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Root disease under intensive cereal production systems
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Root disease under intensive cereal production systems

Bill MacLeod, Senior Plant Pathologist, Vivien Vanstone, Senior Nematologist and Ravjit Khangura, Plant Pathologist, South Perth and Ciara Beard, Plant Pathologist, Geraldton
Summary
This Bulletin describes symptoms and control methods for the most commonly encountered cereal root diseases in Western Australia:

- rhizoctonia bare patch
- root lesion nematode
- take-all
- fusarium crown rot
- cereal cyst nematode
- common root rot
- pythium root rot.

Diseases caused by pathogenic micro-organisms can significantly reduce the yield of cereals. Some of these diseases are uncommon while others occur over a large area of the Western Australian wheatbelt every year. The most prevalent root diseases of cereals in Western Australia are rhizoctonia bare patch, root lesion nematode and take-all. Less widespread are fusarium crown rot, cereal cyst nematode, common root rot and pythium root rot.

There are three components which determine the impact of root infecting pathogens on the yield of a crop:

- The disease inoculum must be present—this refers to the amount of the pathogen that survives from the previous season to infect the current crop. It is rare that inoculum introduced from outside a paddock will contribute significantly to a yield limiting occurrence of these root diseases. The inoculum principally determines the risk and incidence of infection.
- The soil environment determines the extent or severity of disease development from the initial infection. Soil conditions which are most favourable for disease development differ between the pathogens. For example, *Rhizoctonia* is favoured by low soil moisture whereas the take-all fungus is favoured by high soil moisture.
- The availability of water and nutrients influences plant growth and grain filling. Root disease will have less impact if plants are not suffering water and/or nutrient stress.

Diseases that occur underground, unlike foliar diseases, can be difficult to detect and diagnose as the above-ground symptoms are often indistinct. However, these diseases must be identified correctly to enable appropriate control measures to be implemented. This Bulletin illustrates the root diseases that are most likely to be encountered under intensive cereal cropping systems, describes the disease symptoms, suggests management strategies (summarised in Table 1), and outlines testing services that are available.

Figure 1 is a diagram of cereal root architecture which explains the terminology used in this Bulletin.
Figure 1: Root structure of a cereal plant (left) and the root system of a healthy cereal (right)
Table 1. Summary of effective management strategies for root diseases

<table>
<thead>
<tr>
<th></th>
<th>Rhizoctonia bare patch</th>
<th>Root lesion nematode (RLN)</th>
<th>Take-all</th>
<th>Fusarium crown rot</th>
<th>Cereal cyst nematode (CCN)</th>
<th>Common root rot</th>
<th>Pythium root rot</th>
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<tbody>
<tr>
<td>Grass free pasture</td>
<td>X</td>
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<td>Broad-leaved crop–grass free</td>
<td>X</td>
<td>varies with crop and RLN species</td>
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<tr>
<td>Deep cultivation</td>
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<td>✓ ✓</td>
<td>✓</td>
<td>+</td>
<td>X</td>
</tr>
<tr>
<td>Cereal variety</td>
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<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>X</td>
<td>?</td>
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<tr>
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<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Chemical control</td>
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<td></td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>♦</td>
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<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Time of sowing</td>
<td>X or ?</td>
<td></td>
<td>✓</td>
<td></td>
<td>?</td>
<td>X</td>
<td>?</td>
</tr>
<tr>
<td>Grazing/burning stubble</td>
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<td></td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Seeding rate</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

✓ ✓ ✓ ✓ = very effective; ✓ ✓ ✓ = moderately effective; ✓ ✓ = minor effect; ✓ = poor control
X = no control
+ = increases disease
? = unknown / requires further research
# = this rotation is required for two years
Rhizoctonia root rots

There are several root diseases of crop and pasture plants which are generally described as a rhizoctonia disease. However, each disease is caused by a specific variant or strain of the fungus, *Rhizoctonia solani*. The most important rhizoctonia disease of cereals in Western Australia is commonly known as rhizoctonia bare patch. Other *Rhizoctonia* strains that do not cause rhizoctonia bare patch do cause several other diseases including hypocotyl rot of legumes, root rot of legumes, hypocotyl rot of canola and minor root rot symptoms on cereals.

Rhizoctonia bare patch

Rhizoctonia bare patch is caused by the fungus *R. solani* ZG1 (also frequently described as *R. solani* AG8) which can attack cereals, crop legumes, other broad-leafed crops, pastures and weeds. This disease is widespread in Western Australia. However, the highest incidence and most severe occurrences have been on sandy soils, particularly in the Esperance region.

