–60 cm, the condition of the plant deteriorates as the roots go deeper. Grain yield can be severely reduced in susceptible varieties.

What to look for

Paddock:

- Crops appear patchy with uneven growth, and may appear nutrient deficient (Photo 3).
- Double sown and more fertile areas are often less affected.

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.
- Badly affected roots are thin and poorly branched with fewer and shorter laterals (Photo 4).
- Roots may appear withered with crown roots often less affected than primary roots.
- Roots can assume a 'noodle-like' root thickening appearance. [8]

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

Photo 3: *Patchiness in crop caused by RLN.*

Photo by V Vanstone, DAFWA, Source: Soilquality.org

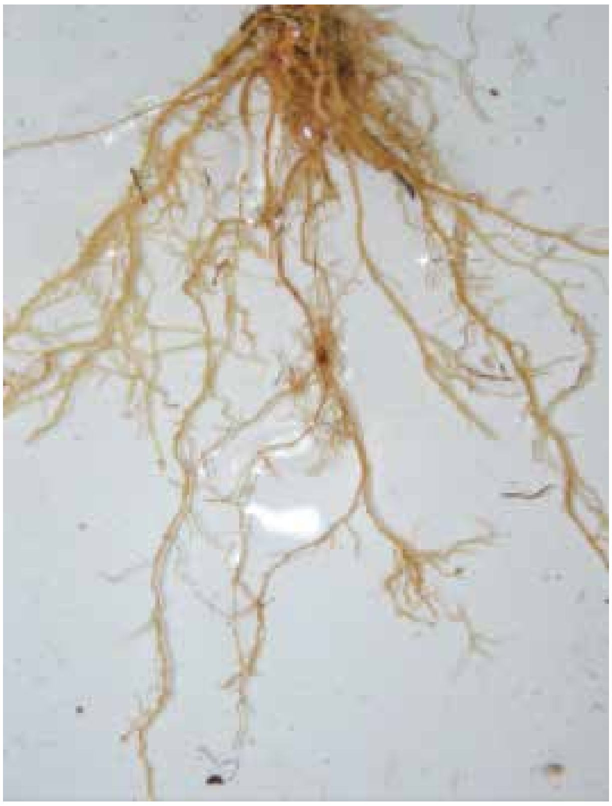


Photo 4: *Cereal roots show general discolouration and reduction in length and number of lateral root branches.*

Photo by V Vanstone, DAFWA, Source: Soilquality.org

VIDEOS

How to diagnose RLN

Soil testing

It is important to know whether nematodes are on your farm and if so, which species are present. This is important because varietal tolerance information for *P. thornei* does not hold true for *P. neglectus*, as they are distinct species.

Proper species identification can help minimise losses that arise from planting intolerant varieties in nematode-infested land.

The Queensland Department of Agriculture and Fisheries (QDAF) Leslie Research Centre can test for and diagnose their presence: Test your farm for nematodes.

Samples for analysis

Since nematodes may not be evenly spread across a paddock, particularly with new infestations, it is important to take samples from several locations within a paddock. For practicality, nine cores bulked in groups of three are recommended.

It is recommended that two layers, 0–15 cm and 15–30 cm, is sampled with either a hand corer or a mattock if no corer is available. Topsoil (0–15 cm) only samples can give inaccurate results and should always be accompanied by a 15–30 cm sample. If deeper samples are already being taken for other analysis (e.g. nitrate), a nematode assessment can be made of the depths 0–30 cm, 30–60 cm and 60–90 cm.

