



Cotton
RESEARCH & DEVELOPMENT

Integrated Disease Management





INTEGRATED DISEASE MANAGEMENT

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the Australian Cotton Cooperative Research Centre

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INTEGRATED DISEASE MANAGEMENT FOR Seedling Diseases

THE PATHOGENS

- *Rhizoctonia solani* - (AG 4).
- *Pythium* spp. – (several species but *P. ultimum* is the most common)
- *Fusarium* spp. – (several species other than the Fusarium wilt pathogen)
Etc. – (over 30 different species of fungi have been isolated from dying cotton seedlings)
- Anthracnose (*Colletotrichum gossypii*) is rarely seen in Australia but has been reported in Northern Australia and Queensland. All parts of the plant may be attacked. Typical symptoms include a girdling of the stem at or near ground level.

SYMPTOMS

- Pre-emergent seed rots
- Post-emergent damping-off (wilting, collapse and death of seedlings)
- Slow early season growth, small cotyledons and reddened hypocotyls
- Lesions on roots

Affected plants may be scattered across the field or concentrated in poorly drained areas. In some situations seedling diseases may be particularly evident in rows where other factors such as fertiliser placement, herbicide application, planting depth etc have had an effect.

ECONOMIC IMPACT

Actual and potential costs associated with seedling diseases include:

- The cost of standard seed treatment fungicides used by all growers
- Replant costs including seed, fuel, labour and in some situations, extra water
- Cost of late season insect control which can be expensive
- Yield reductions associated with late replants or delayed maturity

ASSESSMENT

Estimate the stand by counting the number of established plants/metre at at least 20 sites across the field. The difference between the estimated stand at 6-8 weeks after planting and the number of seed/metre sown indicates the level of seedling mortality. Seedling mortality includes the effects of seedling pests such as wireworms and incorporates seed viability.

An alternative method is to estimate stand immediately after emergence and again 6-8 weeks later.

DISEASE CYCLE

The fungi that cause seedling diseases of cotton are common soil inhabitants and therefore widely distributed.

FAVOURED BY

Anything that slows down germination and seedling growth favours infection by the seedling disease pathogens. Cool and/or wet weather conditions are particularly conducive to disease development. Other factors that may contribute to increased seedling disease problems include:

- Poorly formed, low or loose seed beds
- Incorrect planting depth
- Poor placement of fertiliser (under the planting line)
- Excessive rates of herbicide at planting
- Relocation of herbicide into root zone by rain after planting (esp. in loose beds)
- Smearing of the planting slot or compaction in the seed bed
- Infection by other pathogens such as the black root rot pathogen
- Waterlogging or poor drainage

DISPERSAL

Seedling disease pathogens are easily dispersed with soil and plant residues by wind or water and by the activities of man. They are present in most soils.

SURVIVAL

These fungi can survive indefinitely as saprophytes on plant residues in the soil.

HOST RANGE

Seedling disease pathogens have a wide host range and can survive on the residues of many crops and weeds. There is some evidence that seedling diseases may be more severe after incorporation of legume residues.

A CONTROL STRATEGY

Seedling Diseases

PLANNING

- Use a variety with good seedling vigour
- Use effective seed treatment fungicides

GROUND PREPARATION

- Plant into well prepared, high, firm beds
- Carefully position fertiliser in the bed – not under the plant line!

PRE-PLANTING

- Plant into moisture rather than planting dry and watering-up

AT PLANTING

- Delay planting until temperature and moisture conditions are optimum
- Be careful with the use of herbicides at planting

ROTATIONS

- Incorporate rotation crop residues as soon as possible after harvest (especially legume crop residues)



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The purpose of these guidelines is to help cotton growers minimise the impact of disease on the profitability of their operation. Very few cotton diseases can be completely eliminated but the application of an effective Integrated Disease Management Strategy can produce one of several desirable outcomes that may include:

- Prevention or postponement of the introduction of a disease(s) that is not already present on-farm
- Reduction of the rate of build-up of a disease that has been introduced to the farm
- Elimination of a disease that may be affecting profitability
- OR Minimisation of the impacts of a disease on crop growth and/or productivity

The Guidelines are presented at two levels. There is a general IDM strategy that should be followed by all growers at the farm level. These are general principles that are applicable to all diseases and every farm. On a more specific level there is a programmed IDM strategy for each of the significant diseases affecting the Australian cotton industry. This section contains descriptions of disease symptoms and assessment methods and information on the life cycle, survival and dispersal of the pathogen.

Use of these Guidelines can therefore help you to:

IDENTIFY THOSE DISEASES PRESENT

[See the detachable pocket-size 'Cotton Disease Symptoms' guide.](#)

UNDERSTAND THE BASIC PRINCIPLES OF PLANT PATHOLOGY AND DISEASE CONTROL

[See 'General Introduction' and 'Principles of Disease Management'](#)

APPLY GENERAL IDM STRATEGIES ACROSS THE FARM

[See 'Integrated disease management at the farm or crop level'](#)

ASSESS AND MONITOR DISEASE INCIDENCE AND SEVERITY OVER TIME

[See 'Do it Yourself Disease surveys'](#)

PLAN AND PROGRAM AN EFFECTIVE IDM STRATEGY FOR SPECIFIC DISEASE PROBLEMS

[See 'Integrated Disease Management for Specific Diseases' and 'IDM Timetable'](#)

GET HELP FROM THOSE THAT CAN PROVIDE DIAGNOSIS AND FURTHER INFORMATION

[See 'Sending a sample for diagnosis'](#)

A [glossary](#) is provided to explain those technical terms that are included in the text.

It is relatively easy for cotton pathologists to develop and recommend an Integrated Disease Management strategy. The real challenge is for growers and consultants to integrate these recommendations with the recommendations in ENTOpak, SOILpak, NUTRIpak, MACHINE-pak and WEEDpak. All of this information then has to be further integrated with current weather and weather forecasts, market forecasts and economic forecasts from the bank manager or shareholders! Growers and consultants are the real integrators! We wish them well!!

INTEGRATED DISEASE MANAGEMENT

General Introduction

SOME DEFINITIONS

A plant disease is a set of symptoms caused by the negative interaction of a pathogen with a host plant. When we describe a plant disease we describe that set of symptoms. The negative interaction may be evidenced by death, destruction, discolouration or abnormal growth and development of host tissue. A pathogen is a parasite because it derives its nutrition and or multiplies on, or in, the host plant. It may be a fungus, a bacterium, a virus or phytoplasma, a nematode or even a parasitic plant. The majority of plant pathogens are fungi.

Some define a plant disease more generally as any deviation from normal growth and development. Such a general definition allows nutrient deficiencies, herbicide damage, environmental effects and some insect interactions to be considered as plant diseases. This loose definition can be advantageous when a particular symptom has a suite of possible causes. Yellowing between the veins or leaf mottle in cotton can result from a fungal pathogen (*Verticillium* wilt), herbicide damage (fluometuron) or a nutritional deficiency (zinc).

When describing a plant disease we can refer to its incidence and/or severity. The incidence of a disease indicates the proportion (%) of plants that are affected whereas the severity quantifies the mean intensity or extent of the symptoms on the host plants. The severity may be expressed as the percentage of leaf area infected or the proportion of bolls affected or an arbitrary 0 to X scale may be used where 0 = healthy and X = maximum severity. It is possible for a disease to have a very high incidence and a very low severity. eg: *Alternaria* leaf spot may be present on nearly every plant in a field but with only one or two spots on the lower leaves of each plant.

DISEASES OF COTTON

Diseases of cotton have been a significant concern to cotton growers in Australia. Bacterial blight was widespread and severe in the 1980's and caused millions of dollars in lost production. The development and release of resistant varieties and the successful implementation of a scheme to reduce the level of infestation in planting seed resulted in the virtual elimination of this disease as a threat to the industry.

The use of susceptible varieties coupled with the adoption of minimum and reduced tillage practices was accompanied by an increasing incidence and importance of *Verticillium* wilt in the late 1980's. The release and widespread adoption of varieties with good resistance to the *Verticillium* wilt pathogen resulted in a significant decline in the importance of this disease.

Alternaria leaf spot and *Phytophthora* boll rot have become widespread and common. The severity of *Alternaria* leaf spot and the incidence of *Phytophthora* boll rot have generally been low although both diseases have a demonstrated capacity to cause significant losses when conditions favour the pathogen.

During the 1990's black root rot and *Fusarium* wilt emerged as serious threats to farm profitability. Both of these diseases are caused by soilborne fungal pathogens and the development of effective control strategies represents a difficult challenge. Experience with these diseases has emphasised the importance of good farm hygiene for limiting the spread of pathogens and weeds.

There are many diseases of cotton that occur overseas but not in Australia. The defoliating strains of the *Verticillium* wilt pathogen and the hypervirulent races of the bacterial blight pathogen have not been recorded in Australia. There are some diseases that are present on some farms in some areas but not on other farms in other areas. Prevention is better than cure. Quarantine and farm hygiene are very important.



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Principles of Disease Management

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. Most plants are immune or completely resistant to almost all plant pathogens. In other words resistance or immunity is normal. However, some pathogens have developed the ability to bypass or overcome the natural resistance mechanisms of particular hosts. The host is then regarded as being susceptible to that pathogen and the pathogen is described as being virulent on that host.

When a virulent pathogen is dispersed onto a susceptible host and the environmental conditions are suitable then a plant disease develops and symptoms become evident. Disease control strategies must therefore focus on the host, the pathogen and/or the environment. 'Integrated Disease Management' involves the selection and application of a harmonious range of control strategies that minimise losses and maximises returns.

THE HOST

A particular variety may be immune, resistant or susceptible. Plants of an immune variety are not infected by the pathogen while pathogen growth and multiplication is unrestricted in a susceptible variety. Resistance may appear as less spots or smaller spots on leaves or bolls, less plants affected, symptoms less severe, less spores produced, slower spread of the pathogen in the plant etc. etc. Plant breeders often use the word 'tolerance' to imply good performance (yield) despite the presence of disease.

Examples of disease control strategies that focus on the host include:

1) The use of resistant varieties. Australian bred cotton varieties are completely resistant to the bacterial blight pathogen. Some varieties have good resistance to Verticillium wilt and some varieties have some resistance to Fusarium wilt.

2) The application of systemic activators or biocontrol agents to 'turn on' the host plant's natural defence mechanisms. Dr Emma Colson's work showed that the application of a systemic activator could induce stronger resistance resulting in reduced severity of Alternaria leaf spot and Verticillium wilt of cotton.

3) Provision of balanced crop nutrition. Eg. potassium deficiency results in increased susceptibility to Alternaria leaf spot. Consequently, applications of potassium increase the natural resistance of the host.

THE PATHOGEN

A pathogen must be present in the area, capable of surviving the inter-crop period and adapted for effective dispersal between host plants if a disease is to occur. Disease control strategies that focus on the pathogen therefore include:

1) Exclusion of the pathogen from an area ('Come clean' and quarantine). There are diseases of cotton that occur overseas that are not present in Australia. There are diseases of cotton that occur elsewhere in Australia that may not occur on your farm. There are diseases of cotton that may be present in some fields on your farm but not in others.

2) Control of alternative weed hosts. The pathogens that cause Verticillium wilt, Fusarium wilt, black root rot and Alternaria leaf spot can also infect common weeds found in cotton growing areas.

3) Use of rotation crops that are not hosts. Most legume crops are also hosts of the black root rot pathogen. The Verticillium wilt pathogen has a large host range.

4) Crop residue management to reduce pathogen survival and eliminate sources of infection. The pathogens that cause Verticillium wilt, Fusarium wilt, black root rot, bacterial blight, boll rots, seedling disease and Alternaria leaf spot can all survive in association with crop residues. The Fusarium wilt pathogen can also survive and multiply on the residues of non-host crops.

5) Application of biocides eg. seed treatments for seedling disease control and foliar sprays for the control of Alternaria leaf spot on Pima cotton.

6) Control of insect vectors. Diseases caused by a virus or phytoplasma can often be controlled by controlling the vector that carries the pathogen.

7) Application of biocontrol agents that antagonise, inhibit or compete with the pathogen.

THE ENVIRONMENT

Pathogens have optimum temperature, relative humidity, leaf wetness and/or soil moisture content requirements for infection to occur and for the disease to spread and multiply in the host plant. When environmental conditions are not optimal then the rate of disease development is reduced.

It may appear difficult to manipulate the environment but it can be achieved by altering row or plant spacing, irrigation method or frequency or by changing the sowing date. Possible disease control strategies that focus on the environment include:

1) Good bed preparation. Well prepared, firm, high beds are more conducive to good seedling emergence than low, loose beds.

2) Timing and frequency of irrigation. Applying water prior to planting provides better conditions for seedling emergence than watering after planting. Irrigations late in the season can result in a higher incidence of Verticillium wilt.

3) Crop management to avoid rank growth and a dense canopy. The high relative humidity associated with rank growth and a dense canopy favours development of bacterial blight, Alternaria leaf spot and boll rots.

4) Choosing a sowing date that provides optimum conditions for germination.

5) Crop management for early harvest. Verticillium wilt is favoured by the cool conditions at the end of the season.

INTEGRATED DISEASE MANAGEMENT

The philosophy of integrated control is based on the assumption that populations of all organisms are in some kind of balance with their resources in each crop biosystem. If this balance is upset, it can be restored by manipulation in such a way as to achieve an acceptable level of control of damaging species without unduly harming the desirable flora or fauna or their physical environment.

'Integrated Disease Management' involves the selection and application of a harmonious range of disease control strategies that minimise losses and maximises returns. The objective of integrated control programs is to achieve a level of disease control that is acceptable in economic terms to farmers and at the same time causes minimal disturbance to the environments of non target individuals.

Integrated Disease Management can be considered at two levels. An integrated control program may be aimed at all of the diseases that affect a particular crop or an integrated control program may be developed for a specific disease that affects a crop.



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At the Farm or Crop Level

Effective disease management must be integrated with management of the whole farm. Basic strategies should be implemented regardless of whether or not a significant disease problem exists. These basic strategies include the following:

1. Do your own disease survey in November and February of each season.

- Be aware of what diseases are present, where they are present and whether or not the incidence is increasing.
- Train farm staff to be observant and report back on possible disease occurrences.

2. Practice farm hygiene principles.

- Minimise the movement of pathogens either onto or off your farm or from one field to another on your farm.
- Encourage all visitors to 'COME CLEAN' and 'GO CLEAN'

3. Use resistant varieties where available.

4. Provide a balanced crop nutrition.

- A healthy crop is more able to express its natural resistance to disease (See NURTIpak)

5. Manage crop residues to minimise carryover of pathogens into subsequent crops.

6. Develop a sound crop rotation strategy.

- Repeated cultivation of cotton can contribute to a rapid increase in disease incidence - especially if susceptible varieties are used.



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INTEGRATED DISEASE MANAGEMENT FOR Black Root Rot

THE PATHOGEN

The fungus *Thielaviopsis basicola* (synonym *Chalara elegans*)

SYMPTOMS

Slow growing or stunted cotton, especially during the early part of the season, sometimes in distinct patches initially, often spreading throughout the field in later seasons.

Blackening of the roots due to destruction of the root cortex (the outer layer of cells).

Some roots may die but *T. basicola* does not kill seedlings by itself. Severe black root rot, however, will enhance seedling death caused by *Rhizoctonia* or *Pythium*.

Plants that are badly affected early in the season may not show symptoms later in the season because the dead cells of the root cortex are sloughed off when growth resumes in warmer weather.

Internal stem rot in a proportion of older plants, usually appearing as a black to brown stain in the centre of the stem that extends a few centimetres along the tap root at, and just below, the soil surface.

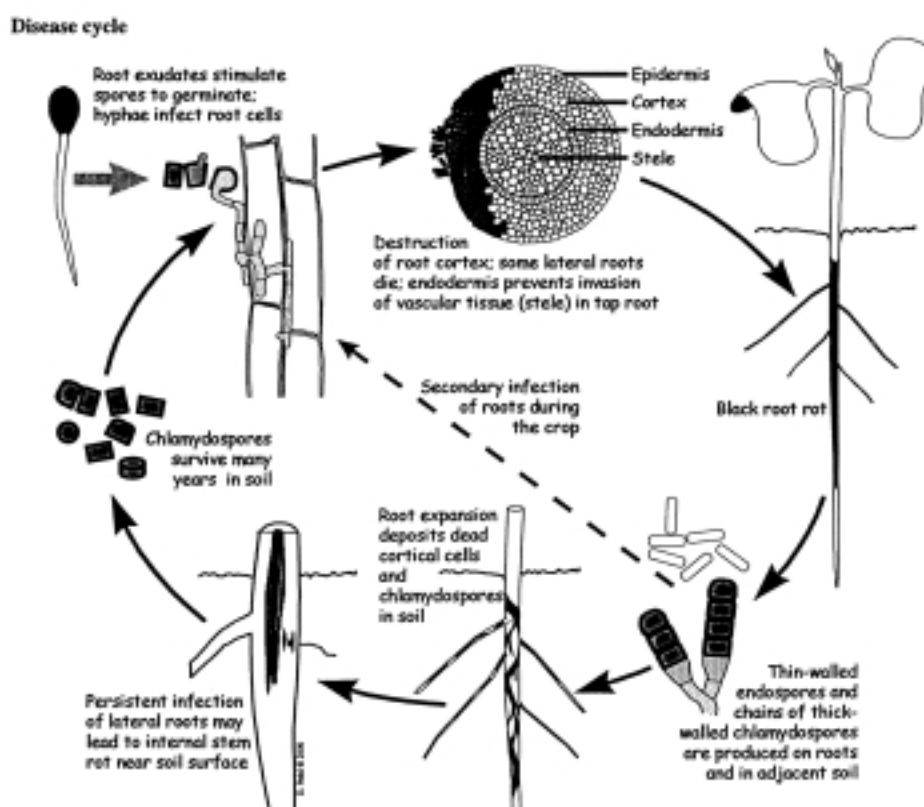
ECONOMIC IMPACT

Black root rot delays development of the crop and, in effect, 'steals time' from the crop. If conditions later in the season are warm then the crop may compensate and yield well. Severe black root rot leads to delays in maturity of up to four weeks and yield reductions as high as 40%.

ASSESSMENT

Look for patches or large areas of slow growing cotton (with or without reduced stand). If symptoms are present, then it may be possible to estimate visually the area of the field affected. The incidence of black root rot in the crop can be assessed using the step point method (see glossary) for ten lots of ten seedlings, preferably between three to six weeks after sowing. Count the number of seedlings with or without characteristically blackened roots and express as a percentage of the total. Later in the season, the incidence of the internal stem rot (if present) can be assessed in a similar way by splitting stems at soil level.

DISEASE CYCLE



FAVOURED BY

Cool wet conditions. Soil temperatures below 20°C are most favourable but infection will still progress at temperatures between 20 and 25°C.

Medium to heavy clay soils. Lighter textured soils as well as very heavy clays are less favourable.

DISPERSAL

T. basicola is dispersed in soil adhering to vehicles and machinery. The fungus is dispersed in tail water or in soil adhering to trash floating in tail water.

SURVIVAL

T. basicola survives as thick walled spores (chlamydospores) that lie dormant in the soil for many years until cotton or some other suitable host is present. Thin walled spores (endospores) are short lived but may cause secondary infection during the crop. Huge quantities of spores are produced on cotton roots and in the adjacent soil.

