

BLACK ROOT ROT OF COTTON – A (RE)VIEW BY AN OPTIMIST

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SUMMARY

Black root rot is a fungal disease affecting cotton seedlings upon germination. Diseased plants show stunted or slow growth early in the season compared to surrounding healthy plants. Belowground symptoms include blackening of the roots and reduced number of lateral roots. Since it was first detected in NSW in the 1980s, the pathogen causing black root rot has quickly spread to all cotton growing areas of NSW and to some areas in Qld (6).

The fungal pathogen causing black root rot, *Thielaviopsis basicola*, is found in the soil in almost every inspected cotton farm in Australia. While it does not kill the plant, it causes substantial loss of yield and severe cases might open the root up for infection by other pathogens, including Pythium and Rhizoctonia (1). It has been considered a significant threat to cotton and other crops in Australia, especially in cooler areas and seasons (1). The symptomatic stunting of seedlings stays with the plant through to maturity, causing up to 40% yield loss (6), depending on the season, environmental conditions and cotton growing practices.

There are several important questions that have been raised about the black root rot pathogen, including: How can one detect black root rot? What makes it spread so fast? What makes it so hard to control? Would rotation with other crops, or fallow, reduce or control the disease? How about biofumigation? Could black root rot episodes be predicted? Are there any means for controlling black root rot? What is next in black root rot research? This review has been written in an attempt to answer some questions on what is known, unknown and currently investigated about cotton black root rot. It is answered from a microbiologist perspective.

BLACK ROOT ROT OF COTTON IN AUSTRALIA

Black root rot was first detected in NSW in the 1980s. Regular disease surveys of cotton fields in NSW have shown an increase of incidence from 22% of fields inspected in NSW in 1995 to over 60% of farms surveyed in NSW in the 2000/2001 season (6), reaching 95% of the fields regularly surveyed in northern NSW in 2004. The 2010/2011 cotton pathology survey (1), showed black root rot found in 93% farms visited and in 83% of the fields surveyed in NSW. Black root rot was previously also observed in many fields in Qld (6).

How can one detect black root rot?

Cotton seedlings affected by black root rot grow slower and may be pale in colour compared to surrounding healthy seedlings. During the first 4-5

weeks of the plant growth roots of infected seedlings appear black and have reduced number of lateral roots. The blackening is due to both necrosis (rotting) of the external layer of the root tissue (cortex) and the build-up of the pathogen's dark spores (reproduction bodies containing melanin) on the root surface. The infection cycle can be completed within three days when spores appear on the surface of the infected roots (5). The fungus can sometimes infect the centre of the root, causing a "black Heart" (1). While care should be practiced when concluding that the blackening of roots is due to black root rot, under the microscope the typical spores of the fungus *T. basicola* cannot be mistaken for anything else. Figure 1 below shows the two types of *T. basicola* spores.



Figure 1. The two types of *T. basicola* spores: endoconidia (thin wall) and chlamydospores (thick wall contains melanin). Spores are arranged in finger-like structures). Both types can infect roots.

When assessing for black root rot one should note that plants that are badly affected early in the season may not continue to show symptoms later in the season as the dead cells of the root cortex may slough off when growth resumes in warmer weather. However, the spores released into the soil increase the soil reserves of the pathogen. In following seasons, one may no longer observe patches of stunted growth as the spores may have spread and the entire field might be infected (1).

What makes black root rot spread so fast?

Once introduced to the soil, the spores of *T. basicola* are very persistent under diverse environmental conditions. The thick walled spores (chlamydospores), produced by the pathogen can survive in the soil for years and start the disease cycle once a host is available. The spores have been easily spread on machinery wheels and foot ware (5). Farm hygiene practices such as "come clean go clean" (clean foot-ware and machinery wheels with anti-fungal substances to reduce spore spreading) is always recommended to avoid further

spreading (4), however, once the spores reached a farm, it is very challenging to eradicate them. There are limited management options for reducing black root rot, highlighting the importance of research into this disease. Current management strategies to reduce black root rot (4) are discussed below.

