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Vivien Vanstone

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Root Lesion *and* Burrowing Nematodes *in* Western Australian cropping systems

By Vivien Vanstone, Senior Nematologist, Department of Agriculture and Food Western Australia

Disclaimer

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Government of Western Australia
Department of Agriculture and Food

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Introduction

Nematodes are common soil pests that feed on the roots of a wide range of crop plants in all agricultural areas of Western Australia, irrespective of soil type and rainfall. Nematodes multiply on susceptible hosts. Consequently, as nematode populations increase, crop production is limited. Cereal yield losses due to nematodes in Western Australia are in the order of 5 to 15 per cent per annum, but individual losses as high as 40 per cent have been recorded.

Figure 1. *Microscopic plant-parasitic nematode.*

When roots are damaged by nematodes, water and nutrient uptake are less efficient, and plants are also less able to tolerate other stresses such as drought. With adequate soil nutrition and moisture, particularly in spring, damaged roots may be able to extract sufficient nutrients to grow and finish well. Plants affected by nematodes can be more prone to attack by fungi that cause leaf and root disease.

In-field diagnosis of nematodes is not easy, as above-ground symptoms of infection are difficult to detect. Plants may show a combination of indistinctive symptoms, all of which can be confused with, or exacerbated by, nutrient deficiencies:

- Uneven growth and yellowing;
- Stunting and decreased tillering;
- Wilting under water stress.

Nematodes are usually distributed unevenly across a paddock, resulting in irregular growth or patchiness.

The best indication of nematodes within a crop is to dig up the plants, wash the soil carefully from the roots, and examine them for indicative symptoms (which are described later in this Bulletin). It is helpful to compare roots of diseased plants with those of apparently healthy plants. Once root symptoms have been diagnosed, laboratory testing of plants or soil is often necessary to determine the numbers and type(s) of nematodes present. Nematodes are microscopic (less than 1 mm in length) so cannot be seen with the naked eye (Figure1).

Figure 2. *Head of a plant-parasitic nematode, showing the stylet (or "spear") which is used for puncturing and feeding on root cells.*

Figure 3. *Plant-parasitic nematodes and eggs (stained blue) within root.*

Nematodes use their stylet (a hollow protrusible "spear") to puncture roots and extract the cell contents (Figure 2). Some spend their life within the plant roots, where they feed and lay eggs (Figure 3), some can move between the roots and soil during their lifetime, and others remain outside the roots with only their stylet entering the plant.

Over summer nematode adults, juveniles and eggs dehydrate and remain in the soil or in the dry roots of the previously infected crop. With autumn rain, nematodes rehydrate and eggs hatch. Nematodes move to the growing roots, where they penetrate and feed on the root cells.

It is virtually impossible to eradicate nematodes. There is no economically viable chemical control for nematodes in broadacre crops, consequently they must be managed. The key to management is reducing their numbers in the soil through appropriate crop rotations. The ability of nematodes to multiply on a host plant is the over-riding influence on nematode population density, and thus the potential for crop damage, in both current and subsequent crops. Resistant or moderately resistant crop species or cultivars limit the capacity of nematodes to reproduce. Frequent sowing of resistant crops will therefore lead to a reduction in nematode levels, and a corresponding yield increase.

Susceptible plants allow nematodes to multiply and their numbers to increase. It may take several seasons of growing a resistant crop to significantly reduce nematode numbers, especially if they were initially high. Conversely, only one year of a susceptible crop can lead to a rapid increase in the nematode population, achieving yield-limiting densities.

Before rotations are implemented, however, it is crucial to determine the density and identity of the nematodes present, and the amount of damage they are causing:

- Inspect crops for uneven, patchy or unthrifty growth and/or symptoms of nutrient (particularly nitrogen) deficiency;
- Examine roots for distinguishing symptoms;
- Laboratory tests are required to identify nematode species and levels.

Rotations for nematode management should be tailored to the identity of the predominant nematode species.

Root Lesion Nematode

Several damaging species of Root Lesion Nematode (RLN, *Pratylenchus)* occur in cropping areas of Western Australia. These nematodes feed on root tissues of a wide range of plant species. The worm-like nematodes are microscopic (less than 1 mm in length). They live in soil and roots, and cannot be seen with the naked eye. RLN can be present for several years before they build up to levels high enough to cause noticeable symptoms.