T. basicola can only reproduce on living host plants and cannot grow on crop residues. Therefore, the cropping sequence determines its density in soil.

HOST RANGE

All varieties of cotton are susceptible. Most legumes are susceptible, including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. *Datura* (variously known as thornapple, castor oil, false castor oil etc. etc.) is a host but little is known about the susceptibility of other weeds. Non-hosts include all the cereals, sunflower, brassicas such as canola and broccoli, onions and woolly pod vetch.

A CONTROL STRATEGY FOR Black Root Rot

PLANNING

- Choose indeterminate varieties that have the capacity to 'catch up' later in the season

GROUND PREPARATION

- Good bed preparation to optimise stand establishment and seedling vigour
- Pre-irrigate in preference to 'watering up'

EARLY SEASON

- Time sowing to avoid cool temperatures if possible, but sow early if conditions are warm enough (a soil temperature of 16°C is OK, 20°C is better) and soil temperature is rising. Temperature measurements should be taken in the fields where black root rot occurs.
- Replanting decisions should be made on the basis of stand losses, not the size of the seedlings.
- Watch for early onset of water stress (ie. because the root system is weak) and irrigate accordingly, but avoid waterlogging.

LATE SEASON

- Anticipate delayed growth and later maturity and manage the crop accordingly (black root rot 'steals' time from your crop).

AFTER HARVEST AND AT ALL TIMES

- Practice good farm hygiene. Farmcleanse (used at 10%) is effective against *T. basicola* and is a useful aid to decontaminate vehicles after mud is removed – COME CLEAN, GO CLEAN

ROTATION

- Rotate with non-host crops (eg. cereals, canola) for more than one season if possible.
- Biofumigation with woolly pod vetch or mustard (canola?) between consecutive cotton crops or after a wheat fallow. The success of biofumigation depends upon the growth of the biofumigation crop and good incorporation (at least four weeks before cotton).
- Avoid rotation with legumes (except vetch) and control alternative weed hosts (eg. *Datura*).
- Flooding of fields for 30 days during summer reduces the population of *T. basicola* dramatically. This option will be limited by the topography of fields and the availability of water.



INTEGRATED DISEASE MANAGEMENT FOR Verticillium Wilt

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THE PATHOGEN

Verticillium dahliae (Group 4 strains based on VCG analysis)

NOTE Group 1 and 2 strains include the defoliating and non defoliating strains of the pathogen that occur overseas and have not been detected in Australia. Australian strains are described as being mild in comparison!

SYMPTOMS

- Leaf mottle – yellowing between the veins and around the leaf margins
- Vascular discolouration or browning extending throughout the stem and into the petioles
- Root system appears otherwise healthy
- Some defoliation may occur if weather conditions are cool

ECONOMIC IMPACT

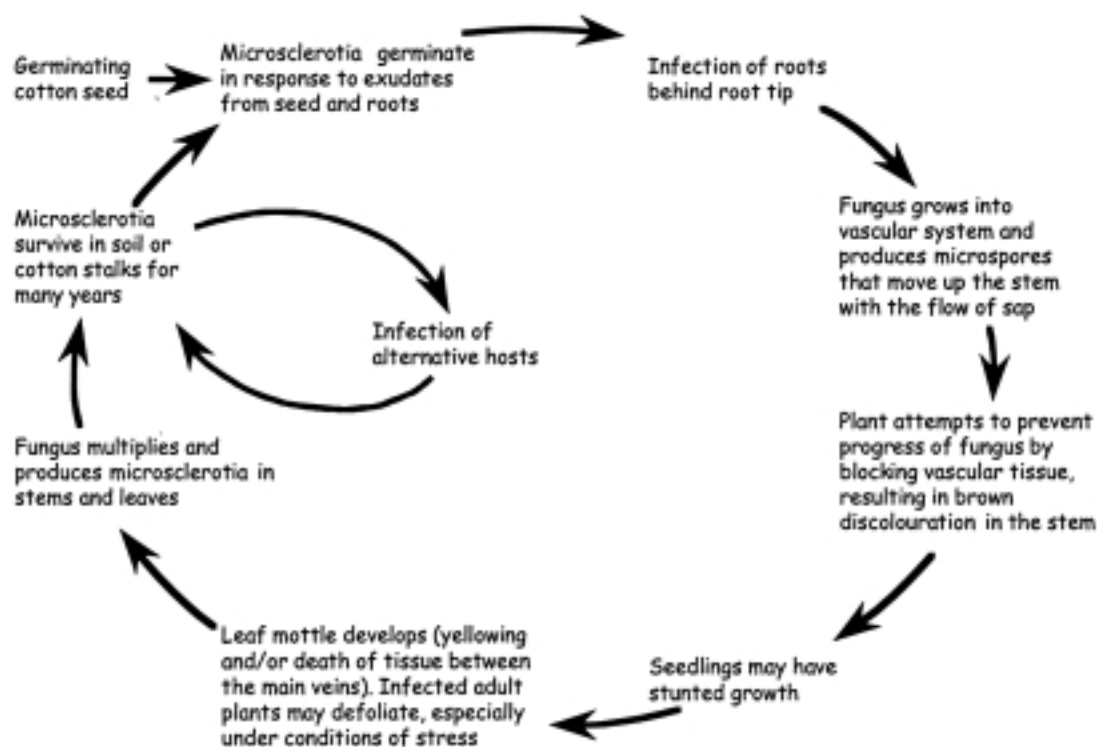
The impact of Verticillium wilt is dependent on the time of infection which is in turn dependent on the occurrence of cool and/or wet weather. Yield is most significantly affected when weather conditions are conducive to severe symptoms mid-season and plants do not have time to compensate. Under such conditions yield reductions of up to 30% are possible. There is minimum impact on yield when the disease is most severe either early in the season or very late in the season.

ASSESSMENT

The presence or absence of leaf symptoms can be assessed at any time throughout the season but will not be particularly obvious in mid summer. The best time to assess foliar symptoms is after the final irrigation. The presence or absence of vascular symptoms is best assessed immediately after harvest using secateurs. Under Australian conditions with Australian strains of the pathogen all plants with vascular symptoms will also display foliar symptoms.

Disease incidence may be estimated by inspecting 10 plants at a minimum of 20 sites randomly selected across the field. Alternatively, establish a transect across the field and assess for the presence or absence of disease in ten plants in every tenth row.

DISEASE CYCLE



FAVOURED BY

Symptom development is favoured by cool weather conditions. Resistance to the disease is temperature sensitive. Varieties that are resistant at 25-27°C are susceptible at 20-22°C. The disease is most severe when the crop is subjected to extended periods of overcast wet weather and waterlogging or when the crop matures late in the season as conditions become cooler.

Verticillium wilt may be favoured by excessive use of nitrogen fertilisers which result in late season growth and also by potassium deficiency.

DISPERSAL

The pathogen is dispersed in soil and crop residues by wind or water or attached to vehicles and machinery. It may be easily distributed from field to field in tailwater recirculation systems and from farm to farm and along stock routes in the infected burrs of noogoora burr and bathurst burr carried by animals.

SURVIVAL

V. dahliae survives as microsclerotia in the soil and in crop residues. Microsclerotia are microscopic 'knots' of fungal hyphae with dark, thickened cell walls. These microsclerotia enable the pathogen to survive for several years in the absence of a host.

HOST RANGE

The Verticillium wilt pathogen has a very large host range which includes:

Crops Sunflower, soybean, potatoes, tomatoes, olives, etc etc

Weeds Noogoora and bathurst burr, saffron thistle, thornapple, caustic weed, bladder ketmia, burr medic, black bindweed, pigweed, devils claw, turnip weed, mintweed, black nightshade, etc. etc.

A CONTROL STRATEGY FOR

Verticillium Wilt

PLANNING

- Use a resistant variety

GROUND PREPARATION

- Provide balanced crop nutrition (especially nitrogen and potassium)

IN CROP

- Avoid long periods of waterlogging

LATE SEASON

- Manage for earliness
- Avoid late season irrigations

AFTER HARVEST

- Incorporate crop residues as soon as possible after harvest
- Minimise the movement of crop residues in tailwater recirculation systems

AFTER HARVEST AND AT ALL TIMES

- Practice good farm hygiene – COME CLEAN, GO CLEAN

ROTATIONS

- Rotation with non-host crops such as sorghum and cereals
- Control alternative weed hosts



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INTEGRATED DISEASE MANAGEMENT FOR Fusarium Wilt

THE PATHOGEN

Fusarium oxysporum forma specialis *vasinfectum* (Fov) is a soil-inhabiting fungus that invades cotton plants via the roots and causes a blockage of the water conducting tissues resulting in wilting and eventual death of affected plants. Two different strains have been identified in Australia since the disease was first recorded in the 1992-93 season. The Australian strains of Fov belong to either Vegetative Compatibility Group (VCG) 01111 or 01112. Strains of Fov from overseas have not yet been found in Australia.

SYMPTOMS

External: Growth is stunted and leaves initially appear dull and wilted, before yellowing or browning progresses to eventual death from the top of the plant. Some affected plants may re-shoot from the base of the stem. External symptoms can appear in the crop at any stage but most commonly become apparent in the seedling phase when the plants begin to develop true leaves and after flowering when the bolls are filling.

Internal: Lengthwise cutting of the stem of an affected plant will reveal continuous brown discolouration of the stem running from the main root up into the stem. The internal discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecking in the stem tissue. The severity of external symptoms does not always reflect the degree of internal discolouration that might be seen when the plant is cut open. Often the discolouration might only be visible up one side of the plant.

Symptoms can appear as only a few individual plants or as a small patch, often but not always in the tail drain or low-lying (waterlogged) areas of a field.

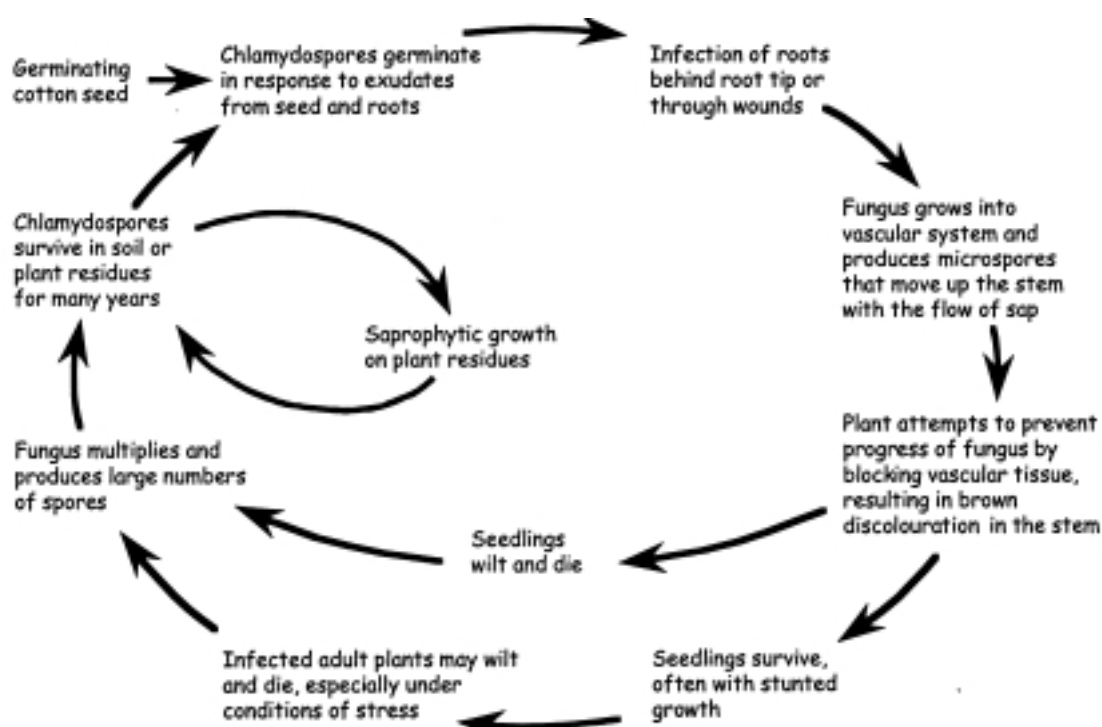
ECONOMIC IMPACT

Once introduced it is almost impossible to eradicate and failure to control the build-up of the disease results in fields becoming no longer suitable for cotton production. Once introduced into a field on a farm the pathogen may be quickly dispersed to other fields via the irrigation system.

ASSESSMENT

Establish a transect across the field and assess for the presence or absence of disease symptoms in ten plants in every tenth row. The presence of the disease is best determined by checking for the characteristic brown internal discolouration within the lower stem.

DISEASE CYCLE



FAVOURED BY

- Use of susceptible varieties
- Stresses in the crop such as waterlogging, root damage through cultivation, unfavourable growing conditions
- Poor farm hygiene on and between farms and between districts
- Dispersal
- Infested soil or plant material (eg. infected stems) attached to vehicles, machinery, boots etc. is the major mode of dispersal of this fungus. One gram of soil can contain up to 5000 Fov spores
- Spores can survive in soil and in crop residues and can be spread in overland flows and in irrigation water
- Fov can also be seed-borne

SURVIVAL

Spores: This fungus produces two types of spores. Conidia for short term survival and dispersal and thick-walled chlamydospores that enable long-term survival.

Saprophytic growth: Once introduced into a field, this fungus is also able to persist in the absence of cotton plants by surviving with low levels of saprophytic growth on decaying organic matter in the soil and also in the rhizosphere of some other plants eg. some weed species. It may not cause disease in these other plants but can survive at a reduced population level.

HOST RANGE

The form of *Fusarium oxysporum* that causes disease in cotton plants (*vasinfectum*) is specific to cotton and is not known to cause wilt disease of other crops. The strains of Fov present in Australia appear to be equally capable of causing disease in commercial cotton varieties although the susceptibility of these varieties varies from highly susceptible to partially resistant. The relationship of the Australian strains of Fov with the native *Gossypium* species (native members of the cotton family) is unknown at this stage but is being investigated.

Alternative weed hosts include bladder ketmia, sesbania pea and dwarf amaranth (etc??)

A CONTROL STRATEGY FOR Fusarium Wilt

PLANNING

- If your farm is free from this disease, try to keep it that way! – See 'Farm Hygiene'; 'Come clean-Go clean'
- Use the most resistant cotton varieties available, especially if Fov occurs in your district
- Ensure that seed is treated (eg. Quintozene and Apron)

PLANTING

- Plant to avoid unnecessary stress to germination and early growth eg. not in cold conditions.

IN CROP

- Control weeds during and between crops
- Avoid mechanical inter-row cultivations if possible during the crop (eg. use shielded sprayer to control weeds)
- Manage the crop to avoid stresses such as waterlogging, over-fertilisation, root damage
- Maintain farm hygiene and awareness of incoming traffic through the season
- Conduct regular inspections to allow early detection of any suspicious looking plants. If any are found, send immediately to QDPI for analysis. Educate farm workers what to look for and encourage reporting
- If Fov is confirmed, rogue and burn for small patches
- Solarisation may also be an appropriate treatment for small affected patches detected early in the season.
- Isolate affected areas from irrigation flows and traffic to avoid spreading the fungus. Minimise tail-water from affected fields.

LATE SEASON

- Ensure that harvesting machinery is clean
- If Fov has been confirmed on your farm notify all relevant parties so that measures can be taken to avoid spreading the fungus to other fields on your property and to other regions

AFTER HARVEST

- After harvest, retain crop residues on the surface for as long as possible before incorporation

ROTATIONS

- Selection and management of rotation crops is important as the pathogen is able to survive in association with the residues of non host crops.
- Summer flooding, where possible, has been shown to be effective but does not eradicate the pathogen.



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INTEGRATED DISEASE MANAGEMENT FOR Alternaria Leaf Spot

THE PATHOGEN

Alternaria macrospora

Alternaria alternata

SYMPTOMS

A. macrospora

Leaves – brown, grey brown or tan lesions 3–10mm in diameter - especially on lower leaves - sometimes with dark or purple margins – sometimes with concentric zones obvious. The environment is most favourable within the crop canopy and therefore Alternaria leaf spot should be most severe on lower leaves and least severe on the upper leaves (unless the upper leaves have been affected by premature senescence). Plants with a high fruit load are more susceptible than plants with a low fruit load.

When a susceptible crop is exposed to a favourable environment then defoliation occurs rapidly – especially in Pima varieties. Affected leaves develop an abscission layer, senesce and drop to the ground.

Bolls – circular dry brown lesions up to 10mm across.

A. alternata

Leaves and bolls – usually purple specks or small lesions with purple margins.

ECONOMIC IMPACT

Most commercial varieties of cotton are relatively resistant to Alternaria leaf spot and the impact of the disease on yield is insignificant – unless the crop is severely affected with premature senescence associated with Potassium deficiency. However, Pima cotton is very susceptible and when weather conditions are optimal for disease the crop is defoliated and yield reductions of up to 40% have been reported overseas.

ASSESSMENT

When Alternaria leaf spot is severe and plants are being defoliated then disease severity can be assessed by determining percentage defoliation. Randomly select at least 10 plants (preferably 20-50) and count the total number of nodes with and without mainstem leaves still present. If bolls are affected then the percentage of bolls affected may be determined by counting affected and unaffected bolls on at least ten randomly selected plants.

When disease severity is low it is best assessed by determining the percentage of leaf area affected using a pictorial assessment key (see Assessing Disease on your Farm). An average of one small lesion on each and every leaf is approximately equivalent to 0.1% leaf area infected. Disease severity may also be quantified by assessing the percentage leaf area affected for the lowest one, two or three mainstem leaves. Alternatively, the lowest mainstem leaf from at least 20 randomly selected plants can be collected and dried in a plant press in newspaper for later assessment.

DISEASE CYCLE

The large multi-celled asexual spores (conidia) germinate on the leaf surface when the leaves are wet and the germ tubes enter the leaf via stomates or directly through the cuticle and epidermis. Under ideal conditions the pathogen kills the surrounding leaf tissue and produces more spores on the surface of the lesions within a few days. Numerous spores are produced on defoliated leaves on the ground under the crop.

FAVoured BY

Spores can only germinate when there is an adequate dew period – a period of several hours of free moisture on the leaf surface. Epidemic development is therefore favoured by either repeated heavy dews or extended periods of wet weather. Symptom development is suppressed by periods of very hot weather.

Plants are most susceptible at the seedling stage and late in the season when the crop begins to 'cut out'. Symptom development is favoured by any physiological or nutritional stress eg heavy fruit load or premature senescence.

Pima varieties are most susceptible. Most upland (*G. hirsutum*) varieties are considered to be moderately resistant although some are quite susceptible.

DISPERSAL

Spores and infected crop residues are dispersed by wind and on machinery and vehicles. Seed borne dispersal has been reported overseas but is thought to be insignificant.

SURVIVAL

Alternaria alternata is widespread and common on any dead or dying plant tissue and vast numbers of spores can originate from dry weeds and grasses and mature cereal crops after rain.

Spores and mycelium of *Alternaria macrospora* can survive on or in infected crop residues as well as on volunteer cotton plants and alternative weed hosts. Survival on crop residues is favoured by dry winter weather conditions.

HOST RANGE

The host range of *Alternaria macrospora* includes cultivated cotton and some malvaceous weeds such as bladder ketmia, sida and anoda weed.