Symptoms

Although rhizoctonia bare patch looks spectacular in the field, the overall reduction in crop yield may be small. Yield reduction is generally proportional to the area of the paddock affected by patches, although plants in some patches may suffer little stunting.

The most striking symptom of rhizoctonia bare patch is the occurrence of severely stunted plants in patches with a distinct edge (Figure 2a). The crop changes abruptly from diseased plants to apparently healthy plants in a few centimetres. These bare patches vary in size from less than half a metre up to several metres across.
Plants within severe patches are stunted, with stiff, rolled leaves and are sometimes darker green than healthy plants. Their roots are short with brown, pinched ends that are called ‘spear tips’ (Figure 2b). Plants within patches may have a purple tinge to their leaves, especially oats and clover.

Plants within the patch may remain stunted until maturity or die prematurely. The edge of the patch usually becomes less distinct towards the end of the growing season. Plants within the patch may appear to recover but their yield is still low. Plants outside the patch appear normal (large and apparently healthy) but may also have a low proportion of roots with the spear tip symptom.

**Survival and spread of patch-forming Rhizoctonia strains**

The fungus causing the patches grows through the soil and colonises living plant tissue and dead organic matter. Since it does not need a live host plant to survive (that is, it can live as a saprophyte) this pathogen can survive for long periods on plant residues, even in fallow soil. After opening rains in autumn, the fungus quickly grows beyond the organic matter to infect young seedlings.

The method of spread of the fungus from one paddock to another, or from farm to farm, is not proven. However, there is evidence for spread on plant residues, including subterranean clover and medic burr, and in soil and trash spread by machinery and animals.

**Management strategies**

- **Deep cultivation** (to at least 10 cm) remains the only effective method of reducing damage caused by rhizoctonia bare patch. Deep cultivation does not destroy the pathogen but disturbs its growth and reduces its impact on the host. Deep ripping reduces the incidence of disease. It is important that cultivation is done just prior to seeding, otherwise the fungus may be able to recolonise the root zone and attack seedlings. Where deep cultivation is used to remove soil compaction it has the dual benefit of reducing the aggressiveness of the pathogen and encouraging better root growth.

- **Avoid using zero tillage** in paddocks that have a history of or are liable to have rhizoctonia bare patch. Tillage systems that minimise soil disturbance also have minimal effect on the fungal hyphae in the soil, so the actively growing pathogen is able to attack the seedling soon after germination. In paddocks with rhizoctonia bare patch, replace zero tillage systems with minimum tillage. Use tines that cultivate to 10 cm but place the seed at standard depth (2 to 5 cm).

- **Observe on-farm biosecurity.** Wash or knock the soil from tines before moving tillage machinery from infected paddocks or farms to non-infected areas. This may reduce the rate of spread of this disease, since the pathogen is spread in soil and trash buried in the soil. Spread by tillage machinery is clearly illustrated by the elongation of patches in the direction of cultivation and the initiation of new patches along the direction of cultivation.

- **Provide adequate nutrition.** The major impact of rhizoctonia bare patch is to reduce the size of the functioning root system. Therefore, supplying plants with adequate nutrition, particularly nitrogen and zinc, can reduce the impact of the disease on shoot growth and yield. All sources of nitrogen are equally effective.

- **Rotations** have little or no effect on the incidence of rhizoctonia bare patch since all crops and pastures are susceptible. In problem areas, sow oats in preference to wheat or barley. Barley is more susceptible to rhizoctonia bare patch than wheat and triticale, whereas oats are least susceptible.

- **Fungicides** applied as seed dressing may suppress the disease in wheat and barley. In paddocks that have a history of or
are liable to have rhizoctonia bare patch, consider applying a fungicide seed dressing containing difenoconazole (for example, Dividend®). However, this treatment should be used with other appropriate strategies to significantly decrease the impact of this disease on crop yield.

- **Herbicides**, particularly sulfonylurea herbicides such as Glean® and Logran®, can exacerbate rhizoctonia bare patch. This is probably the result of the herbicide reducing root elongation and thus limiting the plant’s ability to compensate for lost root length. The effect of sulfonylurea herbicides is more pronounced in calcareous soils because these chemicals persist for longer, and at a higher concentration, in alkaline soil (that is, soils with a pH above 7). No direct effects of sulfonylurea herbicides or other herbicides on the pathogen have been observed.