Procedure:

1. Take nine cores across the paddock in two depths, 0–15 cm and 15–30 cm.
2. As you go, bulk the topsoil of the first three cores in one plastic bag labelled A0–15 and in a second bag labelled A15–30, the next three cores as B0–15 and B15–30 and the last three cores as C0–15 and C15–30.
3. Note which parts of the paddock were A, B and C respectively. Break up the soil by hand in a bucket so that all pieces are less than 1 cm in size keeping the six lots separate. About 500 g of soil or more is required in each bag. Seal the bags securely with a twist-tie or string to prevent the soil drying out.
4. Do not expose the bags of soil to heating from sun in the field or in vehicles or from proximity to exhaust pipes etc. Preferably place the soil in a polystyrene box for transport to Leslie Research Centre although a cardboard box or a poly or hessian bag will do if heating is avoided.
5. Fill out the sample submission form with details on the paddock history and forward this with the samples to Leslie Research Centre. Completed forms must be sent with the samples for them to be processed. The centre will then determine which species are present and their population for each of the six soil samples. This will provide a good indication whether RLN are present and likely to pose problems.

Send samples to:

Soil Microbiology Section
Leslie Research Centre
PO Box 2282
Toowoomba Qld 4350
13 Holberton Street
Toowoomba Qld 4350

Phone: 07 4639 8888
Fax: 07 4639 8800

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 which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 5).

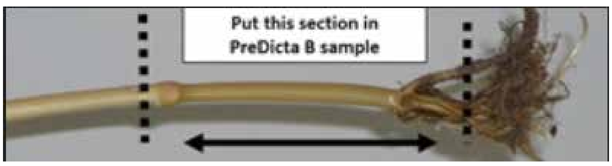


Photo 5: *Add one piece of cereal stubble (if present) to the sample bag at each of the 15 sampling locations – this improves the detection of crown rot. Each piece should be from the base of the plant and include the crown to the first node (discard material from above the first node).*

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 program.

PreDicta B™ is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services. [9]

8.1.2 Varietal resistance or tolerance

Rye is resistant to *P. neglectus* [10] limiting the expansion of this nematode within a paddock. There is limited research on the tolerance of cereal rye to *P. thornei.*

8.1.3 Damage caused by pest

These nematodes can severely affect yields. *P. thornei* is the most common RLN in the Northern grains region and is capable of causing crop damage and yield loss up to 70%, [11] however, cereal rye is unlikely to incur this amount of yield loss.

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 following crops can be significantly reduced.

How long does it take to reduce Pt in soils?

Key points:

- *P. thornei* populations greater than 40,000/kg at harvest will require a double break of around 40 months free of a host to reduce the population below the accepted threshold of 2,000 *Pt*/kg. *P. thornei* populations greater than 10,000/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 2,000 *Pt*/kg.
- Weeds can be a host so fallows must be weed free and free of volunteers.

Following two consecutive wheat crops using wheat cultivars with different levels of tolerance and resistance, a range of nematode populations were created in the soil. At the harvest of the second wheat crop the nematode population from each plot was recorded and characterised as high, (H >20,000 *Pt*/cm^2/1.2 m profile), medium (M >10,000 *Pt*/cm^2/1.2 m profile), low (L >5,000 *Pt*/cm^2/1.2 m profile) and very low populations (VL <5,000 *Pt*/cm^2/1.2 m profile) calculated as the sum of nematodes across the whole profile. Over the next 30 months soil samples were collected from

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.

9 PIRSA, SARDI (2016) PreDicta B™. http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

10 A Wherrett, V Vanstone Root lesion nematode. Soilquality Fact Sheet,Soilquality.org.au, http://soilquality.org.au/factsheets/root-lesion-nematode

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

these plots to monitor the change in nematode population over time. Two 1.8 m soil cores were collected from each plot and divided into eight layers (the top four being of 15 cm and the bottom four of 30 cm). Nematodes were extracted from the soil and manually counted to give a live nematode population estimate for each soil layer. The rotation over the 30 months was long fallow from wheat to sorghum then long fallow from sorghum to wheat. In the fallow commencing in 2011 no sorghum was sown due to drought.