A CONTROL STRATEGY FOR

Alternaria Leaf Spot

PLANNING

- Don't plant susceptible varieties in fields with infected residues from a previous crop retained on the surface.

GROUND PREPARATION

- Incorporate residues from a previous crop.
- Provide balanced crop nutrition (especially potassium)

IN CROP

- Use foliar fungicide applications for Pima varieties – NOT before flowering

AFTER HARVEST

- Incorporate crop residues as soon as possible after harvest

ROTATION

- Control alternative weed hosts and volunteer cotton plants



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INTEGRATED DISEASE MANAGEMENT FOR Bacterial Blight in Susceptible Varieties

THE PATHOGEN

Xanthomonas campestris pv. *malvacearum* (*Xanthomonas axonopodis* pv. *malvacearum*)

There are over 20 races described on the basis of their ability to overcome different resistance genes in the cotton plant. Race 18 is the most prevalent race of the pathogen in Australia. Two races that originated in parts of Africa and have been used in field plots in the USA are described as hypervirulent and could possibly be pathogenic on Australian varieties.

SYMPTOMS

- Leaves and bracts – ‘Angular leaf spot’ - dark green, watersoaked, angular lesions – 1 to 5 mm across - especially obvious on the undersurface of leaves. Sometimes extensive dark green, watersoaked lesions along the veins. Symptoms are usually more prevalent on lower leaves than on upper leaves. Lesions dry and darken with age and leaves may be shed prematurely resulting in extensive defoliation.
- Bolls – Dark green, watersoaked, greasy, circular lesions – 2 to 10mm across – especially at the base of the boll under the calyx crown. As the boll matures the lesions dry out and prevent normal boll opening.
- Stems – ‘black-arm’ – black lesions which girdle and spread along the stem or branch – can be associated with hail damage.

ECONOMIC IMPACT

Bacterial blight cost Australian cotton farmers millions of dollars in the 1980’s. Most cotton varieties now grown in Australia have excellent resistance to the blight pathogen and only the older US varieties and Pima are susceptible. When the pathogen is present and weather conditions are favourable then bacterial blight can be devastating to Pima cotton. In recent years a crop of Pima at Bourke was completely defoliated and 80% of bolls were affected by Bacterial blight.

ASSESSMENT

Seedlings – disease incidence can be assessed by inspecting 20 randomly selected sets of ten plants – carefully checking the undersurface of cotyledons and leaves for the presence or absence of bacterial blight.

Leaf symptoms – disease severity can be assessed on the basis of ‘percentage leaf area infected’ using a pictorial assessment key (See – ‘Assessing Disease on your Farm’). Either assess every leaf on ten randomly selected plants or assess disease severity on the lowest one, two or three mainstem leaves on each of 20 randomly selected plants.

Bolls – The percentage of bolls with blight can be estimated by inspecting all bolls on at least ten randomly selected plants. It is important to peel back the calyx crown when checking each boll.

DISEASE CYCLE

Pathogen inoculum may either be present in the field on infected crop residues from a previous season or it may be introduced at planting within infected seed. Lesions on cotyledons may be initiated by inoculum within the seed during germination. Inoculum from infected crop residues may be splashed onto the foliage and into the growing point of young seedlings where it can survive saprophytically on leaf surfaces. When environmental conditions are favourable the bacteria enter the plant via the stomates or wounds. As lesions develop bacteria exude out onto the leaf surface for further dispersal.

The pathogen is able to enter the seed when mature, open, blight-infected bolls are exposed to wet weather prior to harvest.

FAVOURABLE BY

Symptoms of bacterial blight develop when the temperature is over 25°C and relative humidity exceeds 85%. Wind driven rain, hail and sand-blasting significantly increase disease severity. Under glasshouse conditions bacterial blight will not become apparent if temperatures are below 25°C or if the leaves are kept dry.

DISPERSAL

Seed borne inoculum allows long range dispersal and introduction of the pathogen (or new races of the pathogen) into new areas, new countries and new fields.

There is evidence that the pathogen is also capable of symptomless epiphytic transfer that enables undetected passage through quarantine. Seed-borne inoculum can move to a symptomless, saprophytic existence on the leaf surfaces of growing plants under glasshouse conditions where the leaves are kept dry.

Dispersal within the crop is accomplished by rain splash from crop residues to cotyledons and lower leaves. Once established in the growing point then all leaves become 'inoculated' as they are produced.

SURVIVAL

The pathogen is able to survive for long periods on infected crop residues and within the seed. Survival on crop residues is favoured by dry conditions.

As mentioned previously the pathogen can also survive in a saprophytic phase on leaf surfaces and in the terminals of otherwise healthy plants.

HOST RANGE

The bacterial blight pathogen is specific to *Gossypium* spp. and there are no other known crop or weed hosts in Australia. Most Australian varieties of *Gossypium hirsutum* are completely resistant to the races of the blight pathogen that occur in Australia. Some of the older US varieties are susceptible. Pima varieties (*G. barbadense*) are very susceptible and cotton breeders are developing new blight resistant varieties for Australian conditions. Bacterial blight has been observed on several of the native Australian *Gossypium* spp.

A CONTROL STRATEGY FOR Bacterial Blight in Susceptible Varieties

PREVIOUS SEASON

- Seed companies should ensure minimal carryover of the pathogen in planting seed

PLANNING

- Do not plant susceptible varieties in or near fields that contain residues of susceptible varieties grown in the previous season

IN CROP

- Avoid rank growth and a dense crop canopy if possible

AFTER HARVEST

- Thoroughly incorporate crop residues as soon as possible

AT ALL TIMES

- Practice good farm hygiene – COME CLEAN, GO CLEAN



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INTEGRATED DISEASE MANAGEMENT FOR Boll Rots

THE PATHOGENS

Several fungi can cause boll rots and some fungi can rapidly colonise bolls that have been damaged by insects or their larvae.

Phytophthora boll rot (*Phytophthora nicotianae* var *parasitica*) is the most common boll rot under Australian conditions and can cause significant yield losses.

Sclerotinia boll rot (*Sclerotinia sclerotiorum*) and Fusarium boll rot (*Fusarium* spp.) are far less common and are usually only seen in very rank crops. (The Fusarium species that are associated with boll rots are not the same as that which causes Fusarium wilt.)

Anthrachnose boll rot (*Colletotrichum gossypii*) has been reported from Northern Australia and is occasionally seen in crops in Queensland. There has only been one old (1923) unconfirmed report of this disease in NSW.

Rhizopus sp. and *Botrytis* sp. produce profuse gray fungal growth over bolls that have been damaged by insect attack.

ECONOMIC IMPACT

Boll rots are most significant when there is a wet finish to the season and especially in tall, rank crops. The incidence of boll rots is generally less than 5% although under optimum conditions up to 30% of bolls can be affected.

ASSESSMENT

The incidence of boll rots can be assessed prior to or after defoliation. Counts should not be confined to areas near the tail drain as this may give a misleading result. Count all of the bolls on ten plants from each of ten randomly selected sites across the field.

PHYTOPHTHORA BOLL ROT

SYMPTOMS

Infected bolls quickly turn brown and become blackened before opening prematurely. The locks, which remain compact and do not fluff out, can be easily dislodged and fall to the ground. Symptoms are most prevalent on the lower bolls.

DISEASE CYCLE

The thick walled survival structures of the pathogen germinate in moist soil to produce the motile zoospores that may be splashed up onto the low bolls during heavy rain. Only bolls that are nearing maturity are susceptible. Bolls that become immersed during irrigation may also become infected.

FAVOURED BY

Low mature bolls or lodged plants.

Heavy rainfall onto wet soil.

Low plant stand that results in more exposed soil and therefore more splash up onto low bolls.

DISPERSAL

The pathogen is easily moved in irrigation water and in association with infected trash. Zoospores may be introduced to bolls by rain splash.

SURVIVAL

The pathogen is a common soil inhabitant that can survive in association with infected crop residues.

HOST RANGE

The pathogen has a wide host range that includes safflower, pineapple, tomato and citrus as well as a large number of ornamental plants derived from the Australian native flora.

SCLEROTINIA BOLL ROT

SYMPTOMS

Infected bolls and lesions on stems or branches are usually light brown in colour and large, black, globular sclerotia (and sometimes white fungal growth) can be seen on the surface of the dead tissue. The large black sclerotia can also be found within the rotted boll.

DISEASE CYCLE

The large black survival structures (sclerotia) in the soil germinate when it is cool and wet and produce small 'golf tee'- like structures called apothecia on the soil surface. Clouds of small ascospores are released from these apothecia and carried by wind to dying host tissue that is rapidly colonized. This dying host tissue may be either flower petals that have not dropped off the developing boll or leaf material that has dropped and become 'hung-up' in the plant. The pathogen grows from this dead host tissue base into the boll or branch. More sclerotia are produced within and on infected plant material.

FAVOURED BY

Cool wet weather and rank crop growth or a dense canopy.

DISPERSAL

The large black sclerotia can be spread in soil and crop residues on vehicles and machinery or carried in flood or irrigation water. The small ascospores produced under the crop are dispersed by wind.

SURVIVAL

The pathogen is capable of surviving for long periods (many years) as sclerotia in the soil. The sclerotia vary considerably in size and may be either thin and elongated (up to 20mm long) or globular (3-8mm in diameter). The sclerotia have a thick black rind that protects them from desiccation and attack by other soil micro-organisms.

HOST RANGE

S. sclerotiorum has a very extensive host range which includes many weed and crop species including sunflower, safflower, soybean and most pasture legumes. This wide host range further enables the pathogen to survive for long periods between crops.

FUSARIUM BOLL ROT

During prolonged wet weather late in the season low bolls in a dense canopy, and sometimes the fruiting branch they are attached to, die and turn light brown. The pathogen may produce a pink mass of spores over the surface of the unopened boll. *Fusarium* spp are common and widespread soil saprophytes and weak pathogens.

ANTHRACNOSE

This disease is characterised by large spreading lesions on bolls often with a pink spore mass in the centre. The pathogen is able to infect all parts of the cotton plant and at any stage of growth. Seedling stems may be girdled at or near the base of the stem. In countries where this disease is a problem the pathogen can be seed borne. It may be effectively controlled by acid-delinting and the use of fungicide seed treatments. The disease is rarely observed in Australia.

A CONTROL STRATEGY FOR

Boll Rots

PLANNING

- Field drainage should not allow water to back-up into the field and inundate low bolls on plants near the tail drain

PLANTING

- Avoid very low plant populations which result in exposed soil that can be splashed up onto low bolls at the end of the season

IN CROP

- Avoid rank growth and a dense crop canopy if possible

AFTER HARVEST

- Thoroughly incorporate crop residues as soon as possible

AT ALL TIMES

- Practice good farm hygiene – COME CLEAN, GO CLEAN



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MYCORRHIZAS (VAM DEFICIENCY)

In most soils cotton is dependent on mycorrhizal (VAM) fungi for successful growth. VAM fungi colonise roots and surrounding soil and act as an extension of the root system by supplying extra phosphorus and zinc. In return the plant 'feeds' the VAM fungi with sugars produced in the leaves. Cotton growth is reduced and maturity may be delayed when there are insufficient VAM fungi in the roots. Seedlings are stunted with small leaves and short internodes and phosphorus and zinc deficiency symptoms may be obvious.

VAM fungi cannot survive without a living host plant and their numbers decline during long, weed free, bare fallows or during rotation with a non-host plant (eg. canola, broccoli). In most cotton growing areas, however, sufficient VAM fungi will survive one season of bare fallow. Problems are more likely after longer periods of fallow. Loss or removal of topsoil can also eliminate VAM fungi and subsequent growth of cotton can be stunted with reduced uptake of phosphorus and zinc. The potential for yield reduction is greatest when the crop is planted late or during short seasons.

If a lack of VAM is suspected then a crop of wheat, which is usually less dependent on VAM fungi, could be grown prior to growing a VAM dependent crop such as cotton. Fertilisation during the crop is unlikely to be of benefit because P and Zn are relatively immobile elements in soil. Foliar fertilisers were ineffective in trials conducted at Narrabri. (See 'Mycorrhizas and Cotton – Research Review')



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ALLELOPATHY

Toxic metabolites are produced during the breakdown of residues of some weed and crop plants. Cotton stand establishment may be affected if cotton is planted into areas where such plants have been recently incorporated. Symptoms include patchy stand establishment and slow seedling growth as well as poor, impaired or distorted root development. Legume crops and medics as well as sorghum have been implicated. It has been suggested that legume residues should be incorporated at least two weeks prior to planting cotton.

BACTERIAL STUNT

Bacterial stunt (also known as early season growth disorder or Galathera syndrome) occurs in many cotton growing areas and is usually associated with very heavy clay soils. Slow early season growth and severe stunting are often the only above-ground symptoms although the leaves of badly stunted seedlings may have symptoms of zinc deficiency: Root browning develops rapidly in response to pathogenic bacteria that colonise the roots and hinder their function. Colonisation by mycorrhizal fungi is slow. The disease is caused by a combination of soil properties and weakly pathogenic bacteria that infect the roots. One of these bacteria appears to be an undescribed species of *Pseudomonas* which is relatively common in soil and widespread in the cotton growing areas.

Bacterial stunt delays the maturity of the crop and yield can be reduced by as much as 50%; although plants in some areas recover after December and yield well if the season is long enough. No direct control measures are currently available for bacterial stunt. Fertilising with zinc may be advantageous. Cover crops (eg. winter cereal, sprayed out before sowing cotton) have increased early season growth in fields where bacterial stunt occurs. The crop should be managed to give maximum time for recovery of growth late in the season. ([See 'Cotton Disease Symptoms Guide'](#))

BEAN ROOT APHID

Areas of poor stand establishment, stunting and uneven seedling growth. Affected patches may be circular or irregular and may vary in size from a few square metres to several hundred square metres. Careful examination of the roots and surrounding soil will reveal a network of tunnels down along the taproot, small (1mm) aphids feeding on the roots and small brown ants 'farming' the aphids. The tunnels collapse and the aphids and ants usually disappear after flood irrigation. ([See 'Cotton Disease Symptoms Guide'](#))

BOLL DANGLE/CAVITATION

The development of young bolls is 'frozen' and the immature small (up to 15mm) boll, bracts and stalk dies and dries on the plant. An elongated dead patch also develops on the fruiting branch below where the stalk of the 'frozen' boll is attached. The condition has been attributed to cavitation and is usually associated with heat and/or water stress and plants with a full fruit load. The fungus *Phomopsis* sp. is frequently, but not always, present and similar symptoms may also result from insect larvae feeding on very young fruit. ([See 'Cotton Disease Symptoms Guide'](#))

The term 'cavitation' has been used to describe a breaking of the water column and entry of air into the plant's vascular tissue just below the developing fruiting structure. Some have argued that water entering the young developing boll is actively transported through the phloem rather than the xylem and that it is impossible for the water column in the xylem to break and cause the condition!

BUNCHY TOP

A proliferation of small leaves, short internodes and small bolls usually becoming apparent as the crop approaches maturity and usually on the upper parts of the plant. When bunchy top is severe the whole plant is affected and the crop takes on a 'climbing ivy' appearance. Some leaves may exhibit a mottling with pale green margins and darker green centres. Symptoms may be more common in unsprayed or poorly sprayed areas of the field. ([See 'Cotton Disease Symptoms Guide'](#))

The cause of bunchy top is uncertain and it is possible that there could be several agents capable of producing similar symptoms. The condition usually occurs in circular patches and often in association with prolonged aphid activity. There is some evidence for the involvement of a 'virus-like' pathogen vectored by aphids. Plants with sub-lethal infection by the Fusarium wilt pathogen also may develop bunchy top symptoms as they approach maturity. Varieties vary considerably in symptom expression with some varieties severely affected and others seemingly immune.

CAVITATION (SEE - BOLL DANGLE)

CAVITOMA

'Cavitoma' is a term coined in the 1950's to describe microbial damage to cotton fibre or the breakdown of the cellulose in fibre by micro-organisms. This damaging microbial activity starts in the field when lint in mature open bolls is exposed to wet weather and may continue while the seed cotton is in the module and when the lint is stored in the bale. Symptoms of fibre damage include elevated pH, reduced length and strength and reduced affinity for dyes. When harvest is delayed by rain it is important to keep module and bale moisture contents to a minimum.

Microbial damage to fibres can be observed microscopically after placing fibres in 10% Potassium hydroxide. Unaffected fibres are cylindrical while affected fibres are distorted, swollen and obviously damaged.

CHARCOAL ROT

Charcoal rot is caused by the fungus *Macrophomina phaseolina* which is a common and widespread pathogen of sorghum and sunflower and many other hosts. Affected plants die prematurely and become brittle. Numerous small black microsclerotia are produced in plant tissues at the base of the stem. This gives these parts of the plant a grey appearance when broken or cut open.

The disease is favoured by very hot and or dry conditions.

CULTIVATION DAMAGE

May occur along narrow guess rows during cultivation, when cultivator 'knives' are set too close to the row or when the concentration of a tractor driver wanders temporarily! Cultivation damage may be exacerbated when hills/beds are very dry and blocky.

FERTILISER BURN

Root tips are 'pinched off' and sometimes blackened. All roots of affected plants are affected at the same level. If a particular row, or rows, are infected in each set across the field then a problem with the fertiliser rig is implied. Fertiliser burn occurs when either solid or liquid fertiliser is placed too close to, or directly under, the planting line. Very dry soil conditions between fertilizer application and planting may exacerbate the problem. ([See 'Cotton Disease Symptoms Guide'](#))



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HERBICIDE DAMAGE

Herbicide damage is most prevalent during the early stages of growth and symptoms vary considerably according to the type and rate of herbicide used. Symptoms may include yellowing between the veins on cotyledons and lower leaves, stunting and slow growth, root pruning and poor root development, death and defoliation of leaves and cotyledons, seedling death, declining plant stand, etc. etc.

Assuming that the rates of application are correct and appropriate for the soil type and assuming the spray equipment is well maintained and calibrated correctly - then - problems are most likely to occur when pre-plant herbicides are incorporated too deeply or when herbicides applied at planting are washed into the root zone by rain that falls after planting. Damage may be accentuated if the press-wheel on the planter has left a depression along the planting line on top of the bed or if the beds are poorly prepared and loose or have dried considerably prior to the rainfall after planting. (See 'Cotton Disease Symptoms Guide' and 'WEEDpak')

LIGHTNING

A circular, or sometimes irregular, patch of dead plants that may be from two to over fifty metres across. All plants are killed or affected simultaneously and there should be no effect on plant stand. Most plants are completely killed, wilt immediately and dry quickly with leaves 'frozen' on the plant. Sometimes only the top of the plant is killed and the roots and lower stem appear unaffected. These plants may shoot again from the live portion of the stem. (See 'Cotton Disease Symptoms Guide')

MITES

Mite activity results in a circular, defoliating patch of plants with reddened leaves that may vary in size from only one or two plants up to a patch many metres across. The mites and their webs may be observed on the under surface of the leaves and in the growing point of the plant. Affected parts of the plant (including bolls?) may develop a 'sandpaper' brown appearance and texture. These mite 'hot-spots' are usually more common towards the end of the growing season. (See IPM Guidelines and ENTopak)

NUTRIENT DEFICIENCY

Nutrient deficiency symptoms are not common and are usually induced by other factors such as waterlogging (Iron and Potassium), the absence of mycorrhizal fungi (Zinc and Phosphorus) or extended periods of overcast, cool weather late in the season when bolls are filling (Potassium). Some soil types are inherently low in Phosphorus or Zinc or Potassium and the addition of foliar or pre-plant fertilizer is therefore advantageous.