Disease cycle

When soil is dry and no living roots are available, RLN become dormant and survive in a dehydrated form, either in the soil or protected within the dried roots of the previous crop. These roots also contain RLN eggs. With autumn rain, RLN become active and move to growing roots nearby where they penetrate and feed on the root cells (Figure 4).

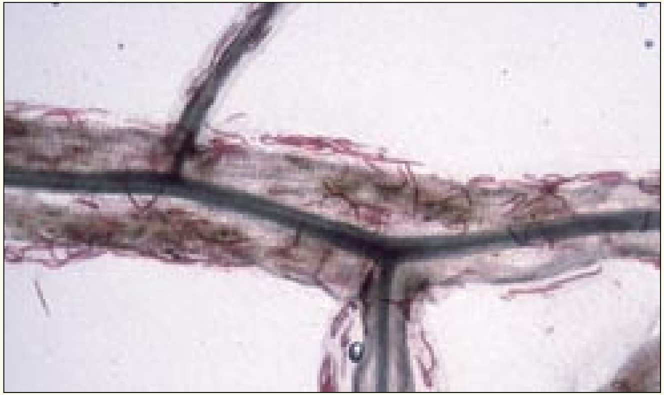


Figure 4. *Heavily infested root containing Root Lesion Nematode adults, juveniles and eggs (stained pink).*

Nematodes will also become active in response to summer rain, when they are able to feed on susceptible weeds and volunteer crop plants that may be present. However, unless the soil is moist for several weeks, they are unlikely to complete their life cycle, and will dehydrate once again when the soil dries.

RLN are migratory parasites, able to move within and between the roots and soil. As the older, damaged roots die, the nematodes are able to move to fresh roots and continue feeding. Females lay eggs in the roots, so three or four generations of RLN can develop during a cropping season. The nematode numbers on susceptible hosts may increase to more than 100,000 RLN per gram of root. As soil starts drying in spring, the RLN become inactive as they dry out. The nematodes then remain in a dehydrated state until the soil next becomes wet.

It is estimated that RLN females can lay one egg per day while actively feeding. However, this varies with the species and health of the host plant, combined with the temperature and soil moisture conditions. Juveniles hatch from these eggs in about 10 days, invade roots and begin feeding. These juveniles reach adulthood in approximately 35 days, when they in turn begin to lay eggs. Thus, the nematode population in a susceptible crop increases rapidly as the season progresses.

The primary factor influencing the density of RLN is crop rotation, which determines the availability of susceptible plant tissue on which nematodes are able to feed and multiply. Intensive cereal cropping often results in increased RLN numbers.

RLN species and distribution

Worldwide, the genus *Pratylenchus* is the second most important group of plant-parasitic nematodes. More than 90 species of RLN are known worldwide, and seven have been identified as pests in Western Australian cropping areas: *Pratylenchus neglectus, P. teres*, *P. penetrans, P. thornei, P. zeae, P. scribneri* and *P. brachyurus*. *P. teres* is not known to occur elsewhere in Australia, and worldwide there is little information available for this nematode.

Figure 5. A

Figure 5. B

Figure 5. C

A *Above-ground symptoms of Root Lesion Nematode are indistinct, consisting of patchiness, uneven growth, stunting and poor tillering in cereal crops.* ***B*** *Field pea infested with high levels of* Pratylenchus penetrans. ***C*** *Severe stunting of cereal infected with* Pratylenchus teres.

At least 60% of Western Australia's cropping paddocks are infested with one or more species of RLN, and about 40% of these represent levels capable of causing crop damage and yield loss in the order of 5 to 15%. *P. neglectus* dominates (detected in 40% of paddocks), followed by *P. teres* (detected in 10% of paddocks). A further 10% of paddocks contain a mix of RLN species. *P. penetrans* occurs infrequently, but severe damage has been observed to the roots of wheat, oat and field pea. *P. thornei* occurs rarely in Western Australia, where it is usually found in mixed infections with other RLN species.