- **Grass removal** for short chemical fallow has not reduced rhizoctonia bare patch in Western Australia. Although South Australian research has shown that the removal of grass, or a short chemical fallow (four to six weeks) immediately before sowing, reduces rhizoctonia bare patch, similar experiments conducted in Western Australia have not shown any such disease reduction. Before implementing a short chemical fallow in autumn, growers should take into account that this strategy may delay sowing and consequently reduce potential yields.

**Root lesion nematode**

Root lesion nematode (Pratylenchus spp.) inhabits soil and feeds on the roots of plants. Several damaging species of Pratylenchus occur in cropping areas of Western Australia: Pratylenchus neglectus, P. teres, P. penetrans and P. thornei. Population densities of all root lesion nematode (RLN) species will increase under intensive cereal production systems.

For nematode diseases, particularly RLN, the resistance of a crop species or variety is determined by the plant’s ability to inhibit or support nematode reproduction. Resistant varieties can be used to reduce the nematode population over one or more seasons. However, resistant crops will not eliminate RLN and will still support low nematode levels. For this reason, the nematode population can quickly increase again when a susceptible crop is sown.

Root lesion nematode feeds on root tissues of a wide range of plant species including cereal crops. Wheat is particularly susceptible to RLN. At least 60 per cent of Western Australia’s cropping paddocks are infested with one or more species of RLN, and about 40 per cent of these are at levels which may cause yield losses in the order of 5 to 25 per cent. There have been individual cases of losses as great as 40 per cent. In Western Australia, *P. neglectus* is the most commonly identified species (detected in 40 per cent of paddocks), followed by *P. teres* (detected in 10 per cent of paddocks). *P. thornei* is rare in Western Australia. More than one species of RLN can occur in a single paddock. These nematodes occur across the entire wheatbelt.

**Symptoms**

Above-ground symptoms of nematode infection are often indistinct and difficult to identify. Affected plants are stunted and tiller poorly, and may wilt despite moist soil. Crops will appear patchy with uneven growth (Figures 3a and 3b).

Roots may have indistinct brown lesions or, more often, generalised root browning (Figure 3c). 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 roots often less affected than the primary roots (refer to Figure 1 for placement of root systems).
In some cases, noodle-like root thickening may be observed. All species of RLN cause identical root symptoms. Unlike cereal cyst nematode, RLN does not produce cysts or knotting on the roots.

Management strategies

Root lesion nematode can be managed with rotations and other cultural practices but cannot be eradicated. The first step towards effective management of nematode diseases is correct identification of the species present. Extraction and identification of nematodes needs to be undertaken by a laboratory service to confirm the RLN species present and their population density.

- **Rotations** that include resistant crops in the sequence are the most effective means of reducing the number of RLN in soil, or preventing its build-up. Rotations need to be tailored to the

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**Figure 3a:** Damage to barley crop due to severe infestation of root lesion nematode.

**Figure 3b:** Moderate levels of root lesion nematode cause uneven crop growth and patchiness.

**Figure 3c:** Root discolouration caused by root lesion nematode. Note that lateral roots are shortened and long sections of the main roots have no laterals.
predominant RLN species present. To maintain low nematode population densities, avoid continuous cropping with susceptible crops such as wheat and chickpea. Crops resistant to *P. neglectus* include field pea, faba bean, narrow-leafed lupin, lentil, rye and triticale.

- **Use resistant varieties.** Wheat, barley and oat are susceptible to RLN; however, some varieties are less susceptible than others (particularly for *P. neglectus*). Information on the relative resistance of varieties can be found in DAFWA publications such as Agribusiness Crop Updates and regional AgMemos. These are available online at [http://www.agric.wa.gov.au](http://www.agric.wa.gov.au). Use the alphabetical index to find ‘AgMemos’ and ‘Agribusiness Crop Updates’.
- **Focus weed control** on controlling susceptible weeds (particularly wild oat, barley grass, brome grass and wild radish) and susceptible volunteers (especially cereals) to reduce RLN build-up and carryover.
- **Pesticides** to control root lesion nematode are **NOT** economically viable.

Further detailed information is available in Bulletin 4698 ‘Root lesion and burrowing nematodes in Western Australian cropping systems’.

**Take-all**

Take-all can be a serious disease of wheat and barley; however, during the past two decades it has been greatly reduced in severity and occurrence through the effective control of grass weeds in non-cereal phases of rotations.

