Integrated Disease Management

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These pages are a brief version of Integrated Disease Management for Cotton published by the Australian Cotton CRC. For more details on any of the following pages please contact the Technology Resource Centre at the Australian Cotton Research Institute or see the Cotton CRC website.

INTRODUCTION

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. 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. Each of the disease control strategies by itself is not able to provide adequate control. However, when several such strategies are used in combination then acceptable control is achieved.

Effective disease management must be integrated with management of the whole farm. The absence of symptoms does not indicate an absence of disease. Basic strategies should be implemented regardless of whether or not a significant disease problem is evident. These basic strategies should focus on the host, the pathogen and the environment.

THE HOST

A particular plant may be immune, resistant or susceptible. Breeders also use the term 'tolerance' to imply good performance (yield) despite the presence of the disease. Examples of disease control strategies that focus on the host include:

The use of resistant varieties

Australian upland cotton varieties are completely resistant to Bacterial blight. Some have good resistance to Verticilium wilt and some have some resistance to Fusarium wilt. Use varieties with good seedling vigour. When the Black root rot pathogen is present, use the more indeterminate varieties that have the capacity to catch up later in the season. Avoid growing susceptible varieties in fields that contain infected residues.

Balanced crop nutrition

A healthy crop is more able to express its natural resistance to disease. Adopt a balanced approach to crop nutrition, especially with nitrogen and potassium. Both deficiencies and excesses provide better conditions for the development of diseases such as Verticillium and Alternaria. For more information on cotton nutrition see NUTRIpak available from the Cotton CRC.

Replanting

Replanting decisions should be made on the basis of stand losses, not on the size of the seedlings.

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 include:

Monitoring

Be aware of what diseases are present, where they are present and whether or not the incidence is increasing. Do your own disease survey in November and February of each season. Train farm staff to be observant and report back on possible disease occurrences.

Practice good farm hygiene

Minimise the movement of pathogens onto and off your farm, and between fields within your farm. Clean down machinery and vehicles of mud, crop and weed residues between fields and farms. Minimise movement of crop residues in tailwater recirculation systems. Encourage all visitors to 'COME CLEAN' and 'GO CLEAN'. For more information refer to the Farm Hygiene booklet in the BMP Guidelines manual.

Use rotation crops that are not hosts

Develop a sound crop rotation strategy. Successive crops of cotton can contribute to a rapid increase in disease incidence – especially if susceptible varieties are used. Use rotation crops that are not hosts for the pathogens present. The Verticillium wilt pathogen has a large host range and most legume crops are hosts of the Black root rot pathogen.

Control alternative hosts and volunteers

The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, Tabacco Streak Virus and Alternaria leaf spot can also infect common weeds found in cotton growing areas. Control alternative hosts to prevent build up of inoculum and carry over of disease from one season to the next.

Cotton volunteers and cotton ratoons can significantly increase the risk of disease carry over between seasons. Ensure weed management strategies for fallows and rotation crops consider the need for volunteer control, particularly in systems where herbicide tolerant crops are grown. Manage cotton stubble to avoid the occurrence of ratoon cotton as herbicides are rarely cost effective or highly efficacious.

Crop residues

Manage crop residues to minimise carryover of pathogens into subsequent crops. The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, boll rots, seedling disease and Alternaria leaf spot can all survive in association with crop residues. Incorporate cotton crop residues as soon as possible after harvest, except where Fusarium wilt is present. Where Fusarium is present residues should be slashed and retained on the surface for at least one month prior to incorporation.

The Fusarium wilt pathogen can also survive and multiply on the residues of non-host crops such as cereals. Currently recommendations are that residues should be buried or baled as soon as possible after harvest.

Application of fungicides

Examples include seed treatments for seedling disease control and foliar sprays for the control of Alternaria leaf spot on Pima cotton. For more details see Tables 31 and 32 on page 129 and 131.

Biofumigation

In addition to fixing substantial quantities of nitrogen, vetch has a biofumigation effect against Black root rot. As the vetch breaks down in the soil, ammonia is released in sufficient quantities to kill spores of the Black root rot pathogen. In contrast, vetch residues can increase the activity of Fusurium wilt in the following cotton crop.

The success of biofumigation depends on the growth of the biofumigant crop and good incorporation (at least 4 weeks before planting). Biofumigant crops can been grown and incorporated a year before planting the following cotton crop.

Control of insect vectors

Diseases caused by a virus or phytoplasma can often be prevented by controlling the vector that carries the pathogen.

Cotton Bunchy Top (CBT) can be transmitted by aphids feeding on infected plants then migrating to healthy plants. Transmission of Tobacco Streak Virus (TSV) to plants relies on the virus from infected pollen entering plant cells through the feeding injury caused by thrips. Many species of thrips are potentially capable of transmitting TSV. For more information on these diseases, see the following section. Aphid and thrip thresholds can be found on pages 22–23.

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:

Good bed preparation

Plant into well prepared, firm, high beds to optimise stand establishment and seedling vigour. Carefully position fertiliser and herbicides in the bed to prevent damage to the roots. Fields should have good drainage and not allow water to back-up and inundate plants.

Irrigation scheduling

Applying water prior to planting provides better conditions for seedling emergence than watering after planting.

Watch for signs of water stress early in the season if the root system has been weakened by disease (eg. Black root rot) and irrigate accordingly. Avoid waterlogging at all times, but especially late in the season when temperatures have cooled. Irrigations late in the season can result in a higher incidence of Verticillium wilt.

Agronomic management

High planting rates can compensate for seedling mortality however a dense canopy favours development of bacterial blight, Alternaria leaf spot and boll rots. Avoid rank growth and a dense canopy with the use of growth regulators. Manage irrigations, nutrition and insects for early maturity as many pathogens are favoured by cool conditions at the end of the season.

In fields where Fusarium wilt is present avoid inter row cultivations after seedling stage as mechanical damage to the roots provide a site for infection by the pathogen.

Sowing date

Delay sowing as late as possible within the planting window to avoid cool, wet conditions that favour disease. Sowing when the soil temperature is above 20°C would be best for reducing cotton's susceptibility to disease, but generally this is not practical. Time planting to coincide with soil temperatures of at least 16°C and rising.

Soil health

Fields where soil borne pathogens cause chronic disease in cotton are not 'unhealthy' as healthy cereal crops could be grown in the same field. These diseases are not present because the soil has been mistreated, the presence of the pathogen creates a problem with the health of the plants but not a problem with the health of the soil.

Common Diseases of Cotton

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Seedling Diseases

There have been over 30 species of fungi isolated from dying cotton seedlings. Death of seedlings is often referred to as 'damping off' but is mainly caused by

Rhizoctonia solani
***Pythium* spp.**
***Fusarium* spp. (not Fusarium wilt)**

Symptoms

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

Favoured by

Anything that slows down germination and seedling growth favours infection by seedling disease. This includes cool and/or wet weather, poorly formed beds, compaction, waterlogging, incorrect planting depth, fertiliser under the plant line, excessive rates of planting herbicide, movement of herbicide into root zone (ie by rain) and infection by other pathogens.

Host range

These pathogens have wide host ranges and can survive on residues of many crops and weeds.