High population of 80 nematodes/cm3 (~80,000 *Pt*/kg) took four years to reduce below the threshold. This would require two non-host crops such as sorghum and fallows to reduce the population. A moderate initial population of 50 nematodes/cm3 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/cm3 took 24 months. The long survival mechanisms of RLN 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. [12]

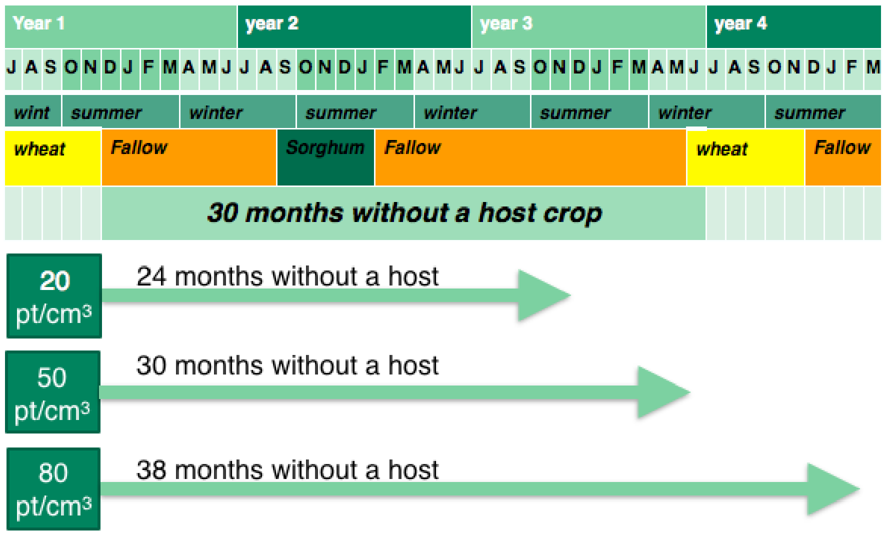


Figure 2: *An example of a non-host fallow showing the time required to reduce different starting populations of RLN.*

Source: GRDC

8.1.5 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. [13]

8.1.6 Management

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

12 J Whish, J Thompson (2016) How long does it take to reduce *Pt* (RLN) population in the soil? GRDC Update Paper 23 February 2016, 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

13 GRDC (2015) Root-lesion nematodes Northern Region. GRDC Tips and Tactics February 2015, www.grdc.com.au/TT-RootLesionNematodes

MORE INFORMATION

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

- 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 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 RLNs. 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.

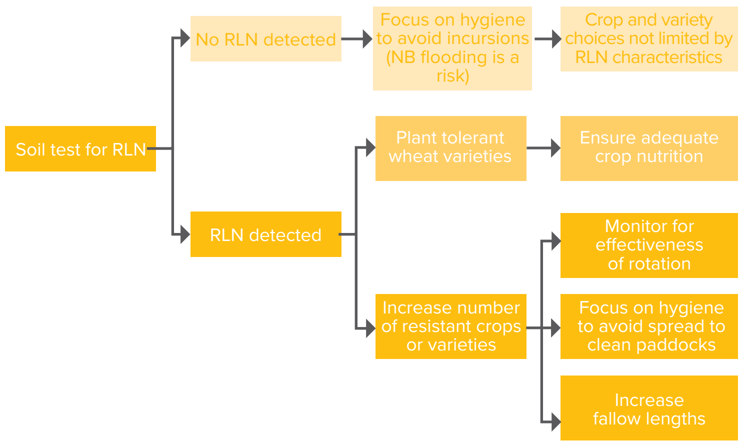


Figure 3: *RLN management flow chart—A simplified chart that highlights the critical first step in the management of RLN is to test your soil and determine whether or not you have an issue to manage. NB where RLN are present, growers should focus on both 1) planting tolerant wheat varieties and 2) increasing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

Source: GRDC

There are four major control strategies against RLN:

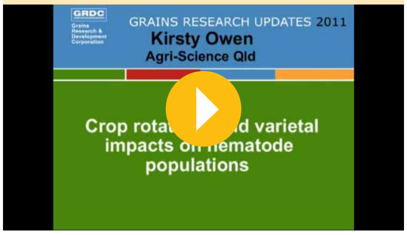
1. *Nematicides* (control in a drum): there are no registered nematicides for RLN in broadacre cropping in Australia. Screening of potential candidates continues to be conducted but RLN are a very difficult target with populations frequently deep in the soil profile.
2. *Nutrition*: damage from RLN reduces the ability of cereal roots to access nutrients and soil moisture and can induce nutrient deficiencies. Under-fertilising is likely to exacerbate RLN yield impacts; however over-fertilising 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.* However the focus is on two different characteristics—*Tolerance* (ability of the variety to yield under RLN pressure)