The pathogen that causes take-all in cereals is *Gaeumannomyces graminis* var. *tritici* (Ggt) which attacks wheat, barley and triticale. In Western Australia this fungus can also infect oats but it has little effect on the growth or yield of the crop. Although widespread in Western Australia, this disease causes most damage to crops on the wetter, western edge of the wheatbelt and in southern areas.

In high rainfall areas, second wheat crops and wheat crops after grassy pasture or a grassy break crop represent a higher risk for take-all. Successive seasons with good winter rainfall can increase the take-all inoculum in paddocks which had cereal, grassy pasture or grassy break crops.

The fungus that causes take-all survives over summer on residues of cereals and grasses. During the non-cereal phase of the rotation, the fungus is carried over on the roots of susceptible grasses or cereal volunteers. The fungus only infects grasses; therefore subterranean clover, medic, lupin, canola, field pea and pulse crops are not infected.

Survival is affected by soil conditions and tends to be longer in paddocks with high soil nitrogen, such as where clovers or medics have been established. The density of fungus in the soil increases as the grass content increases during the non-cereal phase.

Most recommended wheat varieties are equally susceptible to take-all. Wheat is the most susceptible cereal crop, followed by barley, oats, triticale and cereal rye (the least susceptible). Infection is similar in wheat and barley but barley suffers less yield loss from take-all infection than wheat.

**Symptoms**

Plants affected by take-all usually become evident in the crop after flowering. The affected plants occur in areas of up to several metres in diameter with indistinct and irregular edges. The fungus may affect individual plants or all plants over large areas. The root infection can kill seedlings but more often causes stunting and premature haying-off.
Because of the tendency to hay-off, the heads of some affected plants are seen as ‘whiteheads’ in the green crop. Take-all occasionally causes all the tillers on a plant to produce whiteheads which are usually empty (hence the term ‘take-all’), or they contain only small, shrivelled grain. However, whiteheads do not prove that take-all is present, since whiteheads can also be caused by water stress, frost, crown rot or copper deficiency. In fact, take-all does produce moisture stress in spring as the roots of infected plants are ineffective and not able to supply the plant with sufficient water. With a severe take-all infection, the whole crop may hay-off early, causing a large reduction in yield. Severely infected crops may not be worth harvesting, however, such crops are rare.

The most characteristic plant symptom of take-all is blackened and brittle roots which break easily leaving a square end. A distinct symptom of take-all is that the centre of the root (the stele) is black, not just the outer surface. Plants need to be dug from the ground (not pulled) and washed thoroughly with clean water to reveal these symptoms. As affected plants mature, infected roots become brittle and plants can be pulled easily from the soil. Moderately and severely infected plants may develop blackening around the base of the stems and crown. Removal of the leaf sheaths from the stem may reveal a black crust (Figure 4a), or sometimes just dark brown to black streaks or spots (Figure 4b) in plants that are less severely infected.

**Soil moisture**

Within any season, high rainfall increases take-all severity. This will produce a greater amount of inoculum which can lead to a higher take-all risk in the following year. However, without moisture stress, plants are better able to cope with the root damage caused by the fungal invasion.

A dry finish to the season is unlikely to restrict take-all but makes it difficult for the plants to obtain enough moisture through their damaged root systems. As a result, yield may be drastically reduced.

Take-all inoculum in the soil will quickly decline if no host plants are present or if there has been a succession of years with low winter rainfall. Surveys of the agricultural region have shown that take-all is more severe and more prevalent in the high rainfall areas.

**Management strategies**

The take-all fungus can survive between growing seasons in old crowns and roots of host plants. Any practice that encourages the
breakdown of this trash will reduce the amount of fungal inoculum, provided new hosts such as grasses or cereals are not available for the fungus to infect.

A very early break to the season may encourage take-all infection in two ways.

- The time during which the infected trash may break down is reduced, so that the consequent starvation and death of the fungus is also reduced.
- If the early break allows grass hosts to become established, the fungus can grow and multiply before the crop is sown.

The take-all risk in a cereal crop is also determined by the rotational history of the paddock. Determine the risk for a cereal crop from Table 2 and apply one or more of the following management strategies.

**By far the most effective method of reducing take-all is to adopt a grass-free cropping system.** This can be achieved by two farming practices: 1) establishing a rotation that includes a grass-free rotation or break crop, and/or 2) grass-free pastures.