IDM tactics

- Use a variety with good seedling vigour.
- Use effective seed treatment fungicides.
- Avoid freshly incorporated rotation crop residues.
- Plant into well prepared, high, firm beds.
- Carefully position fertiliser away from the plant line.
- Plant into moisture.
- Delay planting until temperatures are optimum.
- Take care with use of herbicides at planting.

Black Root Rot

Thielaviopsis basicola

Symptoms

Affected crops appear to be slow growing or stunted, especially during the early part of the season. The disease causes destruction of the root cortex (outer layer), seen as blackening of the roots. Some roots may die but *T. basicola* does not kill seedlings by itself. Severe black root rot opens the root up for infection by *Pythium* or *Rhizoctonia*. Plants that are badly affected early in the season may not continue to show symptoms later in the season as the dead cells of the root cortex are sloughed off when growth resumes in warmer weather.

Host range

The host range of *T. basicola* includes all varieties of cotton, most legumes including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. Datura weeds (thornapple, caster oil) are also hosts, but little is known about other weeds.

Non hosts include all the cereal crops, sunflower, canola and vetch.

IDM tactics

- Choose varieties that can 'catch up'.
- Use Bion seed treatment.
- Prepare beds well ('high and firm' not 'low and loose')!
- Pre-irrigate and/or plant into moisture.
- Delay planting if possible.
- Rotate with non-hosts for up to 3 years.
- Avoid legumes and control weeds.
- Effective biofumigation with vetch or mustard,
- Minimize your tailwater.
- Always practice good farm hygiene.
- Summer flooding if possible.

Verticillium Wilt

Verticillium dahliae

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 otherwise healthy, some defoliation may occur if cool.

Internal symptoms can be checked by cutting the stem. The vascular tissue of an infected plant will reveal flecking brown discolouration extending throughout the stem and into the petioles. Under Australian conditions with Australian strains of the pathogen, all plants with vascular symptoms will also display foliar symptoms,

The discolouration is similar to that of Fusarium wilt but usually appears as flecking rather than continuous browning. Severe cases often need to be tested by a pathologist to determine whether the pathogen is *Fusarium* or *Verticillium*.

The root system appears otherwise healthy.

Favoured by

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 during extended wet weather and/or waterlogging and in late maturing crops. The disease is favoured by excessive use of nitrogen which results in late season growth and also by potassium deficiency.

Host range

Verticillium wilt has a large host range which includes sunflower, soybean, noogoora and bathurst burr, saffron thistle, thornapple, caustic weed, bladder ketmia, burr medic, black bindweed, pigweed, devils claw, turnip weed, mintweed, blackberry nightshade and others.

Non host crops include sorghum and cereals.

IDM tactics

- Choose varieties with V.ranks over 100.
- Manage for earliness.
- Avoid late season irrigations.
- Incorporate cotton residues soon after harvest.
- Rotate with non-hosts such as cereals or sorghum.
- Control alternative weed hosts.
- Minimize your tailwater.
- Always practice good farm hygiene.

Fusarium Wilt

Fusarium oxysporum* var. *vasinfectum (FOV)

Symptoms

External symptoms include stunted growth and dull and wilted leaves followed by yellowing or browning of the leaves and eventual death from the top of the plant. Some affected plants may reshoot from the base of the stem. External symptoms can appear in the crop at any stage. Most commonly they become apparent in the seedling phase when plants are beginning to develop true leaves, or after flowering during boll fill. 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 areas of the field.

Internal symptoms can be checked by cutting the stem. An affected plant will reveal continuous brown discolouration of the stem tissues running from the main root up into the stem. The discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecking.

Favoured by

Use of susceptible varieties. Stresses in the crop such as waterlogging, root damage through cultivation and cool, wet growing conditions. Spores surviving in soil and on crop residues can be spread by overland flows, in irrigation water and attached to people and machinery.

Host range

The FOV pathogen is specific to cotton but can live of the residues of most non host crops. Known alternative weed hosts include bladder ketmia, sesbania pea and dwarf amaranth, however there are possibly more.

IDM tactics

- Plant a high F.rank variety with Bion seed treatment.
- Delay planting to the end of October.
- Avoid cultivating with knives.
- Retain cotton residues on the surface for 60 days.
- Bare fallow rotation is best.
- If using a cereal rotation then bury, bale or burn cereal residues ASAP.
- Minimize your tailwater.
- Always practice good farm hygiene.
- Summer flooding if possible.

Alternaria Leaf Spot

Alternaria macrospora
Alternaria alternata

Most commercial varieties of cotton are relatively resistant to *Alternaria* and the impact of the disease on yield is insignificant, unless the crop is severely affected with premature senescence associated with potassium deficiency. Pima cotton is very susceptible.

Symptoms – *A. macrospora*

Brown, grey brown or tan lesions 3–10 mm in diameter on lower leaves, sometimes with dark or purple margins. Circular dry brown lesions on bolls. Pima varieties can defoliate rapidly when the environment favours the disease.

Symptoms – *A. alternata*

Purple specks or small lesions with purple margins on bolls and leaves.

Favoured by

Heavy dews or extended periods of wet weather resulting in long periods of free moisture on the leaf. Suppressed by hot dry weather. Nutritional stress can favour development. Pima varieties are quite susceptible.

Host Range

Cotton, bladder ketmia, sida and anoda weed.

Boll Rots

Phytophthora boll rot is the most common, while Sclerotinia boll rot and Fusarium boll rot (not Fusarium wilt) are usually only seen in very rank crops.

PHYTOPHTHORA BOLL ROT

Phytophthora nicotianae* var. *parasitica

Symptoms

Infected bolls quickly turn brown and become blackened before opening prematurely. Symptoms most prevalent on the lower bolls.

Favoured by

Heavy rainfall on exposed soil that splashes soil up onto low bolls enables infection. Low mature bolls and lodged plants are at highest risk of infection.

Host range

Safflower, some horticultural and many ornamental plants.

Tobacco Streak Virus

Tobacco streak virus (TSV)

Symptoms

Symptoms included dark purple or necrotic, spreading lesions on leaves, sometimes forming numerous diffuse ring spots. On plants with numerous necrotic lesions the upper leaves sometimes also display chlorotic mottle and deformed, down-curled leaves. Symptoms in young cotton crops are generally mild and consist of single, diffuse necrotic lesions on one leaf of infected plants.

Favoured by

TSV disease is favoured by climatic conditions which enable high thrips populations to develop, and large amounts of infective pollen to be produced by host plants such as parthenium. These conditions generally occur during warmer months and is highly dependant on rainfall and weed growth patterns.

Host Range

Cotton, sunflower, mung beans, chickpeas, soybean and peanuts. Weed hosts include parthenium, native jute, native rosella, milk weed, thornapple, ground cherry, rattle pods, crownbeard and Noogoora burr.

Cotton Bunchy Top (CBT)

CBT is viral disease that is relatively new to Australian cotton being first observed in the 1998/99 season. The disease has since been reported from the Macquarie Valley in the south to the Emerald region in the north. CBT is spread by the cotton aphid (*Aphis gossypii*, Glover).