ZINC – plants stop growing and leaves become more 'shiny', cupping upwards with yellowing, and sometimes dead spots, developing between the veins.

PHOSPHORUS – slow, poor growth with leaves becoming a darker green.

POTASSIUM – See 'Premature senescence'

IRON – transient yellowing (usually following an irrigation or waterlogging event) especially of the younger leaves and shoots at the top of the plant.

See NUTRIpak for a more detailed description of symptoms and information on addressing nutritional issues.

PREMATURE SENESCENCE

The cotton plant's peak demand for Potassium occurs during boll filling. Potassium is mobile within the plant. If the levels of Potassium in the soil are inadequate or if prevailing weather conditions are not conducive to Potassium uptake from the soil, then there is a relocation of Potassium within the plant from younger leaves to maturing bolls. The younger leaves towards the top of the plant turn red and senesce prematurely. Well shaded leaves and branches remain green. Plants with a heavy boll load are affected first while plants with few bolls are usually unaffected. The plants in the row along the edge of the field are also less affected because of less competition for available soil nutrients.

Premature senescence often develops during extended periods of overcast, cool weather late in the season when bolls are filling. Crops affected by premature senescence are very susceptible to epidemics of *Alternaria* leaf spot if exposed to further periods of wet weather. (See '[Cotton Disease Symptoms Guide](#)')

SAND-BLASTING

The combination of lighter soil types and strong winds blowing across adjacent bare fallow fields or along rows may result in sand-blasting. Symptoms are obvious on one side of the plant. Affected cotyledons or leaves become desiccated and may shrivel up. The exposed side of stems and branches may also become dry and brown. Sand-blasting can significantly exacerbate development of bacterial blight on susceptible varieties. (See '[Cotton Disease Symptoms Guide](#)')

SEED ROT

A brown to black 'rotting' of the seed coat and adjacent lint that develops prior to opening of the boll. The condition is often confined to one lock in a boll and affected seeds are sometimes hollow. When the boll opens the affected lock does not fluff out and remains in the boll. Similar symptoms have been attributed to the activity of sucking insects attacking young developing bolls.

A condition known as seed rot has also been described in the USA. All varieties appear susceptible and the cause has yet to be determined.

SOIL COMPACTION, SMEARING AND PLOUGH PANS

Soil compaction and smearing occur when field operations such as picking or planting are completed over moist soil. Smearing of the seed slot during planting results in poor stand establishment and slow seedling growth. Seedling roots may grow horizontally along the bottom of the seed slot or may become twisted and contorted.

When warm dry weather follows planting under wet conditions the smeared seed slot may dry out and the bed may crack open along the seed line. Further problems may occur if rain then washes soil-applied herbicides into the crack and directly into the root zone.

Under certain conditions, when there are compacted areas beneath the plant line, some cotton plants grow 15–50 cm taller than other plants in the field. These larger plants feature a well developed shallow root system, few bolls and reddened stems and long branches, especially towards the top of the plant. Similar symptoms have been described as 'acromania' or 'crazy top' in the USA.

Significant plough pans may develop immediately below the zone of cultivation in fields used for rain-grown or dryland cropping. There may be sufficient soil moisture for seed germination and seedling growth but not enough to soften the ploughpan and allow the tap root to penetrate and grow into the sub-soil. The consequences are a poor stand with surviving plants unthrifty and featuring a nub root. (See '[Cotton Disease Symptoms Guide](#)')

SOIL CRUSTING

Some soil types are prone to crusting after rain. When this occurs soon after sowing then the germinating seedlings are unable to emerge and poor stand establishment results.

SOWING DEPTH

Seed should be sown very shallow when planting into a dry loose seedbed as they tend to sink further into the soil when water is applied. Seedlings emerging from depth feature small cotyledons and poor vigour early in the season.



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SUDDEN WILT

Sudden wilt most commonly occurs mid-season when the final cultivation is followed by an irrigation or rainfall event and then fine hot weather. The plants wilt suddenly, drop their leaves and squares and, in some cases, then shoot again. Affected plants usually occur in patches extending along the rows, especially in low-lying areas of the field. All of the plants in a patch are affected simultaneously. Symptoms include a brown discolouration of the vascular tissue just below the bark on the lower stem and roots.

Sudden wilt is not common and only occurs spasmodically. It does not re-occur in the same patch in subsequent years. Weakly pathogenic *Fusarium* spp. have been found associated with the condition. (See 'Cotton Disease Symptoms Guide')

SUNSCALD

The symptoms of sunscald have been compared to those resulting from an early application of defoliant. Upper leaves become desiccated, bleached and twisted before eventually dropping off the plant. Sunscald develops when a period of wet overcast weather is followed by a quick return to fine hot weather late in the season when bolls are filling. Well grown dryland (rain-grown) crops are most susceptible although symptoms have also been seen in small areas of some irrigated crops. (See 'Cotton Disease Symptoms Guide')

SUPERNUMERARY CARPELS

James Stewart from the University of Arkansas described supernumerary carpels as the result of a genetic stutter. A boll starts undergoing normal development of carpels, but instead of development stopping when it should, a second round of carpel development starts so that a "mini-boll" with one or two carpels forms on the inside of the first one.. It can best be seen in a cross section of the boll. They appear as a light-green, elongated growth in the centre of a normal boll.

THRIPS

Thrips are sucking insects that attack seedling cotton soon after emergence and cause newly formed true leaves to be small and deformed. Effective control can be achieved by the use of appropriate insecticide seed treatments. Despite the damage done by thrips they provide a valuable contribution to the control of mites later in the season. (See IPM Guidelines and ENTopak)

TROPICAL RUST

Tropical rust, caused by *Phakopsora gossypii*, has been recorded on wild cotton and tree cotton in the Northern Territory and North Queensland. Under favourable conditions numerous small (1-2mm) pustules develop on the undersurface of the leaf. Each pustule is a mass of powdery spores that may be effectively dispersed by wind over long distances. The disease has not been recorded on cultivated cotton in Australia but has previously caused significant losses in parts of North and South America. (See 'Cotton Disease Symptoms Guide')

WIND-BURN

Young seedlings may be killed by exposure to strong, hot, dry winds. Plants become completely desiccated with leaves remaining attached to the plant and the plant leaning in the direction the wind was blowing. (See 'Cotton Disease Symptoms Guide')

In less severe conditions one side of the seedling stem, between the soil surface and the cotyledonary node, becomes blackened and seedlings die or further growth is inhibited. The blackened lesion occurs on the same side of every seedling in the affected area. Symptoms are more likely to develop if the wind is blowing along rows rather than across rows.

WIREWORM

Wireworms can cause death of scattered seedlings throughout a field. Either single plants or small groups of just a few seedlings may be affected. The wireworm, which is the larvae of a beetle, attacks the plant 10-30mm below the soil surface by 'chewing' a hole in the taproot or lower stem leaving a characteristic wound. (See IPM Guidelines and ENTopak)

timeetale

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At all times - practice good farm hygiene - come clean - go clean

PLANNING		GROUND PREPARATION
Seedling diseases	- Use a variety with good seedling vigour - Use effective seed treatment fungicides	- Plant into well prepared, high, firm beds - Carefully position fertiliser in the bed - Plant into moisture rather than water-up
Black root rot	Choose indeterminate varieties that have the capacity to 'catch up' later in the season	- Prepare beds well to optimise stand establishment and seedling vigour - Pre-irrigate in preference to 'watering up'
Verticillium wilt	Use a resistant variety	Provide balanced crop nutrition (especially nitrogen and potassium)
Fusarium wilt	- If your farm is free from this disease, try to keep it that way! Minimise the risks that could allow this fungus to be introduced onto your farm. For example, do not share machinery with known affected farms unless it has been cleaned to remove soil and plant debris. Provide an area at an appropriate place for incoming machinery and visitors to remove soil and be disinfected if they are not following the "Come Clean" protocols) - Use the most resistant cotton varieties available, especially if Fov occurs in your district - Ensure that seed is treated (eg. Quintozene and Apron)	
Alternaria leaf spot	Don't plant susceptible varieties in fields with infected residues from a previous crop retained on the surface.	- Incorporate residues from a previous crop. - Provide balanced crop nutrition (especially potassium)
Bacterial blight	Do not plant susceptible varieties in or near fields that contain residues of susceptible varieties grown in the previous season	
Boll rots	Field drainage should not allow water to back-up into the field and inundate low bolls on plants near the tail drain	

PLANTING/EARLY SEASON		LATE SEASON
Seedling diseases	Delay planting until temperature and moisture conditions are optimum. Be careful with the use of herbicides at planting	
Black root rot	- Time sowing to avoid cool temperatures if possible, but sow early if conditions are warm enough - Replanting decisions should be made on the basis of stand losses, not the size of the seedlings. - Watch for early onset of water stress (ie. because the root system is weak) and irrigate accordingly, but avoid waterlogging.	Anticipate delayed growth and later maturity and manage the crop accordingly (black root rot 'steals' time from your crop).
Verticillium wilt	- Avoid long periods of waterlogging - Manage for earliness	- Manage for earliness - Avoid late irrigations
Fusarium wilt	- Plant to avoid unnecessary stress to germination and early growth - Control weeds during/between crops - Minimise damage to roots during cultivation (eg. use a shielded sprayer to control weeds) - Manage the crop to avoid stresses eg. waterlogging and over-fertilisation. - Maintain farm hygiene and awareness - Conduct regular inspections to allow early detection of any suspicious looking plants. If any are found, send immediately to QDPI for analysis. Educate farm workers what to look for and encourage reporting - If Fov is confirmed, rogue and burn for small patches - Solarisation may also be an appropriate treatment for small affected patches - Isolate affected areas from irrigation flows and traffic to avoid spreading the fungus - Minimise tailwater from affected fields	- Ensure that harvesting machinery is cleaned - If Fov has been confirmed on your farm notify any contractors/your local gin before harvesting so that measures can be taken to avoid spreading the fungus to other fields on your property and to other regions - Minimise tailwater from affected fields
Alternaria leaf spot		Use foliar fungicide applications for Pima varieties – NOT before flowering
Bacterial blight		Avoid rank growth and a dense crop canopy if possible.
Boll rots	Avoid very low plant populations which result in exposed soil that can be splashed up onto low bolls at the end of the season	Avoid rank growth and a dense crop canopy if possible

AFTER HARVEST		ROTATIONS
Seedling diseases		Incorporate crop residues as early as possible - especially if a legume
Black root rot		- Rotate with non-host crops (eg. cereals, canola) for more than one season if possible. - Biofumigation with woolly pod vetch or mustard (canola?) between consecutive cotton crops or after a wheat fallow. The success of biofumigation depends upon the growth of the biofumigation crop and good incorporation (at least four weeks before cotton). - Avoid rotation with legumes (except vetch) and control alternative weed hosts (eg. Datura). - Flooding of fields for 30 days during summer reduces the population of T. basicola dramatically. This option will be limited by the topography of fields and the availability of water.
Verticillium wilt	- Incorporate crop residues as soon as possible after harvest - Minimise the movement of crop residues in tailwater recirculation systems	- Rotation with non-host crops - Control alternative weed hosts
Fusarium wilt	After harvest, retain crop residues on the surface for as long as possible before incorporation	- Selection and management of rotation crops is important as the pathogen is able to survive in association with the residues of non host crops. - Summer flooding, if possible, has been shown to reduce spore levels significantly but does not eradicate the pathogen.
Alternaria leaf spot	Incorporate crop residues as soon as possible after harvest	Control alternative weed hosts and volunteer cotton.
Bacterial blight	Thoroughly incorporate crop residues as soon as possible	
Boll rots	Thoroughly incorporate crop residues as soon as possible	



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Wash-Down Pad Design

LOCATION

- Away from crops if possible
- Readily accessible/visible on arrival
- Between the front gate and the on-farm road system
- Access to power and water?

ACCESS

Where entry and exit are from the same direction then access should be hard standing, sealed or gravel. Where entry is from one side with exit on the other (drive through!) - then entry surface is optional but exit should be to hard standing, sealed road or gravel. There is no point in cleaning down if you are going to pick up more soil as soon as you exit!

DRAINAGE/RUNOFF

- NOT into the tail water return system!
- NOT into a creek or river!
- Into a sump (that can be easily cleaned out)
 - with an overflow into an evaporation pond or drain.

THE PAD ITSELF

Concrete is excellent but expensive. Overlapping strips of rubber belting is cheaper and can be moved as required. Slope – The pad should slope to one side. Slope should be sufficient to enable easy removal of soil and trash. Where entry and exit is from the same direction then the pad can slope down to one end.

Size – The pad should be big enough for the vehicles and machinery to be washed plus room enough for the operator to move around the machinery without having to step back off the pad into surrounding mud.

Module builders and in-field loaders also need to be cleaned down somewhere!

ACCESSORIES

- A pressure cleaner
- Farmcleanse or a similar product
- Lighting (optional)

USAGE

- Keep the area clean
- Remove excess soil and trash with pressure sprayer
 - then apply 10% Farmcleanse - then wash off.
- Allow excess water to drain off before exiting – if possible.
- All vehicles and machinery should be cleaned as they leave your property so that they can arrive clean at their destination!



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Assessing Disease On Your Farm

Seedling diseases

Estimate the stand by counting the number of established plants/metre at at least 20 sites across the field. The difference between the estimated stand at 6 weeks after planting and the number of seed/metre sown indicates the level of seedling mortality. Seedling mortality includes the effects of seedling pests such as wireworms and incorporates seed viability.

An alternative method is to estimate stand immediately after emergence and again 6-8 weeks later.

Black root rot

Look for patches or large areas of slow growing cotton (with or without reduced stand). If symptoms are present, then it may be possible to estimate visually the area of the field affected. The incidence of black root rot in the crop can be assessed using the step point method (see glossary) for 10 lots of 10 seedlings, preferably between three to six weeks after sowing. Count the number of seedlings with or without characteristically blackened roots and express as a percentage of the total. Later in the season, the incidence of the internal stem rot (if present) can be assessed in a similar way by splitting or cutting stems at soil level.

Verticillium wilt

The presence or absence of foliar symptoms can be assessed at any time throughout the season but will not be particularly obvious in mid summer. The best time to assess foliar symptoms is after the final irrigation. The presence or absence of vascular symptoms is best assessed immediately after harvest using secateurs. Under Australian conditions with Australian strains of the pathogen all plants with vascular symptoms will also display foliar symptoms.

Disease incidence may be estimated by inspecting 10 plants at a minimum of 20 sites randomly selected across the field. Alternatively, establish a transect across the field and assess for the presence or absence of disease in ten plants in every tenth row.

Fusarium wilt

Establish a transect (pick a route) across the field and assess for the presence of brown discolouration within the stem in 10 plants in every tenth row. Either split stems (by breaking back low branches) if assessing before harvest or cut stems with secateurs if assessing immediately after harvest.

An established transect allows for repeated assessments in subsequent years or whenever cotton is grown in the field.

Alternaria leaf spot

When Alternaria leaf spot is severe and plants are being defoliated then disease severity can be assessed by determining percentage defoliation. Randomly select at least 10 plants (preferably 20-50) and count the total number of nodes with and without mainstem leaves still present. If bolls are affected then the percentage of bolls affected may be determined by counting affected and unaffected bolls on at least ten randomly selected plants.

When disease severity is low it is best assessed by determining the percentage of leaf area affected using a pictorial assessment key. An average of one small lesion on each and every leaf is approximately equivalent to 0.1% leaf area infected. Disease severity may also be quantified by assessing the percentage leaf area affected for the lowest one, two or three mainstem leaves. Alternatively, the lowest mainstem leaf from at least 20 randomly selected plants can be collected and dried in a plant press in newspaper for later assessment.

Bacterial blight in susceptible varieties

Seedlings – disease incidence can be assessed by inspecting at least 20 randomly selected sets of ten plants – carefully checking the undersurface of cotyledons and leaves for the presence or absence of bacterial blight.

Leaf symptoms – disease severity can be assessed on the basis of 'percentage leaf area infected' using a pictorial assessment key. Either assess every leaf on ten randomly selected plants or assess disease severity on the lowest one, two or three mainstem leaves on each of 20 randomly selected plants.

Bolls – The percentage of bolls with blight can be estimated by inspecting all bolls on at least ten randomly selected plants. It is important to peel back the calyx crown when checking each boll.

Boll rots

The incidence of boll rots can be assessed prior to or after defoliation. Counts should not be confined to areas near the tail drain as this may give a misleading result. Count all of the bolls on 10 plants from each of 10 randomly selected sites across the field.

Only assess those diseases that are relevant for the field

Field Number:	Planting Date:
Variety:	Seed Rate:

Seedling diseases (Seedling mortality) – Count plants /metre at at least 20 randomly selected sites across field

[illegible]

Divide by seed rate to calculate Seedling mortality.

[illegible][illegible]

Alternaria leaf spot (severity) – Assess percentage leaf area infected on the lowest mainstem leaf of 20 plants

[illegible][illegible]

Calculate percentage defoliation.

[illegible]

Split stems to assess presence or absence of disease. Use secateurs if assessing after harvest.