- **Use grass-free break crops.** Take-all can be prevented from building up to yield limiting levels, or reduced if it has reached high levels, by rotating cereal crops with grass-free break crops such as lupin, canola, field pea or a grass-free legume pasture. This break denies the take-all fungus a host, starving it during the winter and spring. The presence of grasses in this break crop will defeat the purpose of the non-host break crop. Oats are not an effective break crop: although the fungus has little effect on oats, it is still carried over on this crop.

- **Prepare pastures the year before cropping.** If cropping to wheat or barley is to follow a pasture phase, use a strategy which minimises the threat of herbicide-resistant weeds to

### Table 2. Previous crop and the estimated risk of take-all in wheat

<table>
<thead>
<tr>
<th>Type of crop two seasons before</th>
<th>Type of crop in previous season</th>
<th>Risk of take-all in wheat in present season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassy legume pasture or lupin, canola or pulse crop</td>
<td>Grassy legume pasture</td>
<td>* * *</td>
</tr>
<tr>
<td></td>
<td>Wheat or barley</td>
<td>* * * *</td>
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<tr>
<td></td>
<td>Oats</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Grass-free fallow</td>
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</tr>
<tr>
<td></td>
<td>Grass-free lupins, canola or pulses</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Grassy fallow</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Grassy lupin, canola or pulses</td>
<td>****</td>
</tr>
<tr>
<td>Broad-leafed pasture or crop with no grass</td>
<td>Pure broad-leafed pasture or crop</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Wheat or barley</td>
<td>**</td>
</tr>
<tr>
<td>Wheat or barley after grassy clover pasture in previous season</td>
<td>Grassy legume pasture</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td>Wheat or barley</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Grass-free lupin, canola or pulses</td>
<td>*</td>
</tr>
<tr>
<td>Continuous wheat or barley with few grass weeds for more than four years</td>
<td>Wheat or barley</td>
<td>**#</td>
</tr>
<tr>
<td></td>
<td>Grassy legume pasture</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Grass-free lupin, canola or pulses</td>
<td>*</td>
</tr>
</tbody>
</table>

* = low risk to **** = high risk

# Take-all decline has been reported in these cropping systems but may take 10 or more years to develop.
remove the grasses from the pasture for the whole of the year before cropping. Broad spectrum or selective herbicides can be used to selectively remove grasses from pasture early in the year before cropping. Alternatively, start a grass control program, using grazing and pasture topping, two years before cropping. If grasses are removed in autumn, infected grass material from the previous season will have approximately six months, during winter and spring, to break down. If grasses are not removed until late winter or early spring, the fungus will have colonised them and the new inoculum will easily survive the dry summer months.

If using the autumn grass removal option, it is essential to ensure that there are sufficient legume pasture plants to provide stock feed and protect the soil surface from erosion. Manage the grazing of the paddock during autumn and early winter so that the stocking rate does not exceed the carrying capacity of the pasture, while providing sufficient grazing pressure to remove surviving and late emerging grasses.

When the level of take-all is expected to be high and the pasture manipulation practices are not suitable, consider using a grass-free, broad-leafed crop as the first crop after the pasture phase. Then continue with a wheat:broad-leafed crop rotation. The risk that lupin grown as a first crop after pasture will be affected by diseases from the pasture may be acceptable to obtain control of take-all in subsequent cereal crops.

- **Control volunteer grasses** and cereals following the break of the season to prevent early build up of inoculum.
- **Delay sowing** following the opening rains. Implementing a short chemical fallow may reduce take-all. A short delay allows some infected trash in the moist soil to break down. If susceptible cereals are to be sown in paddocks that have an acceptable risk of take-all, the level of inoculum may be further reduced by sowing those paddocks last and allowing infected stubble more time to break down. However, consideration must be given to the yield loss that may result from delayed sowing compared to the potential reduction in take-all incidence.

- **Implement fertiliser and weed management.** Encouraging good crop growth, by reducing weed competition and by supplying adequate fertiliser, will help overcome the effects of take-all. Crops low in phosphorus, nitrogen and manganese are more susceptible to take-all. Reduce the risk of take-all by using ammonium forms of nitrogen rather than nitrates (for example, if applying nitrogen, use Agras No. 1® at about 140 kg/ha). A mixture of ammonium sulphate and DAP with the same rate of nitrogen would also be effective.