Symptoms

Symptoms include; reduced plant height, leaf size, petiole length, internode length and boll size. Leaf symptoms are usually an angular pattern of pale green margins and darker green centres. These darker leaves have a leathery and sometimes glossy texture when compared to leaves on healthy plants. Typically, the pale angular patches turn red as leaves age. Bolls are often less than half the size of healthy bolls. Symptoms are also evident on roots. These include the formation of small knots on the secondary root branches. The roots also appear hairy and dark brown in comparison to the light yellow-brown colour of healthy roots.

Usually a period of 3–8 weeks lapses between when the infection occurs and when symptoms are first observed. The severity of symptoms expressed by infected plants depends on their age at the time of infection. After the plant is infected, new growth is also characterised by small leaves, short internodes and small bolls. This is usually limited to growth that occurrs after infection; growth before this stage may appear normal. When plants become infected very early, as seedlings, the growth of the whole plant is affected and the crop takes on a compact, stunted, 'climbing ivy' appearance.

Infections early in the season have the greatest potential to reduce yield. However the extent to which yield is affected also depends on the proportion of plants infected. If the proportion is low, then uninfected neighbouring plants will often compensate and make up any yield loss. Often the CBT-infected plants will become obscured by their neighbours. If the proportion infected is high (>50%), yield may be reduced, but this level of infection rarely occurs.

Plants showing symptoms of the disease are often found in circular patches in association with prolonged aphid activity. These are most likely to occur;

- on field margins, where aphids carrying the disease have moved from other hosts into the cotton crop; or
- in portions of the field where there has been survival of CBT-affected cotton ratoons from the previous season.

Favoured by

Fields at highest risk of CBT are those in close proximity to ratoon cotton. When cotton plants are infected with CBT late in the season, there may not be sufficient time for symptoms to be expressed. However when such plants ratoon, the new growth will be strongly affected. Ratoons act as both a preferred host for the aphids and a resevoir for the disease, creating a source of infection in the new season.

Disease spread is favoured by climatic conditions which are suitable for aphid reproduction, feeding and spread. The risk from CBT is probably higher after wetter winters and lower after dry winters. The presence of weed hosts allow larger aphid populations to overwinter, increasing the likelihood of aphids moving into cotton early in the season when there is sufficient time for infection to result in the development of severe symptoms.

Even when there is a source of CBT in close proximity to a cotton field, the spread of the disease is also highly dependent on the size and movement of the aphid population. CBT is more easily trasmitted when plants are colonised by many infected aphids. If just one CBT-infected aphid colonizes a plant, the transmission rate is ~5% (1 in 20 plants become infected). If there are three or more infected aphids the transmission rate increases to ~40%.

There is a 'latent' period that also slows down the rate of transmission through a field. When a CBT-infected aphid feeds on a cotton plant, transmission will happen within half a hour if it is going to occur. A latent period then passes. Over the next 10–14 days young aphids produced by the infected female can feed on the newly infected plant and not pick up the disease. They move on to nearby plants to start new colonies before becoming carriers of the disease. When the young aphids do pick up CBT from the original plant before moving to the next plant there will again be a latent period in that plant. This is compounded by the low transmission rate when a single aphid colonizes a plant. Many colonization events do not result in successful transmission. This scenario is often seen in commercial fields where at the centre of an aphid hotspot a single CBT infected plant will be found, while the nearby plants are disease free.

Host Range

The most critical alternative host plant is ratoon cotton. Ratoon plants are often large, with a deep tap root. They are able to survive through periods of low rainfall and often retain leaves and active growth through winter, supporting infected aphid populations from one season to the next.

Pima cotton (*Gossypium barbedense*) is a symptomless host. Even if plants become infected when they are very young disease symptoms will not be expressed. Aphids that feed on infected plants can become infected and transfer CBT to upland cotton (*G. hirsutum*) which will then express disease symptoms.

The cotton aphid has a broad host range, including many weeds common in cotton growing areas. At this stage only marshmallow has been confirmed to be an alternative host for CBT. However it is possible that other weeds are also hosts. Weed hosts may not express disease symptoms, similarly to pima cotton. For a comprehensive list of the cotton aphid's alternative hosts, refer to the Cotton CRC Information Sheet 'Managing Aphids in Cotton', available from the Cotton CRC website.

IDM tactics

- Manage cotton stubble to prevent ratoons.
- Control farm weeds that are aphid hosts, particularly marshmallow.
- Consider cotton volunteer management when making weed control decisions for fallows and rotation crops.
- Monitor cotton fields regularly from crop emergence for the presence of aphids.
- Check aphid hot spots for sypmtoms of CBT.
- If CBT symptoms are present early season, consider rouging infected plants or selectively controlling aphids in compliance with the IRMS.

Cotton Pathology Survey 2008/09

SJ Allen[1], CMT Anderson[2], PA Lonergan[2], LJ Scheikowski[3] and LJ Smith[4], Cotton Catchment Communities CRC

Commercial cotton crops across NSW and Queensland were inspected in November–December 2008 and March–April 2009. The incidence and severity of those diseases present were assessed and field history, ground preparation, cotton variety, planting date and seed rate were recorded for each of the 73 and 55 fields that were surveyed in NSW and Queensland respectively. This represents the 26th consecutive season of quantitative disease surveys of cotton in NSW and the 7th consecutive season of cotton disease surveys in Queensland.

Most cotton production areas experienced near average seasonal conditions with the following notable exceptions. Cotton crops in the Burdekin received over 1.5 metres of rainfall during the season. The Emerald area experienced only 49% of the average number of days with temperatures >35°C and rainfall 25% higher than the seasonal average. In contrast Mungindi (+78%), Gunnedah (+44%), Hillston (+39%) and Griffith (+30%) received an above average number of days with temperatures >35°C. Rainfall recorded at Walgett, Bourke and Moree was 64%, 50% and 33% higher than the seasonal average. The number of day-degrees accumulated during the season at Hillston and Griffith was 13% and 14% above average.

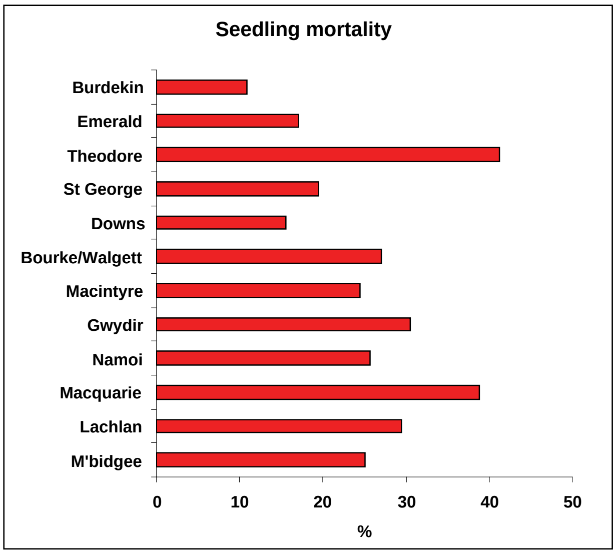
Cotton Industry Biosecurity Plan – Crop Surveillance for Priority Pests

During these surveys particular attention was given to the detection of Cotton Leaf Curl Virus, Blue disease, Phymatotrichopsis root rot, the hypervirulent strains of the bacterial blight pathogen, the defoliating strains of the Verticillium wilt pathogen and exotic strains of the Fusarium wilt pathogen. None of these pathogens were observed.