VIDEOS

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

WATCH: Crop variety effect on nematodes

WATCH: RLN in Northern Region—crop rotation and varietal impacts on nematode populations



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 *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. Additionally long fallows may decrease Mycorrhizal (VAM) levels and create more cropping issues than they solve. [14]

Natural enemies

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

Several key organisms that prey on nematodes have been found in Northern soils, such as *Pasteuria* bacteria that infect and eventually kill *Pratylenchus* spp.

Several species of fungi including some that trap nematodes and predatory nematodes have also been found, all of which have potential to reduce RLN populations.

Research is continuing to develop methods of increasing biological activity to enhance suppressiveness deeper in the profile.

Biological suppression of RLN in northern soils

Key points:

- Biological suppression does occur in most soils tested from the Northern region, showing that populations of *P. thornei* are being 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. Without these practices, it is estimated that RLN multiplication would be significantly greater, especially in top soils, and this would result in much greater losses in the productivity of susceptible crops.
- Several antagonists of *Pratylenchus* were found in Northern grain-growing soils such as nematode trapping fungi, predatory nematodes, parasitic bacteria and root-colonising fungi that enhance the plant's resistance to nematodes. Further research is focussing on these organisms as they are likely to be contributing to the suppressiveness of the soils.

Enhancing the suppressiveness of soil to RLNs is a control option that deserves some consideration. Disease suppression is defined as the ability of a soil to suppress disease incidence or severity even in the presence of the pathogen, host plant 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 soils and provide growers with methods to enhance suppressiveness of their soils to RLNs.

Over four years, a total of 24 different sites were sampled to test the suppressiveness of the soils. This included several farmer paddocks and three long-term farm management trial sites with several fertiliser or tillage treatments. Also, seven of the sites were comparisons of cropped and pasture or native/scrub remnant soils that

14 B Burton, R Norton, R Daniel (2015) Root-lesion nematode; importance, impact and management. GRDC Update Paper 3 August 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management

were in close proximity, to gain an understanding of the impact cropping may have on suppressiveness to RLNs.

Repeated studies over four years of multiple soils from northern NSW and southern Queensland consistently showed general suppressiveness to RLNs does exist in a variety of soils. In glasshouse tests, it was 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 soils tested from the Northern region showing that populations of *P. thornei* are being reduced due to biological activity. Suppression was found to be greater in the top 10 cm of soil than at deeper layers (e.g. 30–45 cm), and practices such as zero tillage with stubble retention enhanced suppression.

Maintenance of a healthy topsoil through diverse organic matter inputs will preserve the suppressive potential of soils against RLN.

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 suppressiveness in their top soil. Without these practices, RLN multiplication would be significantly greater, especially in top soils, and therefore lead to much greater losses in productivity of susceptible crops.v

More work is required to confirm the biological control agents found to be present in our grain-growing soils can have a significant impact on RLN populations on a broad-scale. [15]

MORE INFORMATION

Biological suppression of RLN in the Northern Region.

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

Cultural control

Crop rotation with resistant crops such as cereal rye, grain sorghum, millet, sunflower and canary will reduce the numbers of nematodes in the soil to a level where susceptible wheat varieties can be grown, but will not eliminate them completely. [16]

15 N Seymour, G Stirling, J Li (2016) Biological suppression of RLN in northern grain growing soils. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Biological-suppression-of-root-lesion-nematodes-in-northern-grain-growing-soils

16 QDAF (2015) Wheat—diseases, physiological disorders and frost. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

8.2 Cereal cyst nematode (CCN)

Key points:

- Cereal cyst nematode is more of an issue in the Southern and Western growing regions than in the Northern cropping region. It is rarely found north of northern NSW, however can be found in southern NSW.
- Rye is resistant to CCN, providing an alternative management approach for these diseases. [17]
- Rye can reduce the amount of CCN in a paddock. In one study, the biggest reduction in CCN numbers occurred in cereal rye (cv. South Australia), which reduced populations by 92% in the first year. [18]
- Rotations—use break crops to minimise carryover 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.
- 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.