- **Consider applying fungicides at seeding.** When wheat is to be sown into a paddock which has a higher than desirable risk of take-all, some fungicides applied in-furrow or on seed can be used to reduce take-all infection. Registered products include fluquinconazole seed dressings and many of the in-furrow fungicides containing flutriafol and triadimefon. See DAFWA Note 205, ‘Cereal seed dressing and in-furrow fungicides 2006–2007’ for product registrations. Always read product labels before use.

**Strategies that will NOT reduce take-all**

- **Drill-row spacing** has no effect on take-all.
- **Plant density** has little or no effect on take-all.
- **Burning stubble** reduces the level of infected trash above the ground, but the heat does not penetrate the soil and cannot reduce the amount of take-all infected material below the ground.
• Variety selection. Most recommended wheat varieties are equally susceptible to take-all. Some varieties show small differences in resistance to take-all but the differences are of limited value.

• Spraytopping in the spring prior to sowing a cereal crop does not affect take-all. The take-all infection of grasses will have reached its maximum for the year and colonised root pieces in the soil will not have time to break down.

**Fusarium crown rot**

Fusarium crown rot is caused by the fungus **Fusarium pseudograminearum**, which can persist in infected crop residues for up to two years and be carried over on infected grass weeds. Crown rot is more common when susceptible crops are grown sequentially or after long-term grass pastures. The disease is also exacerbated where stubble retention and reduced tillage are practiced.

Inoculum survival is enhanced by dry summer conditions (due to reduced stubble breakdown), but disease development is favoured by moist, humid conditions, with temperatures between 15°C and 20°C. Crown rot is a minor disease in most cropping areas; however, it is most likely to occur in the eastern part of the Central Agricultural Region and Southern Agricultural Region. Yield losses from crown rot are greater in seasons with a wet start followed by a dry finish.

Crown rot can be a serious problem in wheat, barley, oats and triticale. Barley suffers less yield loss from crown rot than wheat, largely due to its earlier maturity. Durum wheat is the most susceptible and suffers the greatest yield loss. Other host plants include wild oat, canary grass (phalaris), wheat grass, brome grass, barley grass, winter grass and ryegrass.

**Symptoms**

The crown (where roots emerge at the base of the stem, Figure 1) and the lower stem of infected plants have a honey-brown to dark brown discolouration (Figure 5). Sometimes, a pink discolouration appears around or in the crown or on leaf sheaths. If infected plants
are placed in a damp plastic bag and left for a few days, the pink colouration is often more easily observed, particularly within the hollow centre of the lower internodes of stems.

Crown rot is usually first observed at heading when scattered whiteheads (prematurely ripened heads) develop in an otherwise green crop. The whiteheads contain no grain or only light-weight shrivelled seed. When this disease is severe, whole plants may be affected but generally only single tillers have whiteheads. This distinguishes crown rot from take-all which generally causes whiteheads on all tillers of plants which usually appear in patches.

Moisture stress after anthesis exacerbates the development of whiteheads in infected crops. The fungus blocks the base of infected tillers so water movement from root to stem is prevented, leading to an inability to fill the grain on that tiller.

Management strategies
Where fusarium crown rot is yield limiting, a combination of management practices is recommended.

- **Rotations** with non-susceptible crops or fallow are effective. A two-year break with grass-free crops such as pulse, oilseed or lupin, grass-free legume pastures or fallow will reduce crown rot in the following wheat or barley crops.
- **Sow less susceptible varieties.** Sowing partially resistant varieties

**Figure 5**: *Fusarium crown rot causes a honey-brown discolouration to the crown and lower stem of infected plants (left) and sometimes a pink discolouration of the leaf sheath (right).*
can reduce the severity of crown rot. However, most wheat and barley varieties grown in Western Australia are either susceptible or highly susceptible to crown rot.

- **Cultivation** that buries crowns helps break down infected stubble by accelerating its decomposition during the growing season, thereby reducing subsequent inoculum levels. Minimum tillage and practices that slow decomposition of stubble can increase the severity of crown rot.

- **Grazing and stubble burning** only marginally reduce crown rot inoculum levels.

- **Control grass weeds.** Wild oat, canary grass (phalaris), wheat grass, brome grass, barley grass, winter grass and ryegrass can all host crown rot. Control grasses early in the season prior to sowing cereals to allow maximum time for breakdown of trash. Cutting crops for hay will not remove the bottom part of the plant that may be infected with crown rot.