[illegible]

Calculate percentage of blighted bolls over total bolls

[illegible]

Calculate percentage of affected bolls over total bolls

Assessment just prior to or immediately after harvest

[illegible]



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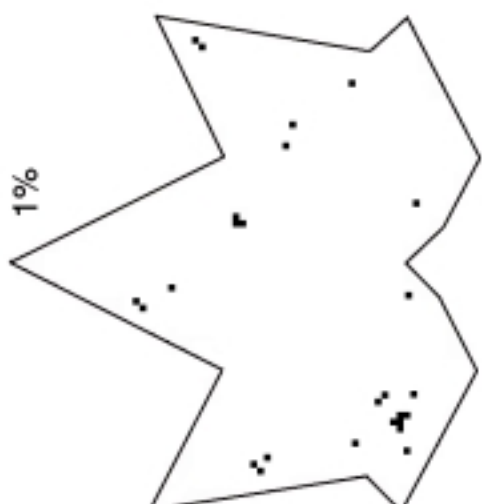
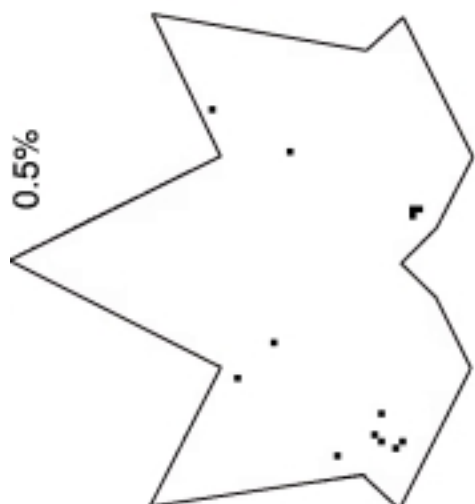
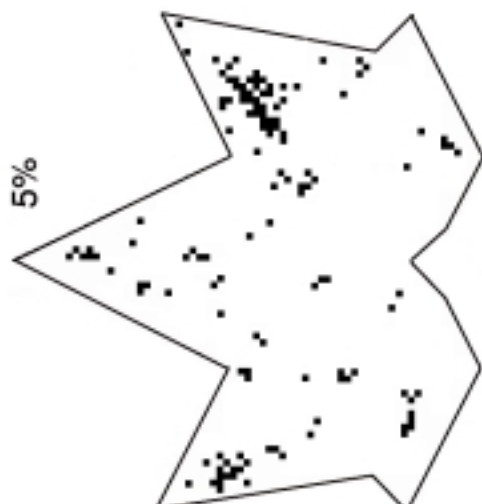
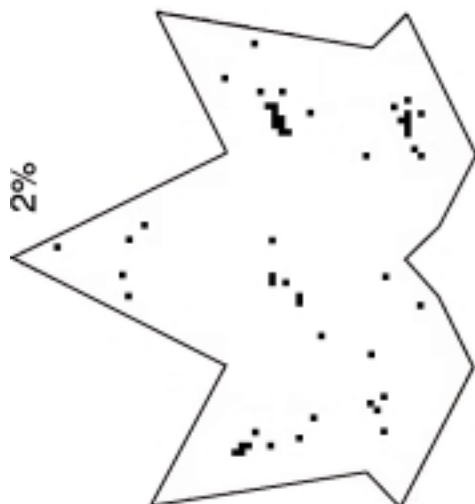
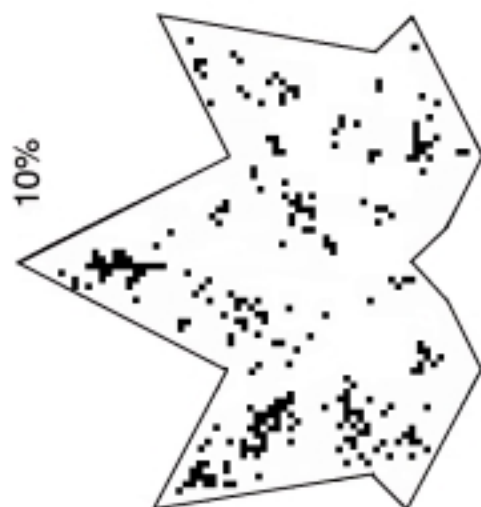
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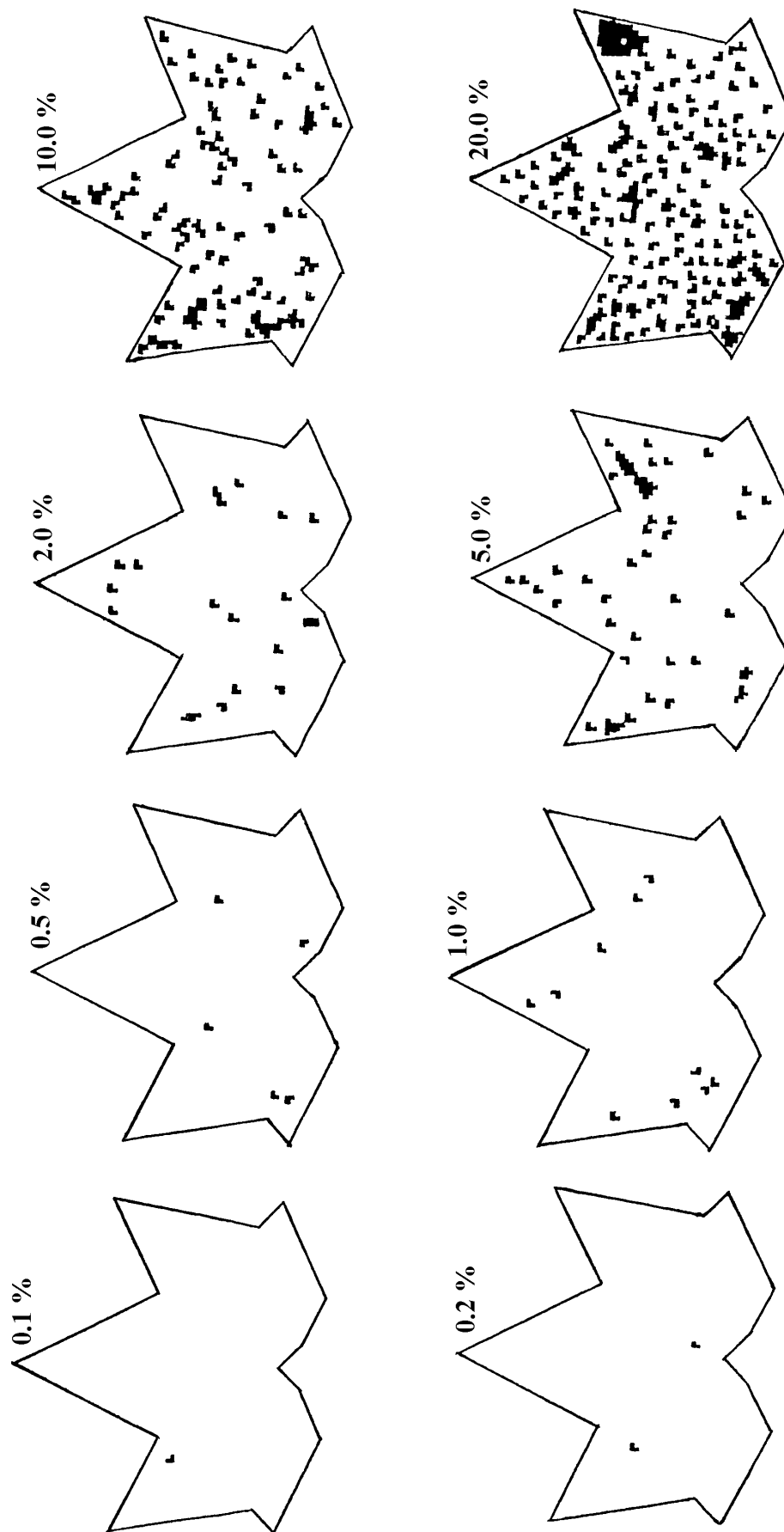
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Pictorial Assessment Key for Foliar
Diseases - Bacterial blight



Pictorial Assessment Key for Foliar
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AG – (Anastomosis Group) A sub-grouping of a fungal species based on the ability of closely related isolates to exchange nuclear material via the fusion of fungal strands (anastomosis). The seedling disease pathogen, *Rhizoctonia solani* is divided into anastomosis groups – AG4 affects cotton while AG8 affects wheat.

APOTHECIA - A cup-shaped spore-bearing structure produced by some fungi. The apothecia of the pathogen that causes Sclerotinia boll rot of cotton are small (5-8mm across), 'golf tee'-like structures that grow at the soil surface out of buried fungal survival structures called sclerotia.

ASCOSPORES - Sexual spores produced by a particular group of fungi. The ascospores produced in apothecia are forcibly ejected and then dispersed by wind.

ASEXUAL SPORES – Spores produced vegetatively (ie. 'without sex'). The spores and the 'parent' organism are genetically identical.

ASYMPTOMATIC - Without symptoms. An asymptomatic infection is one where the pathogen is present but there are no apparent symptoms indicating its presence.

BIOCIDES – A broad term for man-made chemicals that are used to control pests, weeds, insects and diseases caused by fungi or bacteria. Pesticides, herbicides, fungicides, insecticides, bactericides, rodenticides etc. may all be referred to as biocides.

BIOFUMIGATION – The use of toxic gases produced naturally in the soil by plant roots or decaying plant residues to control the spores of disease-causing fungi that are present in the soil.

CHLAMYDOSPORES – Thick-walled, single-celled, asexual spores produced by some fungi to aid survival in the soil and/or between seasons.

CONIDIA – Asexual spores produced by fungi. Conidia are often produced in large numbers and may be single-celled or multi-celled. They are often short-lived and adapted for wind or splash dispersal.

CORTEX – The outer tissues of the stem or root between the vascular bundles and the epidermis.

DEW PERIOD – The time period or number of consecutive hours, during which there is free water ('dew') on the leaf surface.

DISEASE – A set of symptoms incited by a biological agent (a pathogen). Symptoms of a disease may include death, destruction or discolouration of host tissue or abnormal growth or differentiation.

DISPERSAL – The means of spread or transfer of the cause of a disease (the inoculum of the pathogen) from one area to another or from one host plant to another host plant.

EPIDERMIS – The outermost, single-celled layer of tissue ('a skin') covering all plant parts.

EPIPHYTES – Non-parasitic or parasitic organisms such as bacteria, fungi, yeasts and algae that live and multiply on plant surfaces.

FORMAE SPECIALES – (f.sp.) A sub-grouping (special form) of a fungal species based on specificity for a particular host plant. (See Fov)

FOV – A convenient abbreviation for the full name of the fungus that causes Fusarium wilt of cotton – *Fusarium oxysporum* f.sp. *vasinfectum*

GIRDLING – Encircling. An infection that girdles a stem or root is one that completely encircles the stem or root.

HYPERVIRULENT – More virulent than all previously identified races or strains. The hypervirulent races of the bacterial blight pathogen are able to overcome a combination of several resistance genes in the plant whereas all previously identified races are only able to overcome single resistance genes.

IMMUNE – Completely resistant to infection by a plant pathogen. Immunity is normal as most plants are immune to most pathogens.

INCIDENCE – The proportion (%) of plants or bolls that are affected by a particular disease as opposed to

disease severity which is a measure of the mean intensity or extent of the symptoms on each plant or boll.

INOCULUM – Infective material or spores. That part of a pathogen that is produced on or in infected host tissue and is able to infect a new host or healthy host tissue. Inoculum is usually in the form of spores or sclerotia but may also be in the form of bacteria or fungal fragments growing and surviving in plant residues or seed.

LESION – An area of dead or dying host tissue.

METABOLITE(S) – Chemicals that are end-products resulting from a natural sequence of biochemical reactions. Breakdown products.

MICROSCLEROTIA – See Sclerotia.

MOTTLE – A pattern of light and dark areas across a leaf as seen in leaves of plants affected by Verticillium wilt.

MYCORRHIZA – A mutually beneficial association between a fungus and the roots of a plant. The fungi that form a mycorrhiza grow throughout the cortex of the plant roots and out into the surrounding soil where they function as an extension of the plant's root system. The plant provides a source of carbohydrate for the fungus while the fungus assists plant uptake of the less mobile nutrients such as phosphorus. Most plant species require mycorrhizal associations for normal healthy growth. (See VAM)

PATHOGEN – An organism that can cause disease symptoms to develop. A parasite. Fungi are the most common plant pathogens but plant diseases can also be caused by bacteria, nematodes, viruses, phytoplasmas, etc.

PHYTOPLASMA – A class of microorganisms that can cause disease in some plants. A phytoplasma has no organised nucleus and no true cell wall. Several diseases once thought to be caused by a virus have been shown to be caused by a phytoplasma. Phytoplasmas can only grow inside other organisms and require an insect vector to move them from plant to plant.

RACE – A genetically identical, sub-grouping of a pathogen species based on an ability to overcome a particular gene, or set of genes, for resistance in a plant host.

RESISTANT VARIETY - The infection process, colonisation and/or the production of spores by the pathogen is impeded by some aspect of the host plant's anatomy and/or physiology. Plant resistance may be manifest as smaller spots, fewer spots/leaf, reduced spore production, etc.

RHIZOSPHERE – The biologically active zone surrounding plant roots that includes the root surface and the adjacent soil. A 3-dimensional site of intense microbial activity stimulated by substances exuded from the root.

ROGUE – To remove and destroy infected or abnormal plants from within a crop or plot in order to prevent either further spread of the disease to nearby healthy plants or increased contamination of the site.

SAPROPHYTE – An organism that lives and multiplies on dead or dying organic matter.

SCLEROTIA - Thick-skinned, survival structures (usually black), produced within or on infected tissue by some fungi. Sclerotia vary in size from a few cells (microscopic microsclerotia) up to 5 to 10cm across and enable the fungus to survive for long periods in the soil or in crop residues or during adverse weather conditions.

SECONDARY INFECTION – Colonisation of an established lesion by saprophytic organisms that grow rapidly and reproduce abundantly on the dead and/or dying plant tissue produced as a result of pathogen activity.

SENESCE / SENESCENCE – Yellowing or reddening and death of plant tissue as a result of advanced maturity / old age.

SEVERITY - The intensity or extent of symptoms or the proportion of tissue with symptoms, on each plant or boll. The severity of leaf spot diseases may be expressed as the percentage of leaf area affected. Disease severity may also be described and assessed using an arbitrary scale eg. A scale of 0 –5 where 0 =no symptoms, 1 = minor symptoms, 2 = obvious symptoms, 4 = severe symptoms and 5 = complete death.

SPORE – A single-celled or multi-celled reproductive unit that is capable of infecting host tissue. Spores may be produced sexually, asexually or vegetatively and many fungi produce two or more spore types.

STEP-POINT METHOD – A method for randomly selecting plants within a field. While walking at an angle across the field select the plant nearest the right foot at the completion of a pre-selected number (eg 30) of steps. Continue across the field until the required number of plants has been assessed/sampled.

STRAIN – A sub-grouping of a pathogen species based on genetic uniformity. Derived from a single spore.



INTEGRATED DISEASE MANAGEMENT

SEEDLING DISEASES

BLACK ROOT ROT

VERTICILLIUM WILT

FUSARIUM WILT

ALTERNARIA

BACTERIAL BLIGHT

BOLL ROTS

MYCORRHIZAS

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SURVIVAL – Longevity. Ability to remain viable or infective over time when exposed to seasonal and/or environmental influences. A pathogen may be adapted to survive in soil, in or on crop residues or in seed. Some pathogens produce spores that only remain viable for a few hours while others produce spores or survival structures that remain viable for many years. Some pathogens are able to survive as saprophytes in the absence of a susceptible host.

SUSCEPTIBLE – Having no resistance to infection by the pathogen. The infection process, colonisation and production of spores by the pathogen is relatively unimpeded by the host plant.

SYMPTOMS – The set of visible signs indicating a deviation from normal, healthy growth, appearance and productivity. Symptoms may include death, destruction or discolouration of host tissue or abnormal growth or differentiation. Symptoms may be caused by (i) infection by a biological agent such as a fungus, bacteria, nematode, insect or virus, (ii) a nutritional imbalance such as a deficiency or toxicity, (iii) the impact of adverse environmental conditions such as frost, lightning, drought, waterlogging etc, or (iv) the impact of unwise decisions by the grower such as incorrect fertiliser placement, root pruning during cultivation, sowing depth, herbicide usage at planting, etc.

SYSTEMIC – Active throughout the plant despite application, or induction, to only a part of the plant. Active in a part of the plant remote from the point of application. Distributed throughout the host plant via the vascular system.

TOLERANT / TOLERANCE – Plant growth and/or productivity relatively unaffected by the presence of disease.

TRANSECT – An identified or fixed path across a field allowing representative sampling or assessment that may be repeated over time.

VAM – A convenient abbreviation for Vesicular Arbuscular Mycorrhiza. A particular type of mycorrhiza that is characterised by the production of vesicles and arbuscules by the fungus in the cortex of the plant root. (See MYCORRHIZA)

VASCULAR SYSTEM – The system of vessels that carries water and mineral salts within the plant ie from the roots to the leaves and shoots and from the leaves to the fruiting structures. A VASCULAR WILT is an infection of the vascular system.

VECTOR – An organism that carries a pathogen from an infected plant to a healthy plant. Insects, nematodes, man, parasitic plants, etc. may act as vectors for plant pathogens while remaining unaffected by their presence.

VEGETATIVE COMPATIBILITY GROUP (VCG) – A sub-grouping of a fungal species based on the ability of closely related isolates to exchange nuclear material via the fusion of fungal strands (hyphae).



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Appendix 1

Variety Resistance Ranking

FUSARIUM AND VERTICILLIUM RESISTANCE RANKING PROTOCOL FOR COTTON VARIETIES

Purpose of this protocol

Through the Australian Cotton CRC, a committee of cotton pathologists and representatives from CSIRO, CSD, Deltapine, CRDC and ACGRA have developed the following protocols for describing cotton variety resistance to Fusarium and Verticillium wilt. The purpose of this resistance ranking system is to provide cotton growers and other industry members with a quantitative measure of the relative wilt resistance or susceptibility of new or existing cotton varieties.

1. FUSARIUM RESISTANCE RANKING FOR COTTON VARIETIES

1.1A STANDARD FOR DESCRIBING COTTON VARIETY RESISTANCE TO FUSARIUM WILT

Based on previous trial data DeltaEMERALD and Sicot 189 are nominated as the current standard varieties for Fusarium wilt resistance ranking to Australian strains of Fusarium wilt. It is crucial that at least one, and where possible both, of these varieties be included in all ranking assessments for Fusarium wilt. QDPI and NSW Agriculture will include DeltaEMERALD and Sicot 189 in all variety comparisons

- The resistance of a variety will be expressed relative to the resistance of the standard, which is given the value of 100
- The number of comparisons (experiments/variety trials) will also be specified in the resistance ranking description

Example 1 - The Fusarium Resistance Ranking of new variety ABC = 129(5). This means that the averaged results of five comparisons have indicated that variety ABC is 29% better (more resistant) than the standard.

Example 2 - The Fusarium Resistance Ranking of variety DEF = 87(7). This means that the averaged results of seven comparisons have indicated that variety DEF is 13% less resistant than the standard.

1.2 CRITERIA FOR APPLYING THE FUSARIUM RESISTANCE RANKING PROTOCOL

Field trials must

- be located on sites where the level and distribution of disease in the previous season is known (involve the local IDO in this decision where possible);
- have confirmed the strain of Fov present at the site by sending specimens for analysis;
- be laid out in a statistically valid design eg. appropriate number of replicated plots or repeated check design;
- have plots of no less than 10 meters in length with all plants of 4 bolls or more within this to be assessed at the end of the season ;
- be planted to achieve 10 plants per metre;
- include one or both standards for Fov resistance ie. DeltaEMERALD &/or Sicot 189;
- have a 'Proportion of Plants Rating 0 & 1' (ie. value C below) of no more than 70% in the recommended standard variety;
- replication of trials at more than one site is encouraged.

Other considerations

- trials should be inspected early in the season (eg. by the local IDO and in communication with CRDC) to have the trial requirements verified and a trial number assigned;
- since trials may include both Bt-transformed and conventional varieties, it is important that they be sprayed to control insect pests eg. Helicoverpa. It would be unfair to compare the level of disease in a conventional variety with that of an Ingard variety in an unsprayed trial;
- yield data is not required for calculation of the Fusarium Resistance Ranking of a variety. Other data (eg. yield, fibre quality etc) can be presented in addition to the Fusarium Resistance Ranking at the discretion of the seed company/breeding programme;
- the use of terms like 'slight tolerance' and 'some resistance' to describe new varieties is discouraged in preference to descriptions of resistance in percentage terms in relation to the standard varieties.

1.3 EXAMPLE OF CALCULATIONS TO DETERMINE THE FUSARIUM RESISTANCE RANKING

The following values are calculated for each variety:

A. Initial Plant Stand

This is the total number of seedlings in the row or plot (a minimum of 10m) assessed as soon as possible after emergence (and no later than 3 weeks). Eg. for variety XYZ the initial stand count in the 10m plot is 80 seedlings.