SEEDLING MORTALITY

As part of the disease survey an estimate of the number of seeds planted per metre is compared to the number of plants established per metre. This comparison produces an estimate of seedling mortality which includes the impact of seedling disease (Rhizoctonia and Pythium etc.) as well as seed viability, the activity of soil insects such as wireworms, physical problems such as fertiliser or herbicide burn and the effects of adverse environmental conditions.

Figure 10. Seedling mortality of cotton in the 2008/09 season was relatively low in the Burdekin, Emerald, St George and Darling Downs areas and particularly high in the Macquarie Valley and Theodore area.



Mean seedling mortality (Figure 10) for the crops inspected in Queensland and NSW was 24.9% and 28.8%, respectively, (19.5% and 31% in 2007–08; 22.5% and 28.9% in 2006–07). The highest seedling mortality was observed in the Theodore area (41.2%) and in the Macquarie valley (38.8%) The low incidence of seedling mortality in crops on the Darling Downs (15.6%) reflects the warmer conditions for establishment that resulted from the later planting window. The very low incidence of seedling mortality in crops in the Burdekin (10.9%) results from planting dates in December. The warmer than normal seasonal conditions in the Lachlan and Murrumbidgee valleys plus the inclusion of several fields relatively new to cotton production, resulted in lower than normal seedling mortality in this area.

FUSARIUM WILT

There were no new reports of Fusarium wilt from either NSW or Queensland this season. A fresh sample of affected plants was collected from a property near Mungindi. The results of tests on the original sample had indicated a possible new strain of the Fusarium wilt pathogen. The QPI&F diagnostic service at Indooroopilly are completing the tests.

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[4] Queensland Primary Industries and Fisheries, 80 Meiers Road, Indooroopilly, Qld.

Figure 11. The average incidence and distribution of Fusarium wilt of cotton in the 2008/09 season. The average incidence declined in crops in the St George and Darling Downs areas but increased in crops in the Gwydir and Macintyre valleys.

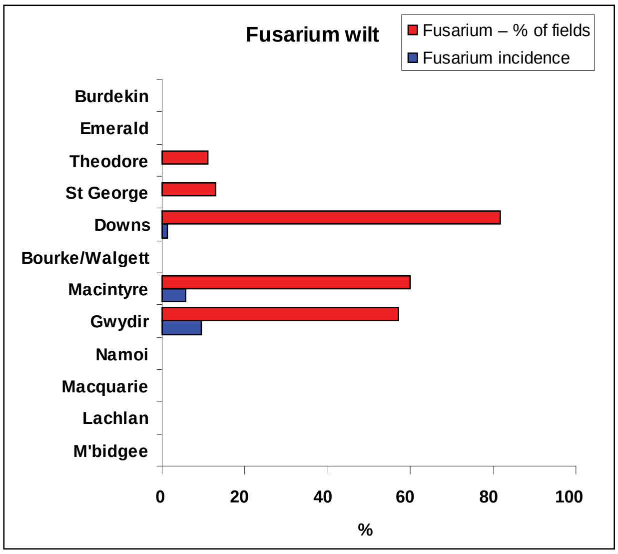
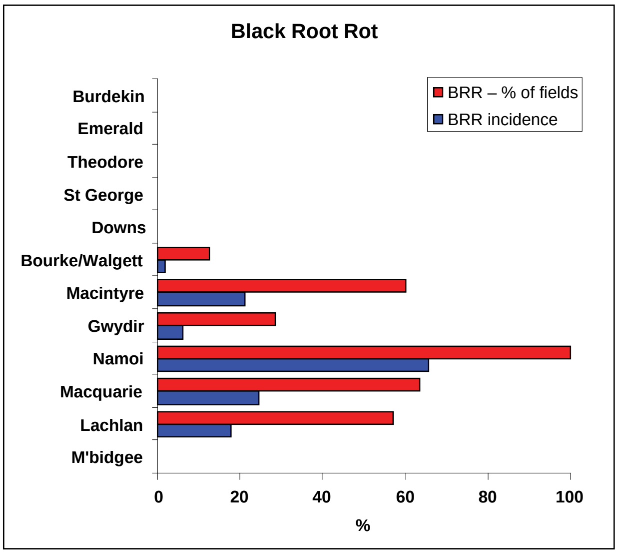


Figure 12. The incidence of black root rot of cotton in the 2008/09 season was highest in the Namoi Valley in NSW. Black root rot was not observed in cotton production areas of Queensland.



Fusarium wilt was most common in crops on the Darling Downs of Queensland where the disease was found in 9 of the 11 crops inspected. However, the average incidence of fusarium wilt was reduced to only 1.4% of plants affected compared to 11.4%, 3.1% and 7.4% for the previous three seasons. Similarly, at St George, the average incidence of fusarium wilt was reduced to only 0.01% of plants affected compared to 1.9% and 3.2% in the last two seasons. In contrast, the average incidence of Fusarium wilt in the Gwydir and Macintyre valleys increased to 9.4% and 5.7% respectively.

Several factors could be responsible for contributing to these observed trends. Previous research has shown that delaying the sowing of the crop by just a couple of weeks can reduce disease incidence by up to 24% by avoiding the cooler spring conditions. More than half of the fields surveyed on the Darling Downs were planted in late October and early November. whereas, all of the surveyed fields in the Gwydir valley were planted in September and early October. Other factors could include the more widespread use of the new more resistant varieties and the more widespread use of the BION seed treatment in Queensland cotton production.

The BION seed treatment, which provides some control of black root rot and Fusarium wilt, was applied to 42% of cotton seed planted in Queensland and 23% of cotton seed planted in NSW. Use of the product in NSW would have been mainly directed at black root rot while use in Queensland would have been almost all directed at Fusarium wilt.

Though Fusarium wilt is known to be present and widespread in the Macquarie valley, upper Namoi valley and Bourke areas it was not detected in the 2008/09 disease survey.

It is important that growers and consultants confirm and declare if the disease is present in an area. The Fusarium wilt diagnostic service provided by the QPI&F is funded by the cotton industry and is free to growers. The majority of samples submitted return a negative result and some growers who are withholding samples could be worried unnecessarily. Early detection of the disease and establishment of a control program has proven to be the best approach.

BLACK ROOT ROT

Black root rot (Figure 12) has been recorded in all production areas of Queensland and NSW. The disease was observed in 65% of fields and 32% of plants surveyed in the major valleys in NSW (Macintyre, Gwydir, Namoi and Macquarie); compared to 58% and 14% respectively in the previous year. The Namoi valley was again the worst affected with black root rot present in all fields inspected and the mean incidence estimated to be 66% of plants affected.

The average incidence of black root rot continued to increase in most areas. The disease incidence exceeded 90% of plants affected in the worst affected fields growing in the Namoi, Macquarie and Lachlan valleys!

Figure 13. The incidence of Verticillium wilt in March 2008/09 was greatest in the Namoi Valley where it was found in 93% of the fields inspected.