How to recognise a Root Lesion Nematode problem

Symptoms

Above-ground symptoms of nematode infection are often indistinct (Figure 5), and difficult to identify and quantify. Affected plants have poor vigour, stunted growth, cereals tiller poorly, and plants may wilt despite moist soil. Symptoms of nematode damage can be confused with, or exacerbated by, nutrient deficiencies. Nematodes are usually distributed unevenly across a paddock, resulting in irregular crop growth or patchiness. All species of RLN cause identical root symptoms.

Washing the soil from affected roots will reveal brown lesions (Figure 6) or, more often, generalised root browning (Figures 7 & 8). Nematodes multiply quickly on cereal roots, so lesions rapidly coalesce to produce extensive areas of browning and discolouration. When roots are infested with high numbers of RLN, they are thin and poorly branched. Lateral root branches are reduced in both length and number. Sections of the root system may appear dead, with the crown (secondary) roots often less affected than the seminal (primary) roots. In some cases, "noodle-like" root thickening may be observed. RLN do not produce cysts or knotting on the roots.

Testing services

Suspected RLN infestations can be confirmed by laboratory analysis. Soil and root testing can be used to define the problem and determine the species of RLN present. This confirmation is important in deciding how to manage RLN infestations with appropriate rotations. Two types of test are available:

Pre-season tests can be conducted on representative soil samples. PreDicta-B™ uses DNA assessment to identify the species and numbers of *P. neglectus* and *P. thornei.* While this test is able to detect *P. neglectus*, the predominant RLN in Western Australian cropping paddocks, other species

Figure 6. *Chickpea roots showing distinctive orange-brown lesions due to infection with* Pratylenchus neglectus.

of RLN cannot, at this stage, be assessed by this method. Results therefore need to be interpreted with caution and reconciled with paddock observations and rotation history.

Test kits are available through accredited agronomists and re-sellers.

Figure 7. *Symptoms of Root Lesion Nematode on cereal roots.*

Figure 8. *Symptoms of* Pratylenchus penetrans *on field pea roots.*

Growing season tests are carried out on affected plants and associated soil. Live nematodes are extracted, counted and identified in the laboratory. The number of nematodes, the species of RLN and proportion of each species present are assessed. The impact of an infestation may vary with the number of nematodes present, the growth stage of the crop and the seasonal conditions.

Although there is little that can be done during the growing season to correct a nematode infestation, it is important to recognise their occurrence in the current crop so that decisions on appropriate rotations can be taken in following seasons. Rotations incorporating less susceptible crops will limit the multiplication of nematodes and their effects on subsequent crops.

Test kits are available from *AGWEST* Plant Laboratories and participating distributors. To obtain submission forms and full sampling instructions contact your local DAFWA office. Information can also be found at www.agric.wa.gov.au

Impact and yield loss

When roots are damaged by RLN, the plants become less efficient in taking up water and nutrients, and in tolerating stresses such as waterlogging, drought or nutrient deficiencies. Depending on the extent of damage and the growing conditions, affected plants may partly recover if the rate of new root growth exceeds the rate at which nematodes damage the roots.

Field trials in Western Australia have shown significant yield losses to both wheat (5 to 10%) and barley (5 to 20%). Losses of 5 to 10% are probably common, though are often unrecognised.

Management

Where RLN have been identified at moderate to high populations, a range of management practices can be implemented. No chemical control options exist. It is not possible to eradicate RLN, but management of their numbers and their impact can be achieved.

Rotation

The most effective means of reducing RLN infestation in soil, or preventing its build-up, is to incorporate resistant crops in the rotation.

Resistance refers to the effect of plants on nematode reproduction. Resistant plants inhibit nematode reproduction, resulting in a decline of the nematode population over one or more seasons. Crops such as field pea, faba bean, narrow-leafed lupin, lentil, rye and triticale have resistance to *P. neglectus*, so make good break crops where this nematode occurs (Table 1). Including these crop species in rotation should reduce the level of *P. neglectus* in soil. Chickpea, wheat and canola are among the crops with the greatest susceptibility to *P. neglectus*. However, some cultivars of wheat, chickpea and canola are moderately susceptible, so can result in lower *P. neglectus* reproduction than susceptible cultivars.

Information on cultivar resistance can be found annually in DAFWA publications such as Agribusiness Crop Updates and regional Ag Memos.