B. Number of Plants Rating 0 and 1 at Harvest

This value describes the number of plants in a plot that have a Vascular Browning Index rating of 0 or 1 (see 1.4 below) when the stems of plants with 4 bolls or more are cut at or near ground level at the end of the season. Eg. after stem cutting plants of variety XYZ, a total of 34 plants had VBI scores of 0 or 1.

C. Proportion of Plants Rating 0 and 1

This value is calculated by dividing the value of B by the value of A and converting to a percentage. Eg. for variety XYZ, $B/A = 34/80 \times 100 = 42.5\%$

D. Fusarium Resistance Ranking

To determine the Fusarium Resistance Ranking value of a variety the "Proportion of Plants Rating 0 and 1" (C) is expressed in relation to the industry standard, which is given the value of 100 for the purpose of this ranking system.

Eg. if the value of C above for Sicot 189 in a trial is 22.4 (Number of Plants Rating 0 and 1 at Harvest 32/ Initial Plant Stand 70) and the value for variety XYZ in the same trial is 42.5, then the Fusarium Resistance Ranking for variety XYZ is expressed as:

$42.5/22.4 \times 100 = 190(1)$ - The figure in brackets gives the number of trials used to determine the figure, in this case only one.

Note

Cotton breeders and seed companies may find it useful to divide the 'Proportion of plants rating 0 and 1'(C) into its two components that describe seedling and adult plant reaction to the disease. Seedling survival can be calculated by comparing the number of plants stem-cut at the end of the season with the 'Initial Plant Stand' (A) while adult plant reaction is described by expressing the number of plants with a 0 or 1 stem-cut rating (B) as a proportion of the number of plants that were stem-cut.

1.4 VASCULAR BROWNING INDEX FOR ASSESSING FUSARIUM WILT INFECTION

This rating system is based on the severity of vascular discolouration (browning) visible in a cross section of the main plant stem cut as close as practicable to ground level where:

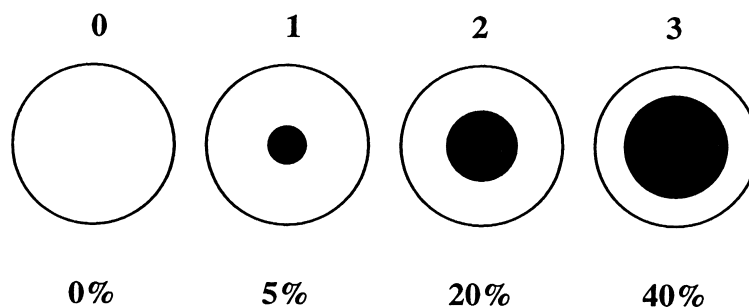
0 = no vascular discolouration

1 = discolouration restricted to small spots or an area less than 5% of the stem cross section

2 = discolouration of between 5% and 20% of the stem cross section

3 = discolouration of between 20% and 40% of the stem cross section

4 = greater than 40% vascular discolouration of the stem cross section



Note: the discoloured areas show the upper limit for each category



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2. VERTICILLIUM RESISTANCE RANKING FOR COTTON VARIETIES

2.1 A STANDARD FOR DESCRIBING COTTON VARIETY RESISTANCE TO VERTICILLIUM WILT

- Based on previous trial data Sicala V2 is nominated as the national standard variety for Verticillium wilt resistance ranking. It is strongly encouraged that this variety be included in all future ranking for Verticillium wilt
- QDPI and NSW Agriculture will include Sicala V2 in all variety comparisons
- The resistance of a new variety will be expressed relative to the resistance of the standard, which is given the value of 100
- The number of comparisons (experiments/variety trials) will also be specified in the resistance ranking description

Example 1 - The Verticillium Resistance Ranking of new variety XYZ = 121(5). This means that the averaged results of five comparisons have indicated that variety XYZ is 21% better (more resistant) than Sicala V2.

Example 2 - The Verticillium Resistance Ranking of variety ABC = 85(7). This means that the averaged results of seven comparisons have indicated that variety ABC is 15% less resistant than Sicala V2.

2.2 CRITERIA FOR APPLYING THE VERTICILLIUM RESISTANCE RANKING PROTOCOL

- Trials to be located on sites where the level of disease is known (involve the local IDO in this decision where possible);
- Verticillium disease assessments should not be made before the final irrigation
- at least 100 plants per plot (or given section of a plot) should be used in Verticillium resistance evaluation
- Trials are to be laid out in a statistically valid design eg. appropriate number of replicated plots or repeated check design
- For data to be used for this ranking system there should be no more than 90% disease-free plants in the recommended standard variety (see 2.3 below)
- Replication of trials at more than one site is encouraged

2.3 CALCULATIONS USED IN DETERMINING VERTICILLIUM RESISTANCE RANKING

- Assess disease incidence (%) at the end of the season (presence or absence of vascular discolouration)
- Determine % healthy plants by subtracting % incidence from 100
- Express relative to the standard, which is given the value of 100

Eg. if the disease incidence for Sicala V2 in a trial is 25% (ie. percentage healthy = 75%) and the disease incidence for variety XYZ in the same trial is 19% (ie. percentage healthy = 81%), then the Verticillium Resistance Ranking for variety XYZ is expressed as:

$81/75 \times 100 = 108(1)$ The figure in brackets gives the number of trials used to determine the figure, in this case only one.

19 Seedling disease



Seedling disease is caused by several weak pathogens that are present in most soils. It is favoured by cool wet weather and most plants become infected to some degree. Seedlings can die before or after emergence, as single plants or in patches. Patterns of seedling death can occur across rows (above).

Pythium usually causes a soft rot and stem collapse (below) while *Rhizoctonia* causes sunken red/brown spots on the lower stem and roots (right).



9 Black root rot

Black root rot is caused by a soilborne fungus that survives as long-lived thick-walled spores. Each crop of cotton deposits more spores in the soil, increasing the severity of the disease. Severity is also increased by cool wet conditions during the early part of the season. As the weather warms up, the plants resume growth and symptoms may no longer be visible.



- Black root rot is often observed first as patches of stunted, slow-growing cotton early in the season
- Black root rot may increase the stand loss caused by other seedling pathogens
- In subsequent seasons the patches may no longer be obvious as the pathogen spreads throughout the field





- Roots of infected seedlings appear black in comparison to those of healthy plants
- Lateral roots die but the tap root usually survives
- Damage in seedlings is limited to the outer layers of the tap root
- In some seasons the fungus infects the centre of the tap root, causing an internal rot in the upper part of the root and lower stem in older plants





Verticillium wilt is widespread and common.

- Plants rarely wilt but may defoliate prematurely at the end of the season
- Leaves develop a characteristic yellow mottle, at the edges and between the veins
- Lower leaves are usually affected first
- Dead tissue develops at the leaf edges and may replace the mottled areas (right)
- The mottle can be diffuse (above) or angular (below)

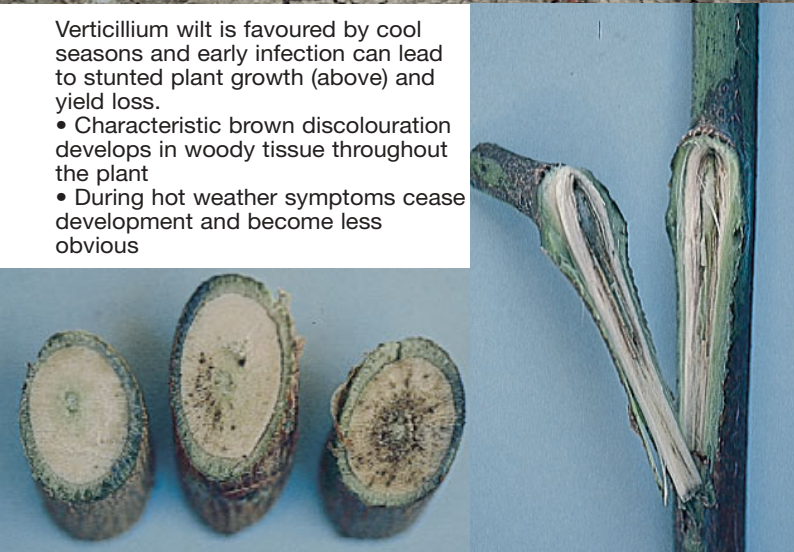


23 Verticillium wilt



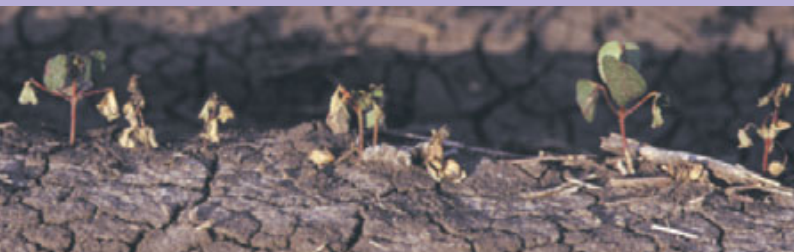
Verticillium wilt is favoured by cool seasons and early infection can lead to stunted plant growth (above) and yield loss.

- Characteristic brown discolouration develops in woody tissue throughout the plant
- During hot weather symptoms cease development and become less obvious



Look-alike symptoms, pages 9, 17, 20

15 Fusarium wilt



Fusarium wilt usually becomes obvious early in the season, especially with cool wet weather. Seedlings are stunted, wilt and die. This results in a gappy stand, often with bare strips along rows in the direction of irrigation.



Stunting, yellowing, wilting and plant death occur at any time during the season.

Plants die back from the top and may re-grow from the base later in the season (left).



The fungus is introduced to fields in infested soil or cotton residues carried on vehicles and machinery and in irrigation or flood water. Movement in irrigation water results in 'comet'-shaped patches (above right) and Fusarium wilt is often first observed as dead plants at the tail drain (below). The disease will be present for a number of seasons before large dead patches become obvious.



17 Fusarium wilt



A feature of Fusarium wilt is solid brown discolouration throughout the woody part of the stem and the tap root of seedlings and mature plants. The browning may progress to fill the whole stem (above).

Some leaves develop a yellow mottle (below right) that may be confused with symptoms of Verticillium wilt.



5 Alternaria leaf spot



Alternaria leaf spot is favoured by humid wet conditions. The pathogen is carried over on infected cotton residues from the previous season.

- Spots on cotyledons, leaves and bracts vary from 1 to 10 mm in diameter and may be brown to grey/brown, sometimes with dark brown or purple margins, and sometimes with obvious concentric zones
- Symptoms should be most severe on lower leaves and least severe on upper leaves, unless leaves are affected by premature senescence





- Plants with a heavy fruit load and Pima cotton are more susceptible
- Affected leaves turn yellow and defoliate prematurely



7 Bacterial blight



Bacterial blight occurs in susceptible varieties and Pima cotton when weather conditions are hot, wet and humid. Storms and hail increase severity. The pathogen may be introduced in planting seed or carried over on infected cotton residues from the previous season.

- Spots on cotyledons are circular, dark green and greasy
- Spots on leaves and bracts are angular, dark green and greasy, and are more obvious on the lower leaf surface. Spots darken and may become black with age
- Large lesions may develop along leaf veins, and along stems and branches ('black arm')



11 Boll rot

Boll rots are caused by a number of pathogens, including fungi and bacteria. Boll rots are favoured by wet weather and humidity deep in the plant canopy.



Boll rot caused by *Alternaria macrospora* begins as small spots with dark margins (above). The spots enlarge and eventually may affect the whole boll.

Bolls infected by *Phytophthora* appear dark brown to black, sometimes with areas of white mould on the surface (below and right). Locks from affected bolls often have a brown stain. They remain hard and don't fluff out. Affected bolls either don't open at all, or open prematurely, with the compact locks easily dislodged and falling to the ground.





The distinctive feature of *Sclerotinia* boll rot (above) is the production of black fungal structures (2 to 10 mm diameter) within and/or on the surface of the rotted bolls. A white cottony fungal growth may be present and the branch adjacent to the boll may also be affected.

There are several other fungi that can cause boll rots in cotton (below). These fungi usually require injury or a wound to allow infection to take place. These boll rots will be more frequent in crops with rank growth.



13 Boll rot



- Bacterial blight of bolls is especially obvious on young, green developing bolls. Spots are circular, dark green and greasy (above)
- When spots develop under the calyx crown at the base of the boll (above right) then further boll development is prevented
- Affected bolls do not open properly (below)
- Secondary fungal growth sometimes develops in old spots on mature bolls





Bacterial stunt occurs when soilborne bacteria infect cotton roots. It is most severe on heavy grey clays and is easiest to identify when soil type varies within the one field. Severity varies from season to season but the distribution in fields does not vary. Symptoms include:

- Uniformly stunted, slow growing plants (growth picks up later in the season)
- Symptoms of zinc deficiency
- Rapid development of root-browning in seedling plants



Bean root aphid causes areas of poor stand establishment, stunting and uneven seedling growth (above). Affected patches may be circular or irregular. Careful examination of the roots reveals:

- A network of tunnels in the soil surrounding the taproot
- Small light-brown aphids feeding on the roots (below, circled)
- Small brown ants 'farming' the aphids
- Tunnels collapse and the aphids and ants usually disappear after an irrigation



35 Boll dangle, chimera



Boll dangle, or cavitation occurs following heat and/or water stress in plants with a full fruit load.

- Immature small fruit die and dry on the plant
- An elongated dead patch always develops along the fruiting branch below the dead boll (right)



A chimera is a genetic fault that causes white or variegated areas on leaves (left). Chimeras usually develop on one branch or one side of the plant.



Bunchy top occurs in small patches and occasionally whole fields. The cause has not been confirmed. Symptoms include small leaves and bolls, short internodes and a pale angular mottle near the edges of leaves. Some branches can be unaffected (left). The leaf mottle may occur without the bunchy growth habit and, on leaves in full sun, may turn red on the upper surface of the leaf (below).





Cotton root tips may die back when fertiliser is placed beneath the planting line or too close to the soil surface.

- Symptoms occur at a consistent depth on the roots
- Severity is increased by dry conditions between fertiliser application and planting



25 Herbicide

Herbicides applied at planting can be washed into the root zone by rain, especially with dry loose seed beds, planting slots that open with drying, or depressions along the top of the bed.



Fluometuron causes interveinal bleaching of leaves that can persist until the end of the season, sometimes with a grey crusty surface (above).

Fluometuron in combination with prometryn can damage (below) or kill seedlings.





High rates of trifluralin may cause swelling at the base of cotton stems (above) and root-pruning. New roots attempting growth from the base of the stem may also 'burn' back (left).

Residual herbicides used on other crops and in fallows can damage cotton. Metsulfuron may cause yellowing and stunting in seedlings (below).





Glyphosate drift causes stunting and reddening of petioles and cotyledons fold down (above, plant at left is a self-sown glyphosate tolerate variety). Patterns of damage reflect the direction of drift. Higher levels of exposure kill seedlings.

'Safe' herbicides can damage cotton if applied under adverse conditions. In very cold weather pyriithiobac-sodium may cause puckering and yellowing of seedling leaves (below).





Zinc deficiency may occur in association with bacterial stunt, lack of mycorrhiza or inadequate zinc in the soil. Plants are stunted, young leaves cup upwards and develop inter-veinal yellowing. Spots may also develop within the yellow areas.



33 Lightning



Lightning can cause circular or irregular patches of dead or damaged plants (above and below).

- A key characteristic is that all plants in a patch are affected at the same height
- In mature crops the damage, including browning inside the stem, may occur at the top of the plant, while the roots and lower stem are unaffected (right)



29 Premature senescence



Premature senescence occurs when potassium is relocated from the upper parts of the plant to maturing bolls. Leaves develop reddening on the upper surface (below). Rows at the edge of fields remain green (above). High fruit load increases the demand for potassium and the severity of symptoms (right). Single plants that have filled all bolls will senesce prematurely and may defoliate (below, right). *Alternaria* leaf spot, if present, is more severe.





Excessive wind can result in sandblasting. Leaves and bark are damaged on the windward side of the plant only (above).

Excessive dry winds may completely desiccate and kill plants (left).

Leaves rubbing across opening bolls can become scratched on the under surface (below left) resulting in burn-like spots on the upper surface (below right).



31 Soil compaction



When the soil is too moist the planter can smear the planting slot, which prevents normal root development (above). Damage occurs at a uniform depth. Under rain-grown conditions a plough-pan can restrict root development and in hot dry weather the plants may die (below and left).





Sudden wilt is caused by a weak pathogen that infects the roots and lower stem. Root damage from late cultivation can contribute.

- Plants wilt suddenly and defoliate, usually in hot weather after irrigation or rainfall
- Plants die or occasionally re-grow
- Affects single plants or small patches
- Does not re-occur in the same place
- Brown discolouration is confined to the woody parts of the roots and lower stem only





Sunscauld, or leaf dessication, may occur in late summer or early autumn, usually when a few days of cool cloudy weather is followed by a rapid rise in temperature and light intensity.

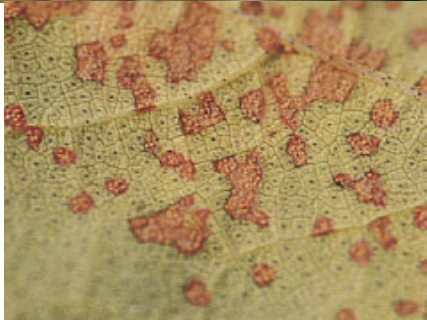
- Entire fields can be affected
- Symptoms can resemble damage by chemical defoliants
- Complete defoliation can occur 10 to 14 days after the initial symptoms develop

21 Tropical rust



Tropical rust is common on feral cotton and tree cotton in parts of northern Australia.

- Numerous small spots develop on older leaves
- Spots are purple with a red/brown centre on the upper side of the leaf (above) and brown, powdery underneath (right)
- More severe during the dry season



Look-alike symptoms, pages 5, 7, 28

Symptoms of diseases and disorders of cotton in Australia



David Nehl
Stephen Allen



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Disclaimer: This document is designed to be used as a tool to assist the management of diseases in cotton. It is not a substitute for personnel with expert knowledge of cotton production or of any aspects of cotton crop management. The Cotton Research and Development Corporation, the Australian Cotton Cooperative Research Centre (Cotton CRC) or its participants do not warrant or make any representation regarding the use of, or the results of the use of, this document. In particular the Cotton Research and Development Corporation nor the Australian Cotton Cooperative Research Centre (Cotton CRC) or its participants do not warrant or represent that the information contained within this document is correct, accurate or reliable. The user relies on this document at their own risk. ISBN number 1 867354 84 4. Printed by Evans Printing 02 6755 5950.





APPENDIX 2:

Sending a Sample for Diagnosis by a Pathologist

(Attach a completed copy of this form to each sample)

Collected/Submitted by: (your Cotton Extension Specialist)	Address/e-mail/Fax/telephone:
Property name and field number: Variety:	Date collected:
Grower/Agronomist:	Grower's address or area/locality:

Mark (X) as appropriate

DISTRIBUTION

- ☐ One field only
- ☐ In several fields
- ☐ In all fields
- ☐ One variety only
- ☐ Several varieties affected
- ☐ Some rows more affected?
- ☐ On lighter soil types
- ☐ On heavier soil types
- ☐ In poorly drained area(s)

INCIDENCE/SEVERITY

- ☐ All plants
- ☐ Scattered single plants
- ☐ Scattered patches of plants
- ☐ In a large patch (>5m)
- ☐ In a small patch (1-5m)
- ☐ In a small patch (<1m)
- ☐ Plants dead
- ☐ Plants defoliating
- ☐ One to a few plants only

THE CROP

- ☐ Irrigated
- ☐ Dryland/rain-grown
- ☐ Seedling stage
- ☐ Setting squares
- ☐ Early flowering
- ☐ Peak flowering
- ☐ First bolls open
- ☐ Defoliated
- ☐ Ready to pick

Rainfall in the last 10 days:

Average temperature range over the last 10 days

Date of last irrigation

Date of last cultivation

Any other information? :

Please contact your Cotton Industry Development Officer or District Agronomist to determine the appropriate Pathologist and address for submitting samples

All samples where Fusarium wilt is suspected must be sent to Indooroopilly.