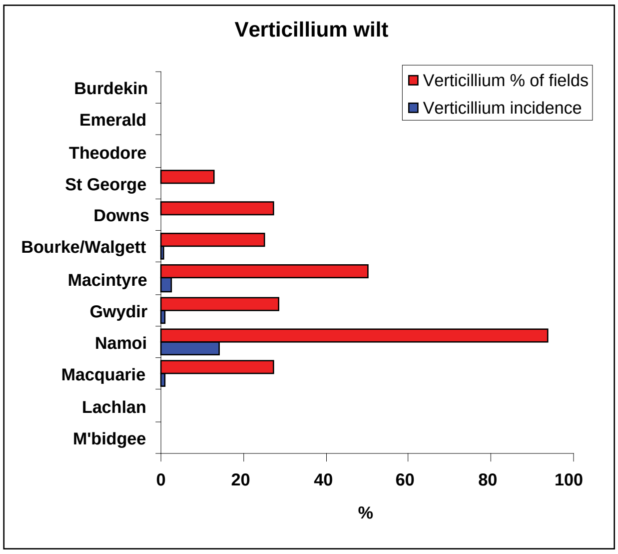
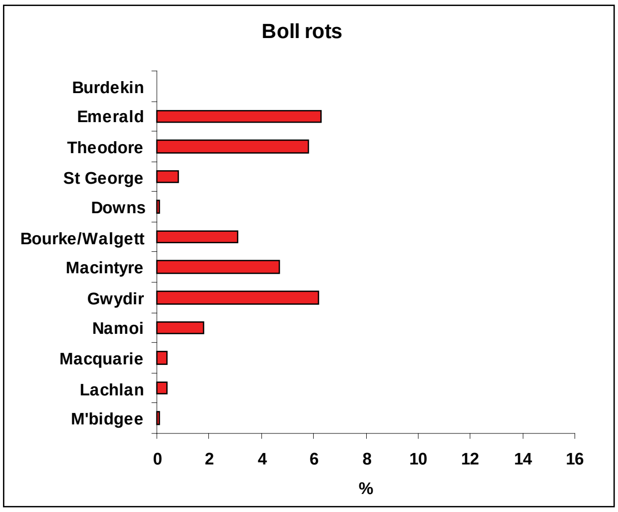


Figure 14. The incidence of boll rots, including those caused by Phytophthora and other fungi, in 2008/09 as assessed at time of survey. The incidence of boll rots is influenced by the timing of boll opening and periods of wet weather.



Black root rot was not observed during surveys in Queensland production areas in the 2008/09 season. The disease has only been rarely observed in the Emerald and Theodore areas over the last six seasons. The late planting window was probably a significant factor for crops in the St. George and Darling Downs areas where many fields were planted in late October and early November.

VERTICILLIUM WILT

In March–April 2009, the average incidence of Verticillium wilt across NSW (Figure 13) was found to be 3.8% (11.2%, 4.9% and 3.4% in the previous three seasons). Verticillium wilt was present in 94% of fields inspected in the Namoi valley where the average incidence of the disease was 14% of plants affected (28.9%, 10.4% and 10.1% in the previous three seasons). Symptoms were present in 31% and 50% of plants in the worst affected fields.

Verticillium wilt was present in 50% of fields inspected in the Macintyre valley where the average incidence of the disease was 2.6% of plants affected. Although present in several other areas the incidence was < 1% of plants affected.

BOLL ROTS AND TIGHT LOCK

Boll rots involve the complete collapse of the boll –'boll wall and all' – and result from fungal infection that is sometimes assisted by insect damage. Tight lock describes the failure of locks to 'fluff out' when bolls open and is also caused by microbial infection that is sometimes assisted by insect damage. These microbes include both bacteria and fungi and can be introduced to the lock by rain splash from the soil, airborne spores from other plants or by insects feeding through the boll wall before the boll opens. Severe boll rot and tight lock occur when there is a coincidence of wet weather, maturing bolls and the appropriate fungi that can thrive on pure cellulose.

The average incidence of boll rots in NSW and Queensland cotton crops was estimated to be 2.7% and 1.9% respectively. Wet weather prior to harvest in the Emerald and Theodore areas of Queensland and in the Gwydir and Macintyre valleys contributed to mean incidences of 6.3%, 5.8%, 6.2% and 4.7% respectively with up to 25% of bolls affected in individual crops. (Figure 14)

Phytophthora boll rot develops when low bolls are inundated with flood or irrigation water or when soil is splashed up onto low bolls as they approach maturity. Boll rots caused by other pathogens tend to be more frequent in crops with tall dense canopies. Phytophthora boll rot was the most common boll rot observed in NSW production areas (2.6%).

ALTERNARIA LEAF SPOT

The pathogen that causes Alternaria leaf spot survives on crop residues from the previous season. Its survival is favoured by dry winter conditions and the retention of cotton crop residues on the soil surface. Alternaria leaf spot was observed in trace amounts in many, but not all, crops surveyed throughout NSW and Queensland in February–March 2009, with the mean severity (percentage of leaf area infected) estimated to be 0.8% in both the

Macintyre valley and the Emerald area. One crop in the Emerald area had 2% of the leaf area affected with some defoliation.

COTTON BUNCHY TOP

Symptoms of cotton bunchy top include small bolls, small leaves and short internodes, usually accompanied by a distinctive light-green angular mottle occurring around the margins of the leaves (the leaf mottle may be masked if infestation by aphids or mites is severe), and usually confined to a few plants or a distinct patch. Bunchy top was observed in crops near Theodore and on the Darling Downs. Symptoms were observed in 7% of crops inspected in Queensland and the average incidence of bunchy top in these crops was <0.1%. Bunchy top was observed in 11% of fields inspected during the NSW surveys where the average incidence was 0.2% of plants with symptoms. The incidence of bunchy top in three crops in the Lachlan Valley was found to be 5%, 4% and 1%.

OTHER DISEASES AND DISORDERS

Tobacco Streak Virus (TSV)

TSV was observed in 7 of 14 crops inspected in November and in 6 of 9 crops inspected in February in the Emerald area. It was not observed on cotton in any other area. However, it was detected in the weed, 'crown beard' (*Verbesina encelioides*) that was collected along the roadside just west of Theodore. The incidence of TSV varied from 0 to 50% in the November survey and from 0 to 2% in the February survey. In all affected crops the symptoms were limited to just one or two lesions per plant.

Seed Rot

In recent years there has been an increasing awareness of a seed rot caused by pathogens transmitted by sucking insect pests, feeding on developing seed, within young developing bolls. These bolls either drop off the plant or open prematurely with affected locks failing to fluff out properly and lint surrounding the affected seed discoloured. Overseas research has suggested that a Pantoea sp. could be one of the pathogens involved. Seed rot was observed in 11.7% of crops inspected in NSW and Queensland. It was particularly noticeable in crops in the Burdekin valley, the Darling Downs and the Lachlan/Murrumbidgee area.

The Burdekin Valley

The Burdekin valley is unique because of its tropical environment with high rainfall and the common rotation with sugar cane. A leaf spot with symptoms similar to 'wet weather blight' caused by *Ascochyta* sp. was observed on the cotyledons of seedlings and on the lower leaves of adult plants. Premature senescence was pronounced in some fields and accompanied by Alternaria leaf spot. The survey was too early to get an assessment of boll rots.