There have been isolated reports of CCN (*Heterodera avenae*) near Tamworth and Dubbo on lighter-textured soils and friable black soils. If growers suspect CCN they should contact a local agronomist. [19]

Cereal cyst nematode is a pest of graminaceous crops worldwide. This nematode is a significant problem across eastern Australia. CCN becomes more problematic in areas where intensive cereal cropping occurs. CCN 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.

Cereal rye is tolerant and will yield well despite being attacked.

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

IN FOCUS

The effect of plant hosts on populations of CCN (Heterodera a venae) and on the subsequent yield of wheat

Microplots containing soil, naturally infested with CCN were left fallow or sown to one of nine cereal cultivars or grass species for five consecutive years. Wild oat was the most efficient host and, after three plantings, the nematode reached a potential increase ceiling of 42.2 eggs/g soil. Of the cereal cultivars tested, wheat (cv. Olympic) and barley (cv. Prior) were the most efficient hosts and levels of approximately 40 eggs/g were reached after five plantings. Barley grass was less efficient than Wimmera ryegrass which maintained a ceiling population of about 10 eggs/g. Under fallow, populations declined to 0.5 eggs/g after four years. The most inefficient cereal hosts were the oat (cv. Avon) and cereal rye (cv. South Australian). The low populations maintained under continuous cropping with these

17 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

18 JM Fisher, TW Hancock (1991) Population dynamics of *Heterodera avenae* Woll. in South Australia. Crop and Pasture Science, 42(1), 53–68

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

cereals suggested that a rapid selection of a resistance-breaking biotype is unlikely to result from the continued use of inefficient hosts. Growth and yield of a subsequent wheat crop on all plots reflected the relative levels of nematode populations. At the low levels of infestation, grain yields were more than double those on heavily infested plots. [20]

Cereal cyst nematode 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. CCNs have only one life cycle/year (Figure 4). However, each cyst contains several hundred eggs, so populations can increase rapidly on susceptible cereals. [21]

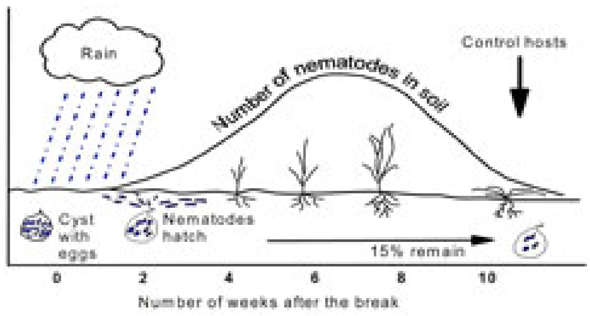


Figure 4: *Life cycle of the CCN.*

Source: AgVic

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 6). 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, wheat and barley roots will be 'knotted' (Figure 7), and oat roots (Figure 8) appear 'ropey' and swollen. 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. [22]

20 JW Meagher, RH Brown (1974) Microplot experiments on the effect of plant hosts on populations of the cereal cyst nematode (*Heterodera avenae*) and on the subsequent yield of wheat. Nematologica, 20(3), 337–346

21 A Wherrett, V Vanstone Cereal cyst nematode. Soilquality Fact Sheet,Soilquality.org.au, http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

22 A Wherrett, V Vanstone Cereal cyst nematode. Soilquality Fact Sheet,Soilquality.org.au, http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