When sending samples:

- It is better to despatch samples early in the week rather than just before the weekend!
- Never wrap samples in plastic. Dry or slightly dampened newspaper is better!
- When collecting seedlings – dig them up rather than pull them out. Include some soil.
- Sections of stem (10-15cm) are usually adequate for wilt diseases.



information sheet

Farm Hygiene for Disease and Weed Control March 2000

Come Clean - Go Clean

Prepared by pathologists and weed scientists from the Cotton CRC

When it comes to diseases and weeds:
**PRACTISE BEST PRACTICE
WHENEVER POSSIBLE !!**

Prevention is better than cure! - It is better to prevent the introduction of a disease, weed or pest than to try and control it after it has been introduced and become widespread. A number of disease and weed problems are currently limited to particular regions or farms within regions ie;

- Cotton anthracnose has been recorded in Queensland and north-western Australia but not in NSW
- Fusarium wilt of cotton is established in most parts of Queensland and NSW but has not been observed in the Lachlan valley of NSW, the Emerald area of Queensland, the Northern Territory, Western Australia or north Queensland
- Tropical rust of cotton has been recorded in north Queensland and the Northern Territory but not in NSW, central or southern Queensland
- Black root rot of cotton is widespread in NSW and southern Queensland but has not been recorded in north Queensland and north-western Australia
- Grey mildew has been observed in north-western Australia but not in cotton production areas of NSW
- Texas root rot; hypervirulent strains of the bacterial blight pathogen; defoliating strains of the verticillium wilt pathogen; leaf curl and leaf crumple gemini viruses and many other serious diseases of cotton have not been observed in Australia
- Anoda weed and velvet leaf are spreading and are now present on isolated properties in both NSW and Queensland.

It is important that efforts be made to prevent the introduction of weeds, pests and diseases into new areas and to minimise the further spread and build-up of weed, pest and disease populations once they have been accidentally introduced into an area or onto a farm.

Pathogens can be spread in soil and trash attached to vehicles and machinery !! (examples follow)

- Dirt was collected from underneath 16 visitor's vehicles parked at the Australian Cotton Research Institute during a Namoi valley field day. The samples were tested for the black root rot and Verticillium wilt pathogens and for species of Fusarium
- 3 of the 16 vehicles were carrying the black root rot pathogen!!
- 12 of the 16 vehicles were carrying the Verticillium wilt pathogen!!
- 15 of the 16 vehicles were carrying species of Fusarium! (not the cotton fusarium)
- Department of Primary Industries (QDPI) staff at Indooroopilly collected soil from around the wheels of the car following a trip to Dalby to collect samples for their work on Fusarium. The soil was placed into pots in the glasshouse and seed of a susceptible cotton cultivar was planted. Symptoms of Fusarium wilt developed in the seedlings.

'Best Practice' involves choosing the best option when a decision has to be made. 'Best Practice' is not always possible, and sometimes not practical, but attempting 'Best Practice' will maximise economic and ecological sustainability on the farm.



BEST PRACTICE

FOR COTTON GROWERS WITH FIELDS WHERE SIGNIFICANT DISEASE OR WEED PROBLEMS ALREADY EXIST.

The following principles should be applied to minimise the spread of Fusarium wilt, Anoda weed or velvet leaf, Black root rot, etc.

- Grow disease resistant cultivars where possible
- Growers should advise neighbours, visitors, contractors, suppliers etc. to take extra precautions
- Avoid vehicle and machinery movements when road conditions are wet and muddy
- Consultants, when on-farm, could use a vehicle (and maybe even footwear!) supplied by the grower and retained on-farm
- Machinery should be cleaned after working in the affected field - before going into other unaffected fields
- Module trucks should be cleaned after transporting modules from affected fields and before transporting modules from unaffected fields
- Gin trash and motes arising from seed cotton modules from affected fields should be burnt. The first load of gin trash from subsequent unaffected seed cotton should also be burnt
- Modules, cotton seed and husks should be transported securely with no 'dribbling along the highway'
- Crop by products and residues should be disposed of responsibly
- The industry should be kept informed of those areas where significant disease or weed problems exist. Such information should indicate areas rather than individual farms.

BEST PRACTICE

FOR ALL COTTON GROWERS & THOSE IN SERVICE INDUSTRIES.

- Tail-water and run-off water should be retained on farm and kept out of river systems
- Machinery and vehicles coming onto or leaving the farm should be free of soil and crop debris. Best results are achieved by using a pressure cleaner followed by a spray with a detergent-based disinfectant such as Castrol 'Farmcleanse'
- Control weeds within and around each field
- Use an appropriate crop rotation strategy
- Maintain good nutrition
- Minimise spillage and loss when transporting modules, hulls, cotton seed or gin trash.



Photo1. Mud attached to vehicles and machinery is a major transmission path for diseases and weeds

**CLEANING DOWN !!!
'GO CLEAN' SO THAT YOU CAN
'COME CLEAN!'**

A thorough clean-down with compressed air will generally be sufficient to reduce the risk of dispersing disease propagules. All dust and plant debris should be removed.

If there is soil/mud attached to the machinery or vehicle OR if the vehicle or machinery has been used in an area where *Fusarium* is known to be present - then it will be necessary to use a pressure cleaner. All soil and plant debris should be removed and an appropriate disinfectant applied.

Staff at QDPI, Indooroopilly have evaluated a range of disinfectant / detergent options for the elimination of *Fusarium* contamination when cleaning vehicles and machinery. Their results indicated that best disinfection was achieved by thorough washdown then chemical disinfection. Ideally, machinery should be thoroughly pressure washed – a detergent degreaser such as Castrol 'Farmcleanse' should then be applied, left for a short period, and then rinsed off. Castrol 'Farmcleanse' which is a biodegradable, agricultural detergent degreaser with anti-fungal properties, has been the most effective product tested to

date. (See - CRC Information Sheet "Detergent based degreaser for disinfecting machinery to reduce the spread of *Fusarium* wilt of cotton March 2000")

Clean-downs should be performed away from crop production and heavily trafficked areas, preferably on a hard surface which can be hosed down. Care should be taken not to contaminate one vehicle or piece of machinery with soil washed off the previous one! It is important that waste water drains to an evaporation pond or is held in a sump. It is best to clean down before you leave where you have been so that you can arrive clean wherever you are going.

Truckwash facilities at Service Stations at Goondiwindi, Brookstead and Moree provide access to a pressure cleaner at a site with hard standing and with waste water retained in a sump / grease trap which is emptied regularly and waste disposed of appropriately.

This policy should apply to everyone who moves machinery - whether it be earth moving equipment or combine harvesters. A little voluntary effort now could save a lot of effort at some time in the future.

Growers should insist on a prior cleandown of vehicles and machinery before arrival at their front gate!

A FOOTBATH FOOTNOTE – A 1% bleach or 10% 'Farmcleanse' footbath can be a good thing in the right place but an absolute disaster if placed poorly !! The footbath must be located on a hard dry surface or lawn and there should be no chance of picking up more dirt after dipping! Appropriate times may include the start and end of a field day and on departure from a *Fusarium* trial site. A footbath will not work on mud-covered boots!!

'Farmcleanse' is recommended as it has higher penetration into attached soil/mud than bleach or other fungicides and is less toxic to the user – but more toxic to *Fusarium*.

AN ALTERNATIVE TO A FOOTBATH IS THE USE OF LARGE POLYTHENE BAGS OVER THE SHOES AND LOWER LEGS FASTENED WITH A RUBBER BAND AND DISCARDED APPROPRIATELY ON LEAVING THE FIELD

CLEAN DOWN THOSE PICKERS AND STRIPPERS !!

To assist growers, contract pickers and importers Mr David Holben of the Australian Quarantine and Inspection Service (AQIS) assisted by Mr Robert Bell of Auscott, Narrabri have developed an inspection protocol for cotton pickers and strippers.

COTTON PICKER (CASE 2044 / JD 9965)

- **Row units:** Inspect the picking heads externally and open all picking head inspection doors to expose moisture racks, doffers, spindle bars and rotor assemblies
- **Doffers and moisture racks:** Inspect in, around and behind these units
- **Rotor Assemblies:** Manually rotate and inspect.
- **Air ducts:** Open rear inspection doors located behind the picking heads
- **Picking heads:** Raise and support on blocks before inspecting the underside

Safety Alert: Picking heads are held up by hydraulic pressure. Do not climb underneath, unless heads are safely blocked in raised position

- **Cabin:** Depending on model type either remove top cabin panel or hinged roof to expose the air conditioning system and filtration unit. Also inspect internal cabin, particularly under the floor mat
- **Horizontal air ducts:** Remove/open all covers and inspection panels
- **Vertical air ducts:** Inspect the duct by looking down the duct from the top
- **External basket steps:** While climbing steps inspect the space in between the cabin and the cotton basket
- **Basket roof:** Inspect the basket roof

Safety Alert: The meshed surface area on the basket roof will not support a person's weight. Walk only on the perforated metal walkways which run from front to back

- **Inside basket:** Gain access through the hinged door on the roof. Use a ladder to descend into the basket and inspect from the inside
- **Undercarriage/chassis:** Inspect underside of machine, chassis rails and telescopic rear axle if fitted
- **Basket:** Tip or elevate basket (depending on model type) and inspect underside, drive shaft

assemblies, blower fan and hollow basket support frames

Safety alert: The basket is operated hydraulically. Do not climb under basket unless it is safely secured into raised position

- **Radiator:** Remove cover panel to expose top of radiator. (This can only be done when basket is in the raised position) Inspect radiator and surrounding area
- **Side and rear screens:** Remove or hinge open all screens on the engine, radiator and fuel bays and inspect the areas inside
- **Tyres and wheels:** Inspect for soil and plant residues.

COTTON STRIPPER (JD 7450)

- **Row units:** Remove all covers to expose vertical and horizontal augers and rotary brushes. Inspect all components
- **Belts and drive assemblies:** Remove and/or hinge open top cover panels to expose belts and drive assemblies. Inspect
- **Horizontal auger:** Raise stripper front platform 300mm or more and check the underside of horizontal auger

Safety alert: Front platform held up by hydraulic pressure. Do not climb underneath unless platform is safely blocked in raised position

- **Pre cleaner:** Remove cover panels then remove saw brush holders. Carefully rotate cleaner manually by using the pulley system on the outside of the cleaner
- **Cleaning fan:** Remove back panel, expose doffer, fan assembly.



Detergent based degreaser for disinfecting machinery to reduce the spread of Fusarium wilt of cotton

March 2000

Prepared by Dr Natalie Moore¹, and Mr Wayne O'Neill¹.

Industry wide priority

Retarding the spread of Fusarium wilt of cotton in Australia is an industry priority. The disease is caused by the soil-inhabiting fungus *Fusarium oxysporum* f.sp. *vasinfectum* (Fov).

This fungus can survive well in soil and infected plant trash attached to vehicles and other farm machinery. It is also spread in flood and irrigation water. Once introduced into soil, the spores of Fov can survive for decades, even in the absence of cotton plants.

The Australian cotton industry is heavily reliant on consultants and contract machinery, especially for picking and transporting the crop so the application of reliable disinfection protocols is essential to retard the spread of the pathogen to disease-free properties and districts. Contractors are also used for many winter crops which may be grown in Fov-infested ground, so it is important that protocols are applied consistently at all times of the

year and to all vehicles and machinery that may be carrying Fov-infected material.

Efficacy trials

To assess the effectiveness of several agents against Fov, studies were conducted by the Department of Primary Industries Queensland at Indooroopilly in Brisbane. A known concentration of Fov spores (typical of a high rate of infestation in field soil) was added to steam pasteurised soil. The inoculated soil was placed onto sections of a metal surface and was then treated in either of two ways. The agents were applied at the recommended rates to half of the soil samples to test their activity against spores in small clods of soil still attached to machinery after cleaning. The other soil samples were washed from the metal surface and then the surface itself was treated with the various agents to test their effectiveness in killing any spores left on the surface after washing. Sterile distilled water

Table 1. Agents tested for activity against Fov spores in infested soil (summary of efficacy trial data compared to sterile water controls)

Agent and rate ^a	Reduction of viable Fov spores
Benomyl, Benlate-0.6g/L	29-40%
Quaternary ammonium compound, Sporekill-1:100 dilution	37-40%
Multiclean, 1:10 dilution	72-98%
Farmcleanse, 1:10 dilution	100% ^b

^a all agents were tested at the recommended rate

^b this result does not mean that all Fov spores will be killed in all situations but reflects the fact that no viable spores could be recovered after the treatment was used in these tests



was used as a control in both types of test. Laboratory tests were used to assess the number of viable Fov spores remaining in the clods of soil and on the washed and treated surfaces.

Low numbers of spores were recovered from the metal surface after washing with water only, indicating that the physical removal of as much attached soil as possible from machinery is highly effective in reducing spore numbers and therefore reducing the spread of this disease. Farmcleanse, an improved detergent-based degreaser, showed the highest efficacy against spores of Fov in infested soil and on the washed metal surfaces where no viable spores were recovered after treatment (Table 1).

On May 31st 1999, the temporary off-label registration permitting the use of the fungicide Benomyl (commercially available as Benlate) for disinfecting machinery moving from Fov infested areas to disease free areas expired. In light of the results presented above, this agent is no longer recommended for this purpose.

Thorough cleaning is the first line of defence!

Chemical disinfectants are no substitute for thorough cleaning of machinery. The more soil and trash that can be removed by high pressure washing, the less chance that Fusarium will be transported to disease free areas. We should look upon the use of disinfectants after washing as a supplementary assurance. Ideally, machinery should be thoroughly pressure washed on a sealed surface with the capacity for waste water retention, a

recommended disinfectant should be applied, preferably with a foaming spray nozzle, left for around 10 minutes, then rinsed off with water.

Many cotton growers have already provided hard surfaces (concrete slabs with a high pressure hose and drainage) at appropriate points for cleaning machinery entering or leaving their properties. For more information about cleaning farm equipment see the open letter to cotton growers from the ACGRA Fusarium Wilt Working Group. (a copy of the letter is available on the Cotton CRC web site <http://cotton.pi.csiro.au/Assets/PDFFiles/CLEANDWN.pdf>)

It is fortunate that a detergent-based product proved to be the most effective treatment for disinfecting machinery as it does not pose any registration problems, and no special safety precautions have to be taken for its use. It is biodegradable (to AS4351) and should not cause the corrosion problems on machinery that can occur with bleach disinfectants.

Farmcleanse is also ideal to use in footbaths as it does not bleach clothing and is safer to use.

Farm hygiene

The adoption of more hygienic farm practices and attention to minimising risks on and between farms not only retards the spread of Fusarium, but several other soil-borne diseases and weed species as well.

For more general information about Fusarium wilt of cotton, please refer to the Australian Cotton CRC Fusarium Information site at: <http://cotton.pi.csiro.au/Publicat/Pest/Disease/fuInfo.htm>

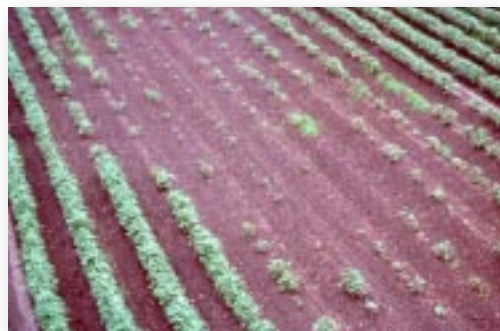
For information about obtaining Farmcleanse please contact your local Castrol distributor.

(NSW State enquiries: 02-9795 4800)

(QLD State enquiries 07-3850 9300)

(WA State enquiries: 09-337 4233)

A Tractor Driver's View of Fusarium Wilt



Early Recognition of Fusarium Wilt is Important
“If in doubt, check it out”

Your cotton local extension specialist can send samples away for identification (*see reverse*)



Fusarium wilt update

March 2000

Compiled by Greg Salmond¹ and pathologists from the Cotton CRC

This season cotton growers on the Darling Downs have experienced a dramatic increase in the incidence of the disease fusarium wilt in their cotton crops. The worst affected areas are the Central and Southern Downs, with samples from other Darling Downs districts confirming that fusarium wilt has spread over a large proportion of the current production area. For the first time, this disease has been officially confirmed in several dryland cotton crops.

Other cotton districts have also had the disease confirmed for the first time from plant samples this current season. Growing districts of Warren and Moura are now no longer regarded as fusarium wilt free. At the time of writing, suspected fusarium wilt plant samples had been received from the Upper Namoi and Bourke districts and are undergoing laboratory testing. New outbreaks have also been recorded in the St George district.

Once fusarium wilt is confirmed on a farm, both seed companies **must** be informed of the farm's location. Fusarium wilt can be seed borne. Informing seed companies is **critical** for the Australian cotton industry to ensure the production of disease free seed.

MOST COMMONLY ASKED QUESTIONS ABOUT FUSARIUM WILT

What is fusarium wilt?

Fusarium wilt is a disease of cotton caused by the soil-inhabiting fungus *Fusarium oxysporum* f.sp *vasinfectum* (**Fov**). The disease was first confirmed in Australian cotton crops on the Darling Downs in March 1993.

Australian isolates of *Fov* are different to *Fov* found in other cotton producing countries around the world. Vegetative compatibility group (VCG) analysis and DNA finger printing techniques have identified two unique strains of *Fov* in Australia - VCG 01111 (formerly known as the Darling Downs Strain) and VCG 01112 (formerly known as the Boggabilla Strain). Both strains are equally capable of causing fusarium wilt disease in all currently available commercial cotton varieties.

What has caused this disease to be more severe this year?

The new occurrences of *Fov* this year are not the result of spread this year. It is more likely that *Fov* arrived several years ago and the number of spores has only now built up enough to cause noticeable disease.

Seasonal conditions during the 1999-2000 growing season have been ideal for the development of *Fov*.

- *Fov* is a stress related pathogen meaning that cotton plants will become more susceptible when stressed. The fungus is able to rapidly colonise the stressed plants.
- Temperatures experienced this past growing season have contributed to plants suffering severe stress. November 1999 on the Darling Downs was the coldest on record. Long periods of unusual cold shock conditions were experienced early in the growing period. The severe heat wave conditions experienced in January (after periods of mild temperatures) contributed to additional plant stress. After both these events, widespread plant deaths as a result of *Fov* infection were reported from many areas.

- Disease symptoms are most commonly seen in cotton crops:
 - * in the seedling phase, after flowering or during boll fill;
 - * a few days after an irrigation, or as a result of over-irrigation;
 - * after water stress (too much or too little);
 - * in plants injured from either fertiliser burn, mechanical implements, or even hail;
 - * and may be first noticed in tail drain areas of fields where plants are stressed from waterlogging.
- As a result it is critical that any unusual patches in fields should be investigated.