ACKNOWLEDGMENTS

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Cotton Disease Control Guide – Registered chemicals as at 15 October 2009

Tracey Farrell, formelry Industry & Investment NSW.

Registration of a pesticide is not a recommendation from I&I NSW for the use of a specific pesticide in a particular situation. Growers must satisfy themselves that the pesticide they choose is the best one for the crop and disease. Growers and users must also carefully study the container label before using any pesticide, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their pesticide programs.

If there is any omission from the list of chemicals, please notify the authors.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Carefully following all label directions.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions

SPRAY LOG BOOKS

To assist in record keeping for pesticide applications, Spray Log Books can be purchased from:

DEEDI, cost $6.60 each plus postage and handling. Contact DEEDI inToowoomba – Natalie Fletcher 07 4688 1460 or Rebecca Simmons 07 4688 1360 or in Dalby – 07 4669 0800 to place an order.

I&I NSW, cost $12.00 each plus postage and handling. Contact I&I NSW, Yanco – 1800 138 351.

ABBREVIATIONS USED IN THE TABLES 31–32

EC = Emulsifiable concentrate
FC = Flowable concentrate
SC = Suspension concentrate
WDG = Water dispersible granule
WP = Wettable powder

Table 31. Control of Cotton Diseases

Active ingredient	Fungicide chemical group	Concentration and formulation	Application rate of product	Comments
Alternaria leaf spot				
mancozeb	Y	750 g/kg WG	2.5 kg/ha	Pima varieties only. Do not apply before flowering. Begin applications as soon as disease symptoms appear and before each infection period. DO NOT apply more than 4 sprays per season.
***Rhizoctonia solani* (Damping off)**				
quintozene	Y	750 g/kg WP	5.0 kg/ha	Apply over seed and surrounding soil at planting.
tolclofos-methyl	X	500 g/L SC	0.12 L/ha or 0.12 L/10km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
		500 g/kg WP	0.12 kg/ha or 0.12 kg/10 km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
***Pythium* spp. and *Phytofthora* spp. (Damping off)**				
metalaxyl-m	D	350 g/L EC	0.1 L/100 kg seed	Commercial application recommended.
		350 g/kg WP	0.085 g/100 kg seed	Apply as a dust or slurry before sowing.
***Rhizoctonia solani* and *Pythium* spp.**				
azoxystrobin + metalaxyl-m + fludioxonil	K D L	75 g/L SC 37.5 g/L SC 12.5 g/L SC	0.2 L/100 kg seed	Commercial application recommended. This seed treatment should be used as part of an integrated strategy to control seedling disease.
Fusarium Wilt				
acibenzolar-s-methyl		500 g/L FC	1.2 mL/100 kg seed	Seed treatment for suppression of Fusarium wilt and Black root rot.
metalaxyl-m	D	350 g/L	0.043 L/100 kg seed	For Fusarium wilt disinfection. Commercial application recommended.

Sending a Sample for Diagnosis by a Pathologist – Attach a completed form to each sample

Collected/Submitted by: (e.g. Cotton Extension Officer)	Address/Email/Fax/Telephone:
Property name and field number:	Date collected:
Grower/Agronomist	Grower's address or area/locality:

Mark (X) as appropriate

SYMPTOMS	DISTRIBUTION	INCIDENCE/SEVERITY	CROP GROWTH STAGE
❑ Poor emergence or seedling depth	❑ One field only	❑ All plants	❑ Irrigated
❑ Leaves: spots or dead areas	❑ In several fields	❑ Scattered single plants	❑ Dryland/rain-grown
❑ Leaves: discoloured	❑ In all fields	❑ Scattered patches of plants	❑ Seedling stage
❑ Leaves: mottled	❑ One variety only	❑ In a large patch (>5 m)	❑ Setting squares
❑ Leaves or shoots: distorted or curled	❑ Several varieties affected	❑ In a small patch (1–5 m)	❑ Early flowering
❑ Plants stunted	❑ Some rows more affected	❑ In a small patch (<1 m)	❑ Peak flowering
❑ Plants wilting	❑ On lighter soil types	❑ Plants dead	❑ First bolls open
❑ Premature plant death	❑ On heavier soil types	❑ Plants defoliating	❑ Defoliated
❑ Bolls: spots or dead areas	❑ In poorly drained area(s)	❑ One to a few plants only	❑ Ready to pick
❑ Roots: discoloured, bent, pruned, etc.	❑ Other: (please specify)		

OTHER INFORMATION

- Cultivar..
- Paddock History..
- Nearby crops..
- Rainfall in last 10 days..
- Average temperature range over the last 10 years..
- Date of last irrigation..
- Date of last cultivation..

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

ALL SAMPLES WHERE FUSARIUM WILT IS SUSPECTED MUST BE SENT TO INDOOROOPILLY

When sending samples:

- Send multiple samples (e.g. more than 1 leaf, stem or plant).
- If possible include a healthy plant as well as the diseased plant material.
- 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.
- Several sections of stem (10–15 cm long) are usually adequate for wilt diseases.
- Keep the sample cool and send as soon as possible.

Table 32. Fungicide trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
acibenzolar-s-methyl	500 g/L FC	Bion Plant Activator	Syngenta
azoxystrobin +	75 g/L SC	Dynasty	Syngenta
metalaxyl-m +	37.5 g/L SC		
fludioxonil	12.5 g/L SC		
mancozeb	750 g/kg WDG	Dithane Rainshield Neo Tec	Dow AgroSciences
	750 g/kg WDG	Mancozeb 750 WG	Ospray
	750 g/kg WDG	Manfil	Runge Agrichems
	750 g/kg DF	Innova Mancozeb 750	Syngenta
	750 g/kg DF	Mancozeb 750 DF	Sabero
	750 g/kg DF	Mancozeb 750 DF	Titan Ag
	750 g/kg DF	Manzate DF	Dupont
	750 g/kg DF	Penncozeb 750 DF	Arkema
	750 g/kg DF	Unizeb	United Phosphorus Limited
metalaxyl-m	350 g/L ES	ApronXL 350	Syngenta
quintozene	750 g/kg WP	Quintozene 750	Barmac
	750 g/kg WP	Terraclor Soil	Chemtura
	750 g/kg WDG	Chloroturf	Barmac
tolclofos-methyl	500 g/kg WP	Rizolex	Sumitomo Chemicals
	500 g/L SC	Rizolex liquid	Sumitomo Chemicals
	500 g/L SC	Tolex	Genfarm

Tracey Farrell, formerly Industry & Investment NSW.

Growth regulators

Excessive vegetative growth is a problem because it reduces the retention of fruit and delays maturity and results in reduced efficacy of insecticides due to poor penetration of the canopy. To determine if growth regulators are required see Cotton Seed Distributors' website (www.csd.net.au) to calculate vegetative growth rates.

Defoliation

The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65% of bolls are open. The other method of assessing physiological maturity is when there are 3–4 nodes of first position bolls above the highest cracked first position boll (last harvestable boll), known as nodes above cracked boll (NACB).

Registration of a chemical is not a recommendation from I&I NSW for the use of a specific chemical in a particular situation. Growers must satisfy themselves that the chemical they choose is the best one for the crop and situation. Growers and users must also carefully study the container label before using any chemical, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their agronomy programs.