What makes black root rot so hard to control?

Other than *T. basicola*'s resilient spores that persist in the soil, one of the reasons that make black root rot hard to control is the wide host range of the pathogen strains, including but not restricted to, all cotton varieties, some grasses, as well as many legumes, including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. *Datura* weeds (thornapple, castor oil) are also hosts, but little is known about other weeds. Non-hosts include most of the cereal crops, sunflower, canola and vetch (4). The wide host range of *T. basicola* makes most crop rotation options ineffective in reducing fungal spore load in the soil.

For example: Lupin was found to be attractive to *T. basicola* strains originally isolated from cotton hosts and the pathogen completed the disease cycle and released reproduction bodies (spores) into the soil (L Pereg, unpublished). Such spores could further infect cotton, indicating a danger in using legumes in rotation with cotton in infected fields.

Naturally existing *T. basicola* strains isolated from different plants show some degree of host specificity. Cotton is susceptible to most, but not all, strains of *T. basicola*. Exudates from cotton roots were found to be exceptionally attractive to a wide range of strains of the black root rot pathogen originated from different hosts. Using proteomics and genomics tools it was shown that in Australia the pathogen strains originated from descendants of a single strain or groups of closely related strains and have most likely adapted to their hosts, with implications in disease severity (2,3).

Putting the two facts together – the attractiveness of cotton to a wide range of *T. basicola* strains and the suggested remarkable ability of the pathogen to adapt to the host could explain the fast spread of this pathogen in and among cotton fields, disease severity and the difficulties in controlling the disease.

Would rotation crops or fallow be effective to control black root rot?

This question was answered to some extent in the previous section. One of the current recommendations to growers is to rotate with a non-hosts for up to three years, while avoiding legumes and controlling weeds (4). Growing non-hosts could reduce the fungal load in the soil, as the fungal spores may germinate but, if they find no host, would not be able to complete the life cycle or produce new spores. However, one should practice care when testing the susceptibility of a rotation crop, as some plants may not show symptoms of disease even when the pathogen infects their roots, completes the life cycle and produces spores (L Pereg, unpublished). Under field conditions such

a rotation crop might enhance the pathogen spore load in the soil. These spores would remain in the soil and infect the next cotton crop.

Fallow is not a good option for eradicating black root rot due to the persistence of the fungal spores in the soil. When new cotton will be sowed, these spores can cause disease. So far, as listed in the previous section, many plants are hosts to the black root rot pathogen. Some grasses and weeds are also hosts and might act as a refuge for the pathogen in the absence of other hosts.

In a combined effort between L Pereg (UNE) and K Kirkby (NSW-DPI), a range of crop plants, native grasses and weeds are to be tested for their ability to host *T. basicola* (and other seedling pathogens) and contribute to the spore load in soils.

How about biofumigation for controlling black root rot?

Biofumigation with vetch or mustard is sometimes recommended as control measure for black root rot (4). Vetch degradation produces ammonium. High levels of ammonium are suppressive to *T. basicola*, probably since plants exposed to high levels of ammonium produce substances that are toxic to *T. basicola* (e.g. putrescine) (7). Other reasons could include the effect of changing the soil's acidity (ammonium may increase the soil's pH).

Note, a possible solution to planting crops that do not produce an income (increase costs) could be to choose bio-fumigant crops that give other benefits, e.g. N benefits, reducing the need for fertilisers in the following crop. Unfortunately, most legumes are highly susceptible to black root rot and might increase the spore load in the field. Another thing to consider is that, although the bio-fumigation crop may reduce the incidence of *T. basicola* infection, it might be a host for other diseases (e.g. *Pythium ultimum* and *R. solani*). If unsure – better check! A researcher could assist here.

Could black root rot episodes be predicted?