How long can the spores of the fungus last in the soil?

Some spores of the fungus (*Fov*) can survive in the soil for at least 10 years, even in the absence of cotton. If highly susceptible cotton varieties continue to be grown in infected fields, the *Fov* population in the soil will build up to the point where production will not be possible even with the most tolerant varieties of cotton. This has already occurred in some fields on the Darling Downs.

Are there alternative hosts?

YES! Bladder ketmia, sesbania pea & dwarf amaranth are hosts that show no external symptoms. These weeds may act as an on farm reservoir for the disease. There is evidence that the fungus can also survive on the residues of other crops and weeds.

Can the fungus be spread from one field to another or from one farm to another?

YES! The disease can spread from field to field, farm to farm and even region to region. Spores of the fungus are effectively spread over long distances in infested soil attached to boots, vehicles, farm machinery and equipment and also in water (irrigation and overland flows). It can also be transferred in infected plant material.

What should growers do if they suspect fusarium wilt in their cotton crops?

Early detection and containment of new outbreaks are key strategies for managing *Fov*. All farm staff and contractors should be advised of the symptoms and be encouraged to be on the lookout.

Growers are encouraged to send stem sections from suspect plants for examination at the DPI

Farming Systems Institute Plant Pathology Laboratories in either Toowoomba or Indooroopilly. Early detection of outbreaks on properties in St George and Theodore in past seasons enabled management strategies to be implemented quickly. Management of *Fov* will be most effective if the whole district agrees to implement a strategy to minimise its spread.

It is essential that specimens from new outbreaks be analysed to detect any new strains of *Fov* and to monitor the stability of current strains.

What are the current recommendations to manage this disease?

In regions or fields where the disease has only just been found it is extremely important to detect all outbreaks as soon as possible and to maximise efforts to contain the spread.

With small patches

- Pull out affected plants and burn them on the spot. Consider soil solarisation (see below). Raking and burning the whole field at this stage is NOT an option as raking is likely to spread the disease.

With large patches

- Kill affected plants, preferably by spraying with herbicide and leaving them to die in place (this includes regrowth and volunteer plants)
- Sow a persistent ground cover in the fallow (eg. a legume) to stabilise the soil in the affected area and to prevent erosion after the cotton plants have died. Clean down any gear used for establishment and maintenance of the crop and do not allow tail water to leave the strip. Such areas may be suitable for the establishment of lucerne strips for IPM as long as traffic in and out of the area is minimised and not conducted under wet conditions.

With any patch

- Destroy one to two metres of plants in the “healthy” area surrounding the patch, taking particular care to minimise the transfer of affected soil from the area
- Reduce traffic to zero in the affected patches. Minimise traffic in adjacent areas and restrict it to dry conditions only.
- Stop irrigating affected patches. Use bunding to divert rainwater around the affected patch and, if possible, to contain rainwater that falls on it.
- Collect the trash from the tailwater of infested fields and burn it on-site. This is to minimise movement of infested trash to other fields.

Growers can reduce the impact of this disease, especially in areas where it has a restricted distribution by:

- Only growing tolerant varieties. Tolerant varieties will slow the build-up of *Fov* in the soil, in contrast to susceptible varieties. In some seasons disease incidence may increase substantially in tolerant varieties when weather conditions are particularly conducive to disease development. **Delta Emerald** and **Sicot 189** are the most tolerant commercial varieties at present. Both breeding programs are making major efforts to develop more tolerant lines. Field observations in recent seasons indicate that some Bt transformed varieties appear more susceptible to *Fov* than their conventional counterparts. Research work is continuing in an effort to understand and confirm this observation
- Field inspection for early detection and containment of isolated outbreaks
- Avoiding stresses in-crop such as over-irrigation, over application of nitrogen etc.
- Practising good farm hygiene to keep farms disease free (vehicle washing facilities / footbaths); Washdown with Castrol Farmcleanse is recommended to minimise disease spread. (refer to Cotton CRC information sheets *Farm Hygiene for Disease and Weed Control* & *Detergent based degreaser for disinfecting machinery to reduce the spread of Fusarium wilt of cotton*). The Castrol product Farmcleanse has been shown to have far greater activity against *Fov* spores in soil than Benlate (see article in Australian Cottongrower magazine April 1999). The temporary registration for use of Benlate on vehicles lapsed in May 1999.
- Ensuring all traffic including contractors

Come Clean! Go Clean!

- Changing stubble management: Early trial trends suggest that mulching infected cotton stubble and leaving it on the soil surface for a month before incorporation may be the best treatment to reduce in-field *Fov* spore levels. This is probably due to the effect of sunlight on the infected plant material. Most mulchers leave a proportion of the infected stem in the ground. However, machines are now available that will pull the whole plant and mulch in one pass (the "Excel puller-mulcher" is one model). Puller-mulchers should be better because more of the infected plant will be left on the surface.

Can the fusarium wilt fungus be eradicated from fields?

NO! However, some treatments may reduce the number of fungal spores....

Solarisation: In fields where small patches of fusarium wilt have been identified, solarisation under clear plastic for a minimum of 5-6 weeks during warm weather over moist soil has been shown to reduce the amount of fungus in the soil. If UV resistant plastic is used, leaving it down for a longer period of time would also help prevent soil movement off site. NB black plastic is ineffective. Following solarisation it is important to grow tolerant varieties in that field.

Flooding of fields: In some circumstances, and where appropriate, summer flooding of fields could be a management option.

Fumigation: The use of soil sterilants (eg. methyl bromide) is **not** recommended as it has been shown to increase the disease in some other crops. As well as killing many beneficial fungi and bacteria, such treatments rarely kill all the *Fov* spores. Spores then germinate and rapidly colonise the sterilised soil eventually leading to higher spore levels in the long term. Fumigants are in general less effective in heavy clay soils than in lighter soils.

What other research is currently being conducted to find answers for this serious problem?

- Identification of tolerant germplasm is being undertaken, both in the field and in the glasshouse, in collaboration with both CSIRO and Deltapine breeding programs.
- *Crop rotations:* Crop rotation studies are yet to be completed. Dr Stephen Allen (CSD, Narrabri) has trials underway in northern NSW (eg. wheat, barley and bare fallow). A PhD student working with Dr Joe Kochman found that *Fov* populations under sorghum and maize did not decrease significantly (in small pot trials). The effects of incorporating non-host crop residues will be investigated. Crop rotation trials are to be expanded on the Darling Downs. Initial research trends have to be verified over several seasons.
- *Biofumigation studies:* Dr David Nehl (NSW Ag, Narrabri) has used biofumigation crops (brassicacae or hairy vetch) to reduce the severity of black root rot in cotton. Dr Ian Rochester (CSIRO,

Narrabri) has shown that vetch also delivers a nitrogen bonus to the soil. Trials are underway to test the effect of hairy vetch against *Fov* and Verticillium.

- *Biocontrol*: Dr Subbu Putcha (NSW Ag Narrabri) is investigating the use of biocontrol (friendly bacteria) and to enhance resistance when using tolerant varieties. A combination of agents

appears to be achieving improved resistance in trials on *Fov* affected farms on the Darling Downs this season.

- *Irrigation*: Several irrigation treatments have recently come to our attention. Future research efforts will investigate the efficacy of these agents against *Fov* spores in irrigation water.

For further information please contact:

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Ph: 07-4688 1245

Fax: 07-4688 1199

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Dr Natalie Moore or Mr Wayne O'Neill, DPI Farming Systems Institute, 80 Meiers Rd, Indooroopilly Q 4068

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Fusarium information on the Cotton CRC website has recently been updated including vehicle cleaning procedures and photographs of symptoms. Website: <http://www.cotton.pi.csiro.au>



COTTON information sheet

Rotations and Cotton Disease

July 2001

David Nehl¹ Stephen Allen²

Rotations are important to plant disease because they affect the survival and reproduction of plant pathogens and the biology and quality of soil. Disease is only one of several factors to consider when choosing a rotation sequence.

SEEDLING DISEASE

(Caused by *Rhizoctonia* and *Pythium*)

Rhizoctonia occurs in all soils and multiplies on crop residues; particularly residues with a low carbon to nitrogen ratio, such as legumes (including woolly pod vetch). However, climatic conditions have the greatest impact on seedling disease.

- Early incorporation of residues from cotton and legumes reduces carryover of *Rhizoctonia*.
- Rotation with cereals is likely to decrease *Rhizoctonia* in cotton. (The strains of *Rhizoctonia* that attack winter cereals are different to those that attack cotton)
- In crusting soils, cereal cover crops and/or standing stubble may improve emergence and establishment of cotton (current research is examining the effect of cover crops on seedling diseases).

BLACK ROOT ROT

(Caused by *Thielaviopsis basicola*)

Black root rot is widespread in NSW and southern QLD. *Thielaviopsis* does not grow on crop residues and survives as long-lived spores in the soil. Each crop of infected cotton deposits more spores in the soil and the severity of black root rot increases according to the number of cotton crops, irrespective of rotations (except for biofumigation crops).

- Woolly pod vetch and Indian mustard have a 'biofumigation' effect on *Thielaviopsis* (i.e. toxic to spores) when grown as 'green manures' (incorporate biofumigation crops at least four weeks before cotton to minimise *Rhizoctonia*)
- Rotation with cereals delays, but does not prevent, the build-up of black root rot (two or more consecutive cereal crops may reduce black root rot and this is the subject of current research)
- Rotation with legume crops may increase black root rot.

ALTERNARIA LEAF SPOT

(caused by *Alternaria macrospora*)

Alternaria leaf spot is ubiquitous in Australian cotton but seldom severe. *Alternaria* survives on cotton residues on the soil surface. *Alternaria* leaf spot at the

pre-square stage is unlikely to cause later problems. *Alternaria* leaf spot affects mature cotton when stressed (e.g. premature senescence).

- Carryover of *Alternaria* is reduced by incorporation of cotton residues between consecutive cotton crops and/or rotation with cereals.

VERTICILLIUM WILT

(caused by *Verticillium dahliae*)

Verticillium is widespread in much of NSW and southern QLD. *Verticillium* survives in infested cotton trash but does not multiply in crop residues. Verticillium wilt increases with the use of susceptible varieties of cotton.

- Rotation with cereals may decrease the severity of Verticillium wilt.

FUSARIUM WILT

(caused by *Fusarium oxysporum* f.sp. *vasinfectum*)

Fusarium wilt is widespread in parts of QLD and is currently spreading in NSW. *Fusarium* survives in infested cotton trash and may also multiply on residues from other crops.

- Rotation with some crops may increase Fusarium wilt ('biofumigation' crops should not be used until their effectiveness is demonstrated by research)
- There is no evidence that any rotation crop will reduce the severity of fusarium wilt
- Retain cotton residues on the soil surface for as long as possible before incorporation
- 'Best bet' option for infested parts of fields: sow cereal in standing stalks, pull and mulch cotton stalks and leave on surface, harvest cereal and burn stubble.

BENEFICIAL ORGANISMS

MYCORRHIZA (a partnership between plants and beneficial fungi)

Mycorrhiza (also known as VAM) occurs when the roots of plants are colonised by 'beneficial' fungi. The plant 'feeds' the fungi with sugars and, in return, the mycorrhizal fungi supply the plant with nutrients from the soil. Cotton is highly dependent on mycorrhizal fungi for uptake of P and Zn. A lack of mycorrhiza development can slow the growth of cotton seedlings. Cropping sequences are important to mycorrhizal fungi because they can only survive and reproduce on living plants.

- Mycorrhizal development in cotton will be adequate after rotation with cereals or legumes in either summer or winter
- After a single season with either bare fallow or rotation with a non-mycorrhizal crop (eg. canola), there will usually be sufficient mycorrhizal fungi in the soil (cotton compensates for a slight lack of mycorrhiza)
- Bare fallow for more than one season or removal of top-soil (especially more than 40 cm) may result in a severe lack of mycorrhiza; a cereal or green-manure crop may restore sufficient mycorrhizal fungi for cotton.

COME CLEAN - GO CLEAN

For further information please contact:

Plant pathologists at the Australian Cotton Research Institute, Wee Waa Rd, Narrabri, 2390.
Ph: (02) 67991500

Plant pathologists at DPI Farming Systems Institute
203 Tor St, Toowoomba 4350 Ph (07) 46881245
or
80 Meiers Rd. Indooroopilly 4068 Ph (07) 38969337

Your local cotton Industry Development Officer or District Agronomist with NSW Agriculture or Queensland DPI

Cotton CRC web site:

[Http://www.cotton.crc.org.au/publicat/disease](http://www.cotton.crc.org.au/publicat/disease)



COTTON information sheet

Black Root Rot Update

March 2001

Compiled by Kirrily Rourke¹ and David Nehl¹ and members of the Australian Cotton CRC Extension Team

Black root rot poses a significant threat to cotton production, particularly in cooler regions. Although this disease does not kill seedlings directly, it stunts cotton growth and, in effect, 'steals time' from the crop. Yield losses of 25 to 50 % have been recorded in severely affected crops.

Distribution

In Australia, the disease black root rot was first detected in cotton in 1989. Black root rot is now widespread in all cotton growing areas of NSW, except Menindee, as well as being present in south west Queensland and the Darling Downs. Disease surveys have shown a steady rise in the number of farms with the disease (Figure 1) and more than 50% of cotton crops on these farms are affected.

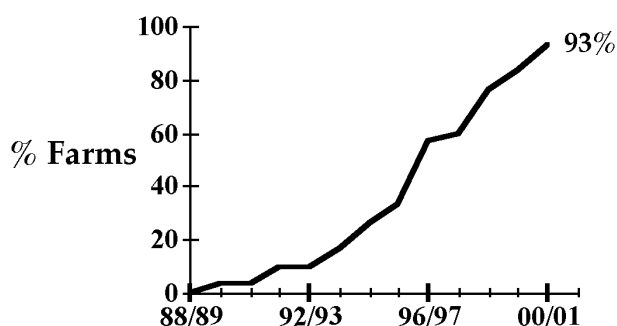


Figure 1. The increase in distribution of black root rot in farms surveyed annually in the Macintyre, Gwydir, Namoi and Macquarie valleys.

Dispersal

The disease is spread by movement of fungal spores in soil attached to vehicles or machinery or suspended in water. Soil in tail-water tends to settle out relatively quickly but soil adhering to floating trash makes a very efficient method of disease spread in irrigation and flood water.

Life cycle

Black root rot is caused by a soil-borne fungus, *Thielaviopsis basicola*. This fungus produces thick walled spores that can survive in the soil for several years. The black root rot fungus can only grow on living host plants, it will not grow on crop residues and it enters a dormant state when no suitable hosts are present. Hence, stubble management is not an issue for control. Farming systems trials are being conducted to study the long-term survival of the fungus in Australian soils. The status of weeds as alternative hosts for the fungus has not been studied in detail. However, to date, the disease has not been observed on commonly occurring weeds.

The fungus can produce a massive quantity of spores in the presence of the right host and soil conditions; as many as 800,000 spores per gram of cotton root in three weeks. Repetitive cropping with cotton deposits an ever-increasing number of spores in the soil (irrespective of rotation with non-host crops) and disease severity increases accordingly.

Optimum conditions for disease

Black root rot is a major problem in cooler regions and less of a problem in warmer regions, unless seasonal conditions are unusually cool.

- The optimum soil temperature for the disease is 16 to 20°C. Infection will continue to progress at soil temperatures up to 25°C.
- Wet conditions favour the build up of the black root rot fungus. In the cooler months of the season wet conditions also increase the chance of soil temperatures falling below 20°C.

In 1999 and 2000, cool conditions during October and November were ideal for the build up of the black root rot fungus in the soil.

Soil type and disease severity

The severity of black root rot varies with soil type. Medium to heavy clay soils appear to be more suited to



survival and proliferation of the black root rot fungus, compared to very heavy clays or lighter soils.

Disease symptoms

Black root rot causes stunted cotton growth early in the season and, in effect, 'steals time' from the crop. The degree of stunting is closely correlated with the severity of the disease and spore levels in the soil. Examination of the roots will reveal a characteristic blackening. This damage to the outer layers of the root reduces the plant's capacity to absorb nutrients. Infection also reduces colonisation of the roots by VAM (beneficial fungi).

Infection with the black root rot fungus will cause the death of some lateral roots but the main vascular tissue of the plant is usually not invaded. The taproot survives so that, as the season progresses and warms up, plant growth continues and the expanding roots slough off the dead tissue. If cool conditions continue, black root rot infections may occur or continue later in the season. Some older plants may develop an internal stem rot in severe cases. Severe black root rot can delay fruit development and maturity by up to four weeks. Yield losses of 25-50% are possible in these cases.

Causes of seedling death

Black root rot generally does not cause seedling death. However, severe black root rot may increase the plant's susceptibility to *Rhizoctonia* and *Pythium*, which can kill the plant and cause plant stand losses.

Management options

- **Planting** Time planting to coincide with soil temperatures of 16°C or more and rising. This is an important way to minimise the risk of seedling diseases, including black root rot. Ideally temperatures above 20°C would be best for sowing but this is generally not practical. Replanting decisions should be based on plant stand loss, not on the degree of stunting.

To help minimise the risk of cool, wet soil conditions during the seedling stage, pre-irrigating would be more favourable than 'watering up'

- **Varieties** At this stage there has been no resistance to black root rot detected in any commercial or trial line varieties. If suitable for your region, choose varieties that have the capacity to 'catch up' later in the season.
- **Rotation** Rotation with cereals does not decrease, or increase, the population of the black root rot fungus in the soil. Many legumes used in rotation with cotton are hosts to the disease and should be avoided.
- **Biofumigation** This method involves sowing a 'green manure' crop that can release substances into the soil that are toxic to the black root rot fungus. Vetch has proved successful against black root rot in the USA. In eight out of eleven

field trials with vetch or mustards in Australia, disease severity in the following cotton crop was decreased significantly (by 24 to 70%). The success of biofumigation depends upon the growth of the biofumigation crop and good incorporation (at least four weeks before cotton). Vetch also provides a nitrogen bonus to the soil (as much as 200 units of N per ha).

A single biofumigation crop will not reverse a severe infestation of black root rot. However, with ongoing research, biofumigation may prove to be a successful tool for integrated management of this disease, with additional benefits to cotton farming systems.

- **Fungicides** There are no fungicides currently available that control black root rot effectively.
- **Summer flooding** Flooding does not eradicate the black root rot fungus but will decrease the population dramatically (down by 96 to 98% in a trial near Wee Waa). Studies in California indicate reductions in black root rot severity for up to four seasons. Flooding is most effective during summer and requires maximum air temperatures of 30°C or more for at least 30 days. Flooding will not be feasible in most situations.
- **Exclusion** Pathogen exclusion is a useful disease management tool. Castrol Farmcleanse (used at 10%) is able to kill the black root rot fungus and, after mud is removed, is a useful aid to decontaminate vehicles. Although black root rot is widespread, many fields and farms, especially in new areas, do not have the disease and are better off without it! Prevention is better than cure and good farm hygiene should be adopted to prevent infection in the first place.

COME CLEAN, GO CLEAN!

The future with black root rot

Moderate infections with subsequent maturity delays may be tolerated in most years, especially in longer season areas. Yield losses associated with severe black root rot can make cotton growing unsustainable. An integrated approach, using a combination of the listed management options, along with good crop agronomy, will be the best way to live with black root rot in the future.

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