If there is any omission from the list of chemicals, please notify the authors.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions near property boundaries. Make it clear that you expect the same courtesy from them.
- Carefully following all label directions.
- Paying particular attention to wind speed and direction, air temperature and time of day before applying pesticides using buffer zones as a mechanism to reduce the impact of spray drift or overspray.
- Keeping records of chemical use and weather conditions at the time of spraying.

ABBREVIATIONS USED IN THE TABLES 33–36

AC = Aqueous concentrate
L = Liquid
LC = Liquid concentrate
SC = Suspension concentrate
WDG = Water dispersible granule

Table 33. Plant growth regulators

Active ingredient	Concentration and formulation	Application rate of product	Comments
Mepiquat	38 g/L AC	0.25–0.6 L/ha 0.25–1.0 L/ha	Pre flowering rate. Post flowering rate. Apply no more than 1.5 L/ha in total. See label for application times.
		0.75–2.0 L/ha	Single application rate. Use high rate where crop growth is excessive, between 1st flower and cut out. Check label.

Table 34. Plant growth regulators trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
Mepiquat	38 g/L AC	Adjust 38	Rotam
	38 g/L AC	Chemquat 38	ChemAg
	38 g/L AC	Mepiquat	Ospray
	38 g/L AC	Mepiquat 38	Accensi
	38 g/L AC	Mepiquat 38	eChem
	38 g/L AC	Mepiquat 38	Conquest
	38 g/L AC	Mepiquat 38	Genfarm
	38 g/L AC	Mepiquat 38	Kenso Agcare
	38 g/L AC	Mepiquat Chloride 38	Generex
	38 g/L AC	PiQme 38	United Phosphorus
	38 g/L AC	Pix	Nufarm
	38 g/L AC	Reign	Bayer CropScience
	38 g/L AC	Reward	Farmoz
	38 g/L AC	Roquat 38	Rotam

Table 35. Cotton defoliation products

Active ingredient	Concentration and formulation	Application rate of product	Comments
Cotton seed oil	860 g/L L	2 L/ha	Apply in combination with thidiazuron as specified on the label.
Diquat	200 g/ L AC	2.0–3.0 L/ha	See critical comments on label. May damage green bolls.
Ethephon	720 g/L AC	1.3 L/ha 2.0–3.0 L/ha	Pre-conditioning. Defoliation.
Ethephon + AMADS	275 g/L + 873 g/L AC	0.5–1.0 L/ha 1.3–2.6 L/ha 4 L/ha	Defoliation and accelerated boll opening. Defoliation. Boll opening.
Ethephon + cyclanilide	720 g/L + 90 g/L SC	0.33–0.67 L./ha 1.3–2.5 L/ha	Enhancement of defoliation. Must have minimum 30 L water/ha. Acceleration of boll opening and enhancement of defoliation.
Flumiclorac–pentyl	100 g/L	0.6–0.9 L/ha + 360 gai/ha ethephon 0.45 L/ha + 1440 gai/ ha ethephon	Defoliation, first application once natural senecence has commenced and 60% open bolls. Apply with 2.0 L/ha DC Tron Cotton Spray Oil. Apply 4–10 days later. Apply when canopy is suitably open to allow good penetration of ethephon.
Paraffinic oil	582 g/L L 598 g/L EC 792 g/L EC 815 g/L EC 830 g/L EC	0.5 L/100 L water 0.5 L/ha 0.5 L/ha 2 L/100 L 2 L/100 L	Compatible with thidiazuron and ethephon. Apply in combination with defoliants such as Dropp and Prep. Apply with Dropp Ultra® or Dropp® WP in accordance with their labels. Apply in combination with thidiazuron defoliant. Apply in combination with thidiazuron defoliant.
Paraquat + diquat	135 g/L + 115 g/L AC	1.2–1.6 L/ha	Apply to cotton in dryland situation only. OPM 0005 (NRA) Can damage immature green bolls.
Petroleum oil	839 g/L L 844 g/L 846 g/L EC 859 g/L L 861 g/L	2 L/ha 2 L/ha 2 L/ha 2 L/100 L water 2 L/ha	Apply in combination with thidiazuron as specified on the label. Apply with Dropp defoliant Apply with Dropp Ultra. Apply in combination with Dropp defoliant as apecified on the label. Apply with Dropp Ultra in accordance with the Drop Ultra label.
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	0.08 L/ha	Always apply as a tank mixture with ethephon (1–2 L/ha) and D-C-Tron (2 L/ha). Apply when the last harvestable boll is physiologically mature.
Sodium chlorate	300 g/L AC	11.0–22.0 L/ha	Apply when 60–65% bolls are open. Apply 2–3 weeks before anticipated picking dates. Apply when temperatures are high and soil moisture moderate.
Thidiazuron	490 g/kg WDG or 500 g/L SC	0.05–0.1 kg/ha 0.1–0.15 L/ha 0.15–0.2 L/ha	Ideal conditions. Good conditions. Average conditions. Do not apply under cold conditions. } plus 2.0 L/ha cotton spray oil
Thidiazuron + Diuron	120 g/L + 60 g/L SC	0.15–0.2 L/ha 0.2–0.25 L/ha 0.25–0.3 L/ha 0.3–0.4 L/ha	Ideal conditions. Good conditions. Average conditions. Cold conditions. } plus 2.0 L/ha cotton spray oil

Table 36. Defoliation products trade names and marketers

Defoliant	Concentration and formulation	Trade name	Marketed by
Cotton seed oil	860 g/L L	Intac Cotton Spray Oil	Nipro
Diquat	200 g/ L AC	Reglone	Syngenta
	200 g/L AC	Diquat 200	Chem Ag
	200 g/L AC	Sanction 200	Conquest
	200 g/L SC	Diquat 200	Kenso
Ethephon	720 g/L AC	Ethephon	eChem
	720 g/L AC	Ethephon 720	ChemAg
	720 g/L AC	Ethephon 720	Conquest
	720 g/L AC	Ethephon 720	Genfarm
	720 g/L AC	Ethephon 720	Ospray
	720 g/L AC	Ethephon 720	Runge
	720 g/L AC	Ethephon 720 SL	Tradelands
	720 g/L AC	Galleon	Nufarm
	720 g/L AC	Prep 720	Bayer CropScience
	720 g/L AC	Promote 720	Farmoz
Ethephon + AMADS	275 g/L + 873 g/L AC	CottonQuik	Dupont
Ethephon + cyclanilide	720 g/L + 90 g/L SC	Finish 720	Bayer CropScience
Flumiclorac–pentyl	100 g/L	Resource	Sumitomo
Paraffinic oil	582 g/L L	Uptake Spraying Oil	Dow AgroSciences
	598 g/L EC	Enhance Spray Adjuvant	Sacoa
	792 g/L SL	Canopy Insecticide	Caltex Australia
	815 g/L EC	Biopest Paraffin Oil	Sacoa
	815 g/L EC	Bioclear	Caltex
	830 g/L EC	Trump	Victorian Chemicals
Paraquat + diquat	135 g/L + 115 g/L AC	Revolver	Nufarm
	135 g/L + 115 g/L AC	Spray.Seed 250	Syngenta
	135 g/L + 115 g/L AC	Spraykill 250	Chem Ag
	135 g/L + 115 g/L AC	Sprayout 250	Ospray
	135 g/L + 115 g/L AC	Di–Par 250	Genfarm
	135 g/L + 115 g/L SC	Combik 250	Sinon Australia
	135 g/L + 115 g/L SC	Brown Out 250	4Farmers