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

Photo: V Vanstone, DAFWA, Source: Soilquality.org

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

Photo: V Vanstone, DAFWA, Source: Soilquality.org

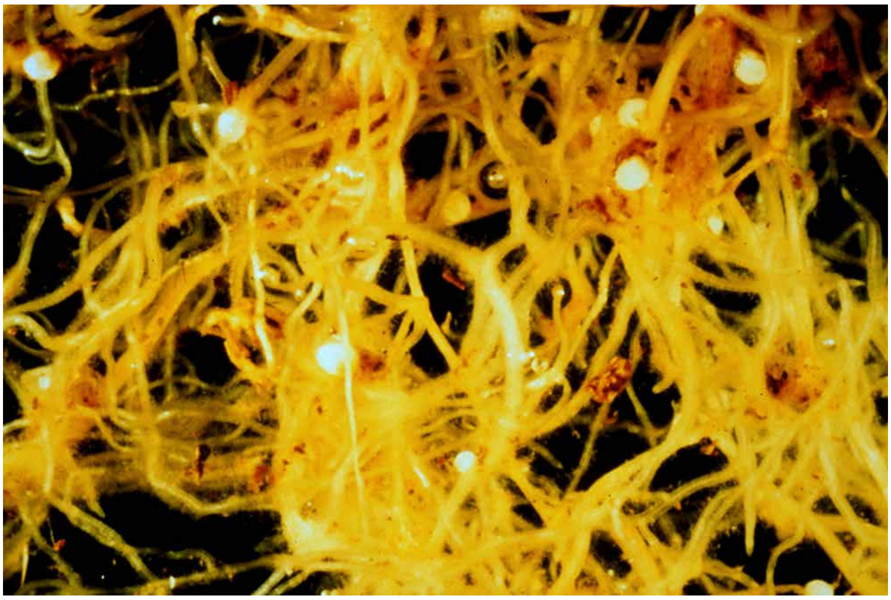


Photo 8: *Cereal roots infected with CCN appear 'ropey' and swollen.*

Source: CropPro

8.2.2 Management

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 is often highly variable. CCN 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. 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 wheat and oat by up to 20% (Figure 13).

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

Photo: V Vanstone, DAFWA, Source: Soilquality.org

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 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, 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. [23]

Disease breaks for CCN:

- grass free pulse and oilseed crops or legume pasture
- resistant cereals, including cereal rye
- chemical fallow prepared early in the season before nematodes have produced viable eggs. [24]

MORE INFORMATION

Cereal cyst nematode - cropPro

23 A Wherrett, V Vanstone Cereal cyst nematode. Soilquality Fact Sheet,Soilquality.org.au, http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

24 CropPro Cereal cyst nematode. Identification and management of field crop diseases in Victoria, Soil-borne diseases of cereals, http://www.croppro.com.au/crop_disease_manual/ch03s03.php

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. [25]

Many trials concentrate on crown rot, 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 N-use efficiency, and increases the severity of crown rot infections. [26]

The NGA has been involved in numerous field trials since 2007, in collaboration NSW DPI, 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 growers 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 wheat variety yield. [27]

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 it could be 30–50% if crown rot is combined with a *Pt*-intolerant variety (Photo 10).

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. [28]

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

26 T Dixon (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

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

28 B Freebairn (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

Photo 10: *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

VIDEOS

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. RLNs, especially *Pt*, need to be taken far more seriously and better factored into crop rotation considerations as well as variety choice. [29]

Soil testing

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

The frequency of the disease has increased in recent years due to continuous cropping of wheat. Crown rot causes significant yield losses. Some of the current strategies for management of the disease 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 allows for growers and consultants to determine if there is crown rot present in a paddock and if so, 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 Protocol to better understand the process, or Contact Crown Analytical services.

29 B Freebairn (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

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. [30]

The approximate order of increasing yield loss to crown rot is: cereal rye, oats, barley, bread wheat, triticale and durum wheat. [31] There is limited research on the tolerance of cereal rye to *P. thornei*.

30 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

31 GRDC. (2016). Tips and Tactics: Crown rot in winter cereals. Southern region. https://grdc.com.au/__data/assets/pdf_file/0029/165917/grdc_tips_and_tactics_crown_rot_southern_web.pdf.pdf