- **Reduce moisture stress** in your wheat or barley crop by avoiding excessively high sowing rates, by matching nitrogen fertiliser inputs to available water and controlling in-crop weeds.

- **Apply adequate soil nutrition** especially zinc, by routine application, to ensure maintenance levels within the soil. Maintaining above minimum nutrient levels will reduce losses to crown rot.

- **Use inter-row sowing.** Crown rot infection occurs when a plant comes in close contact with a piece of residue harbouring the crown rot fungus. New South Wales Department of Primary Industries has found that sowing between the rows of the previous cereal crop decreases the severity and incidence of crown rot in the current cereal crop. This assumes previous cereal rows remain intact and have not been redistributed (for example, through cultivation) into the inter-row area. This is not a complete solution to crown rot but it is another tool to use, in paddocks or crops sown with wider row spacing, that will reduce the impact in the current crop.

### Cereal cyst nematode

The cereal cyst nematode (*Heterodera avenae*) can cause severe damage in areas where continuous cereal cropping is favoured. In Western Australia, cereal cyst nematode (CCN) is reported frequently from the Northern Agricultural Region around Geraldton and from the Central Agricultural Region but it can occur in any area.

CCN only infects cereals and other grasses (particularly wild oat). In infected paddocks, the female nematodes invade the plant roots in autumn. As the females feed and develop within the roots, their bodies swell and erupt through the root surface. They can then be seen as white, spherical bodies about the size of a pinhead on the root surface (Figure 6a). At this stage, the female nematodes each contain several hundred developing eggs.

The cysts turn brown and remain in the soil over summer, where the eggs will hatch at the start of the next season. CCN needs a combination of moist and cool conditions to hatch. However, only 70 to 80 per cent of these eggs hatch each season, so some will remain in the soil for following seasons, even where no hosts are available. For this reason, it can take several years for high CCN populations to be reduced below levels which are yield limiting.

### Symptoms

Above-ground symptoms can be indistinct, consisting of patchy and uneven growth. Plants can also appear stunted, unthrifty and yellowed. With heavy infestation, CCN will cause distinctive patches of yellowed growth (Figure 6b). These patches can increase in size and severity with successive cereal crops. Plants outside the
obvious patches may be infected, but at a low level which is not growth limiting.

Root symptoms are the key to correct diagnosis of CCN. On wheat and barley, roots appear ‘knotted’, which is associated with the infection sites of the female nematodes (Figure 6c). Development of the whole root system is retarded. In contrast to wheat and barley, the roots of oats will appear ‘swollen’ and ‘ropey’ (Figure 6c).

Management strategies

- **Rotations** of legume crops, canola or pastures with cereals are effective. In infected areas, do not grow more than two consecutive cereal crops following a non-host break crop. Severe soil infestations may require more than one non-host crop to reduce CCN below yield limiting levels.

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**Figure 6a:** Wheat roots infected with cereal cyst nematode. The female nematodes can be seen as pinhead-sized white cysts on the root surface (arrows).

**Figure 6b:** Cereal cyst nematode causes patches of yellow, stunted plants.

**Figure 6c and 6d:** Cereal cyst nematode causes knotted roots in wheat and barley (c) and swollen, ropey roots in oats (d).
• **Plant clean break crops.** Control susceptible cereal volunteers and grasses (particularly wild oat) in non-host phases of rotations.

• **Use soil testing** to monitor nematode numbers and maintain low levels with rotations (see ‘Soil and plant testing services’ below).

• **Chemical treatments** to control this nematode are NOT economically viable.

• **Cultivation** is NOT an effective control option. It spreads the nematodes around the paddock and distributes them throughout the soil profile making the problem worse.

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**Common root rot**

Common root rot is caused by the fungus *Bipolaris sorokiniana* which is widespread, but not common in Western Australia. This disease is most prevalent in the northern wheatbelt of the state.

The fungus that causes common root rot survives on roots of grasses and as dormant spores in the soil. It can build up to damaging levels when wheat or barley crops have been grown in intensive cereal production systems or following grassy break crops.

*Figure 7:* Common root rot causes brown lesions on the sub-crown internode. Lesions on severely affected plants enlarge and coalesce (*a, b*). Lesions on moderately affected plants remain discrete (*c*) and unaffected sub-crown internodes are creamy to white (*d*).
Symptoms
The fungus infects any below-ground part of the plant. Symptoms are most evident on the sub-crown internode (the piece of the first stem from the seed up to the crown, Figure 1) as discrete dark brown lesions that may enlarge and coalesce to completely discoulour this area (Figure 7).