Tolerance refers to the effect of nematodes on plant growth. Tolerant plants are less likely to suffer yield loss under a nematode infestation. The nematode population may still increase under a tolerant crop if it is susceptible. Therefore, effective rotation crops are chosen on the basis of their resistance (that is, their ability to limit nematode reproduction) rather than their tolerance.

Some crops are resistant to one RLN species, but susceptible to others. For example, field pea, narrow-leafed lupin and faba bean are susceptible to *P. penetrans* but resistant to *P. neglectus* (Table 1). It is important to recognise that rotations need to be tailored to the predominant RLN species present. Where mixed species populations of RLN occur, crops which are resistant to only one RLN species may allow levels of other species to increase.

Weed management

Grass and broad-leaf weeds can contribute to the build-up and carry-over of nematodes in the soil.

Control of autumn weeds well in advance of cropping is crucial. The most important weeds are self-sown susceptible crop plants, which become prolific following summer or

Table 1. Reaction of major crop and pasture species to *Pratylenchus neglectus, P. teres and P. penetrans*

P. neglectus			*P. teres* *	*P. penetrans* *
SUSCEPTIBLE	**MODERATELY SUSCEPTIBLE**	**RESISTANT**	**SUSCEPTIBLE**	**SUSCEPTIBLE**
Wheat	Barley	Field Pea	Wheat	Wheat
Canola	Oat	Narrow-leafed Lupin	Barley	Oat
Chickpea	Medic	Faba Bean	Oat	Field Pea
Mustard	Durum Wheat	Triticale	Canola	Faba Bean
	Common Vetch	Safflower		Narrow-leafed Lupin
		Rye		Chickpea
		Narbon Bean		Durum Wheat
		Lentil		Triticale
		Lathyrus	**MODERATELY SUSCEPTIBLE**	**MODERATELY SUSCEPTIBLE**
		Clover		
		Bitter Vetch		
			Narrow-leafed Lupin	Barley
				Canola

*Information for P. teres and P. penetrans is based on samples received by *AGWEST* Plant Laboratories for diagnosis, combined with data from preliminary field and glasshouse trials. Results from additional testing will be presented in future DAFWA publications when available.

autumn rains. It is important to limit the potential for increase in nematode numbers during autumn by minimising the weed biomass prior to sowing.

To optimise the benefit of resistant rotation crops, control of susceptible weeds is essential. Wild oat, barley grass, brome grass, wild radish and turnip are all susceptible to *P. neglectus.*

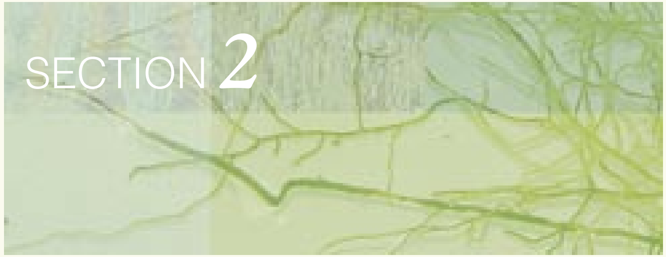
The susceptibility of weeds to other RLN species is not, as yet, known.

Fertility

Adequate levels of nitrogen, phosphorus and zinc help crops to compensate for loss of root function caused by RLN, and are believed to improve plant tolerance. Crops with reduced root function due to nematode attack may also suffer trace element deficiencies.

Summary of management for Root Lesion Nematode

- RLN can be managed with rotations and other cultural practices, but cannot be eradicated.
- If a nematode problem is suspected, use diagnostic services to determine not only the levels, but also the species, of RLN present.
- Monitor nematode levels and maintain low populations by using appropriate rotations.
- Use resistant crops to reduce nematode numbers.
- Cereals are not resistant, but there is useful variation between cultivars (particularly for *P. neglectus*).
- Consider the impact of RLN on the current crop as well as on subsequent crops in the rotation.
- Crops resistant to one RLN species will not necessarily be resistant to all.
- Weeds can allow build-up and carry-over of nematodes: wild oat, barley grass, brome grass and wild radish are susceptible to *P. neglectus.*
- Manage volunteer susceptible crop plants that can harbour nematodes.
- Ensure adequate nutrition (especially nitrogen, zinc and phosphorus), as this will enable crops to better tolerate nematode infection.