While the presence and of *T. basicola* spores in the soil can be determined and their amounts estimated, it is still hard to predict black root rot episodes and their severity. For example, even when *T. basicola* spores are present, if delayed planting is possible (in particular in NSW), one may avoid a severe black root rot episodes. Dry, cool conditions seem to enhance black root rot (1). Although the pathogen can grow at higher temperatures (22-28 °C), delayed planting and increased temperatures promote the plant growth and assist plants to avoid/overcome the disease.

The cotton variety used may also influence the severity of the seedling disease. One of the current recommendations to growers is to choose varieties that can "catch up" (4). As the season progresses and the temperatures increase, the plant may overcome the seedling disease and growth may catch up.

Different *T. basicola* strains may vary in their virulence towards various cotton cultivars (L Pereg, unpublished). It may be possible in the future to advise growers which cotton cultivar to avoid if certain aggressive strain of *T. basicola* is found in their fields. Such prediction tool would be particularly useful as *T. basicola* spores already exist in most cotton-growing fields making prevention methods limited. Plans are in place to commence work towards achieving this goal.

Are there any means for controlling black root rot?

The Cotton Pests Management Guide 2011-12 (can be found on the CRDC web site) suggests some Integrated Disease Management (IDM) tactics to reduce black root rot. Some of these were mentioned already in this review and a summary is given below (with some comments from the author):

- Choose varieties that can 'catch up'
- Use Bion seed treatment: Acibenzolar-S-methyl (commercially known as Bion™) induces host resistance against black root rot. Tests gave mixed results in Australia, with disease suppression of up to 33% observed. It is currently recommended for use in combination with other treatments as part of IDM.
- Prepare beds well ('high and firm' not 'low and loose')!
- Pre-irrigate and/or plant into moisture: Lower water potential seems to reduced disease, so where possible avoid watering after planting.
- Delay planting if possible
- Rotate with non-hosts for up to 3 years (one has to ensure it is indeed a non-host and that it would not increase the loads of other diseases)
- Avoid legumes and control weeds (as they might be a refuge host)
- Biofumigation with vetch or mustard (if they are not hosts for other diseases)
- Always practice good farm hygiene
- Summer flooding if possible: Flooding for 30-60 days before planting seems to reduce disease in the next crop (1,4), possibly since the spores germinate but find no host and die out. However, summer flooding is often impractical due to water restrictions.

Understanding the fungal pathogenicity factors that are employed by *T. basicola* to infect cotton would derive the development of further control measures for black root rot.

What is next in black root rot research?

Current research by plant breeders is concentrating on breeding cotton towards resistance to black root rot and other diseases. Studies show that cotton responses to *T. basicola* infection by producing proteins that are often produced in other plants as a defence against pathogens (2,3). Nevertheless, *T. basicola* obviously overcomes such defence attempts by the cotton plant. The success of Bion™ to induce some resistance of cotton to plant pathogens suggests that breeding plants to

suppress fungal pathogens or to defend against such pathogens may be feasible.

Further research into the host-range of the pathogen as well as the virulence of different *T. basicola* strains towards various cotton cultivar has been initiated in a collaborative effort between UNE (L Pereg) and NSW DPI (K Kirkby). The aims are to test for the suitability of rotation crops, identify potential refuge hosts and have the ability to advise growers on cotton cultivars to be avoided in *T. basicola* infested fields.

Finally, biocontrol options for black root rot and other seedling diseases could be an attractive option, especially if combined with bio-fertilisation to enhance seedling standing. Preliminary work at the laboratory of L Pereg suggests that some soil microbes can protect cotton seedlings from black root rot under laboratory conditions. Biocontrol options and nutrient management are currently under investigation at the laboratory of L Pereg.

CONCLUSION

Black root rot is a serious disease affecting cotton production with few disease management options. It is becoming obvious that effective management would require the integration of different approaches and the initiation of IDM for cotton is a positive progress towards achieving this goal.

Research into black root rot and *T. basicola*, in the field and laboratory, equips researchers with the knowledge of where to look for solutions when dealing with this pathogen. Future research will concentrate on making such knowledge more accessible to growers in dealing with soilborne fungal pathogen.

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