Above-ground symptoms are not distinctive. Affected plants tend to be scattered over a paddock, and they may be slightly stunted, have fewer tillers and produce smaller heads. Common root rot may be tolerated by the plant and produce no above-ground symptoms, as long as sufficient crown roots are generated.

Management strategies
The following recommendations are based on results from New South Wales and Queensland, where this disease is a major constraint.

- **Select less susceptible crops.** Oats are less susceptible than wheat, barley or triticale but these crops are not an effective break crop.
- **Rotations** with non-host break crops (for example, legume and oilseed crops or grass-free legume-based pastures) reduce spore populations in the soil and therefore tend to reduce disease incidence. However, this disease is quite persistent in the soil, so a break of one year may not be enough to avoid crop damage.

Pythium root rot
Several species of the fungus *Pythium* cause root rots of cereals under wet or saturated soil conditions. These *Pythium* fungi are widespread and common in Western Australian soils but only cause root rot when soil conditions are suitable for the fungus.

Research in other states has found that pythium root rot is most common in high rainfall areas and where crops have been sown into cold, wet soil. Damage may be severe where crops emerge among a mat of dead or dying weeds, or significant amounts of green material have been incorporated into the seedbed.

Symptoms
Affected plants have reduced growth and generally occur in patches where water accumulates or the soil has poor drainage. Root rot affected crops generally have poor emergence and seedling growth, and are pale and unthrifty.

Diseased plants have short stubby root systems with few lateral roots. Infected roots have a ‘water soaked’ appearance and develop a soft yellow-brown rot.

Management strategies

- **Fungicides** can suppress pythium root rot in wheat and barley through the application of a fungicide seed dressing containing metalaxyl (for example, Dividend®). Consider using this chemical where soil conditions are expected to be saturated following sowing and the disease has previously been a problem.
- **Avoid weed incorporation** and avoid sowing crops directly after applying herbicides to control autumn weeds, particularly where heavy weed burdens have developed prior to sowing.
- **Rotation** is not an effective control option because *Pythium* fungi can survive for five years or more in soil or plant debris.
Soil and plant testing services

To determine whether a fungal or nematode root disease is affecting a cereal crop, first look at the distribution of symptomatic plants throughout the whole crop. Next, carefully dig up samples of apparently diseased as well as healthy plants. Thoroughly wash the soil from the roots and examine them for the indicative symptoms described in this Bulletin.

Suspected root disease or nematode problems in-crop can be confirmed by laboratory analysis of soil and/or roots. For patch diseases, sample from the edge of the patch rather than the centre. Do not send washed plants to the laboratory. Follow sampling guidelines at [http://www.agric.wa.gov.au/plantlabs](http://www.agric.wa.gov.au/plantlabs).

**Growing season tests** are carried out on affected plants and associated soil. Although little can be done during the growing season to correct a fungal or nematode root disease, it is important to identify the cause of the problem so that decisions on appropriate management strategies can be taken leading up to and during the following seasons. 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 [http://www.agric.wa.gov.au/plantlabs](http://www.agric.wa.gov.au/plantlabs) or by phoning 08 9368 3721.

**Pre-season assessment.** The risk of root diseases being present in a paddock at a yield limiting level next season can be determined by paddock history, paddock monitoring in spring or soil tests. A review of paddock history will identify the diseases likely to be present in each paddock. The level of disease likely to develop can be determined by digging up plants in spring from areas of poor growth and examining the roots for symptoms.

An informed decision can be made about the future use of each paddock based on the presence or absence of a disease and the conduciveness of the current season and crop to further develop that disease.

Pre-season soil tests can be used where the paddock history is not adequate for planning future use. Soil tests are conducted on representative soil samples. PreDicta-B™ uses DNA assessment to determine the root diseases or nematode species present, and the likely risk of crop damage. Test kits are available through accredited agronomists and re-sellers.
Acknowledgments

Information on crown rot was sourced from Victorian Department of Primary Industries (Grant Hollaway), New South Wales Department of Primary Industries (Steve Simpfendorfer), and Queensland Department of Primary Industries and Fisheries (Graham Wildermuth).

Further reading


Vanstone, VA (2007) Root Lesion and Burrowing Nematodes in Western Australian cropping systems. Bulletin 4698, Department of Agriculture and Food Western Australia, South Perth.