Burrowing Nematode

Burrowing Nematode (*Radopholus*) was documented causing crop damage in Western Australia in 1998 (Riley & Kelly 2001). The 18 species of Burrowing Nematode found in Australia are usually associated with native vegetation, and this identification in Western Australia was the first record of these nematodes causing economic damage to cereals.

Since 1998, Burrowing Nematode has been identified from diagnostic samples submitted from more than 30 locations throughout the Western Australian cropping zone.

Burrowing Nematodes are similar to RLN in the way they penetrate, feed and lay eggs within the roots throughout the growing season. Both are able to dehydrate and remain in the soil over summer, becoming active following rain.

At least two species of Burrowing Nematode have been identified from Western Australian crops: *R. nativus* is

Figure 9. *Crop damage associated with Burrowing Nematode.*

predominant, but a second (as yet unidentified) species occurs in some locations. Damage to cereals caused by these two species is identical. Although crop damage due to Burrowing Nematode has yet to be quantified, cereals appear to be more susceptible than pulses or oilseeds.

Symptoms

- Areas of poor growth, patchiness, stunting, reduced tillering and/or yellowing (Figure 9).
- Root symptoms can appear similar to those caused by RLN: general browning and discolouration, combined with reduction in the length and number of lateral roots (Figure 10). It is therefore important that laboratory

Figure 10. *Root symptoms due to Burrowing Nematode infestation can appear similar to those caused by Root Lesion Nematode.*

diagnosis is conducted to determine identity of the causal nematode(s).

- With high levels of infestation, symptoms become more severe and appear as browning, distortion and shortening of the entire root system, combined with absence of lateral roots (Figure 11).
- Some roots may appear swollen, with a "noodle-like" appearance (Figure 12).
- With heavy infestations, patches that may be confused with the fungal disease *Rhizoctonia* can occur (Figure 13).

Figure 11. *Roots containing high levels of Burrowing Nematode.*

It is therefore important to examine roots and/or send samples to a laboratory for diagnosis. Cereal roots damaged by *Rhizoctonia* will show characteristic "spear tipping", which has not been observed on roots infested with Burrowing Nematode.

- Patches are irregularly shaped, up to 2 m across, containing stunted and yellowed plants with few tillers. Plants within patches can be infected with more than 150,000 Burrowing Nematodes per gram of root. Plants outside patches are also infected, but contain fewer nematodes (Figure 14).
- Not all infestations of Burrowing Nematode will result in the appearance of patches.

Hosts

The host range for Burrowing Nematode is still under investigation.

Very high levels have been detected in wheat (up to 176,000 per gram of root) and barley (70,000 per gram of root). Moderate levels have been detected in narrow-leafed lupin (12,000 per gram of root) and canola (7,000 per gram of root). Roots can be infected simultaneously with Burrowing Nematode and RLN, but one nematode species tends to dominate.

Burrowing Nematode has been recorded in some weed species (for example, annual ryegrass and wild radish).

Figure 12. *"Noodle-like" root symptoms due to Burrowing Nematode.*

Figure 13. *Burrowing Nematode can cause patches in cereal crops similar to* Rhizoctonia.

Figure 14. *Plants from within a Burrowing Nematode patch, on the edge of the patch and from outside the patch. Plants in the patch contained 153,000 nematodes per gram root (45 nematodes per gram soil), on the edge of the patch 15,800 nematodes per gram root (33 nematodes per gram soil), and the "healthy" plants contained 1,000 nematodes per gram root (4 nematodes per gram soil).*

Management of Burrowing Nematode

- Further testing is required to identify crops and cultivars that will be useful in reducing soil populations of Burrowing Nematode and to quantify the damage caused by these nematodes.
- Burrowing Nematode has been recorded in a range of wheat and barley cultivars, and can reach high levels (leading to significant damage) in these plants.
- Where Burrowing Nematode occurs, there is potential for high populations to develop under intensive cereal cropping. Rotations incorporating narrow-leafed lupin should be monitored. Although these nematodes may not reduce yield of narrow-leafed lupin crops, they could build-up and affect subsequent cereal crops.
- Soil and/or plant tests should be performed to discriminate between RLN and Burrowing Nematode damage to plants.
- Similarly, diagnosis and/or investigation of root systems may be needed to differentiate between Rhizoctonia and Burrowing Nematode if distinct patches of poor growth are evident in cereal crops.

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