Table 36. Defoliant trade names and marketers (continued)

Defoliant	Concentration and formulation	Trade name	Marketed by
Paraquat + diquat (continued)	135 g/L + 115 g/L SC	Di–Par 250	Genfarm
	135 g/L + 115 g/L SC	Alarm	Sipcam Pacific
	135 g/L + 115 g/L SC	EOS	Titan Ag
	135 g/L + 115 g/L SC	Paradym 250	Ronic Internationsl
	135 g/L + 115 g/L SC	Premier 250	Halley
	135 g/L + 115 g/L SC	Rygel Pre-Seed	Rygel
	135 g/L + 115 g/L SC	Scorcher 250	Conquest
	135 g/L + 115 g/L SC	Speedy 250	Kenso
	135 g/L + 115 g/L SC	Spray & Sow	Farmoz
	135 g/L + 115 g/L SC	Uni-Spray	United Phosphorus Limited
	135 g/L + 115 g/L SC	Wildfire	United Farmers
Petroleum oil	839 g/L L	D-C-Tron	Caltex
	844 g/L	Sacoa Summer	Sacoa
	846 g/L EC	Broadcoat	Caltex
	859 g/L L	Cottoil	Sacoa
	861 g/L	Empower	Innovative Chemical Services
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	ETee	Sipcam Pacific
Sodium chlorate	300 g/L AC	Total Ag Leafex	Total Ag
Thidiazuron	500 g/L SC	Dropp Liquid	Bayer CropScience
	500 g/L SC	Escalate 500	Farmoz
	500 g/L SC	Mace	Conquest
	500 g/L SC	Reveal Liquid	Nufarm
	500 g/L SC	Thidiazuron 500	Genfarm
	500 g/L SC	Thidiazuron 500 SC	eChem
	500 g/L SC	Thidiazuron 500 SC	Kenso Agcare
	500 g/L SC	Tradewyns Thidiazuron 500	Ospray
Thidiazuron + Diuron	120 g/L + 60 g/L SC	Do-away	Ospray
	120 g/L + 60 g/L SC	Dropp Ultra	Bayer CropScience
	120 g/L + 60 g/L SC	Escalate Ultra	Farmoz
	120 g/L + 60 g/L SC	Thi-Ultra	eChem
	240 g/L + 120 g/L SC	Dropp UltraMAX	Bayer CropScience

Best Practices for Aerial and Ground Spray Applications to Cotton

By Andrew Hewitt, Centre for Pesticide Application and Safety, University of Queensland; James Hill, NSW Industry and Investment; Tracey Farrell, CRDC; and Bill Gordon, Bill Gordon Consulting Pty ltd.

Acheiving maximum efficacy from dollars invested in products to control weeds and insects in cotton requires the careful consideration of many factors. The aim of spray application is to transfer the active ingredient of the product through the atmosphere to the target in an effective manner with minimal off-target losses. To do this the application process needs to be matched to the local target and weather conditions. Movement of spray beyond the target area is undesirable. It represents wastage of product and exposure of non-target sensitive areas to potentially damaging materials.

This chapter provides guidance on factors to be considered in optimizing the spray application process. It should be noted that new technologies and information are continually becoming available, so this is meant as a summary guide only. Readers should consult additional information where available.

Plan ahead

The development of a comprehensive pesticide application management plan (PAMP) is an important part of the Best Management Practice (BMP) program in cotton. The PAMP for farming enterprises should be completed prior to the season and should cover;

- Farm layout
- Identification of sensitive areas, potential hazards and awareness zones
- Communications procedures
- Pesticide Management Guidelines
- Accident and emergency procedures.

Having a PAMP in place helps to ensure that everyone involved in pesticide application has a clear understanding of their responsibilities.

MEET LEGAL OBLIGATIONS

Always read and follow the label when handling and applying chemicals and be aware of federal and state regulations pertaining chemical application. Staff responsible for handling and applying pesticides must be qualified according to state and federal requirements for the handling and application of chemicals. Keep records of chemical storage and applications including conditions during and following the application. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

> **New approaches to chemical labels**
>
> The APVMA is applying a spray drift risk assessment to all new registered products, and progressively to those existing products that have been subject to review. To access or download the APVMA document that explains this approach, check the APVMA website; apvma.gov.au

NOTIFY NEIGHBOURS OF SENSITIVE AREAS AND SPRAY INTENSIONS

Prior to spray application and product selection, check the proximity of susceptible crops and sensitive areas such as houses, schools, waterways and riverbanks. It is good practice to notify neighbours of your spray intentions, regardless of label requirements. By doing this, sensitive crops or areas that you may be aware of can be accounted for.

To assist in communicating with neighbours the location of cotton fields, a mapping tool is now available for all cotton growing districts. Maps can be found at www.cottonmap.com.au

Add your own cotton fields to your district map as soon as planting decisions are made. This gives others in your region the best chance of identifying the surrounding sensitive crops to be considered when planning spray applications. Share the maps with your neighbours.

Open communications with neighbours is critical due to herbicide tolerant cottons. Herbicide drift onto fields of non-tolerant cotton can result in serious yield losses.

No spray zones

Some pesticide product labels may refer to a mandatory no spray zone. This is the downwind distance between the sprayed area and the property boundary or a sensitive area. The no spray zone CANNOT BE SPRAYED when the wind is towards the sensitive area (which may be a residence, water body, pasture, native vegetation or another susceptible crop).

Always check the label to see of a no spray zone is required, and how wide the no spray zone has to be for the product you wish to apply.

Keep accurate records

It is always best practice to maintain accurate spray records.

Under the Records Regulations of the NSW Pesticides Act, when spraying you must record the weather and relevant spray details. An example form is presented on page 69 of this book in the Chemical Use section.

It is always best practice to maintain accurate records of every spray application made on your property. These records provide a valuable management tool for comparing spray applications and identifying factors that may have contributed when an application does not perform as well as expected. Accurate records can also assist in identifying issues such as the onset of resistance and sensitivity of the target to particular products or tank mixes.

Spray log books

Spray log books can be purchased from DEEDI for $6.60 each plus postage and handling.

In Toowoomba – contact Natalie Fletcher 07 4688 1460 or Rebecca Simmons 07 4688 1360.
In Dalby – phone 07 4669 0800.

Spray log books are also available from I&I NSW, Yanco for $12.00 each plus postage and handling.

Phone 1800 138 351.

ENHANCE VEGETATIVE BUFFERS

Vegetative buffers tend to be more effective than bare ground in intercepting spray that moves off target during spray application. Good buffers can reduce drift by as much as 60 to 90 percent.

Farm planning should consider where the protection of sensitive areas can be improved by enhancing vegetative buffers. Effective buffers are comprised of a mixture of tree and shrub species with foliage all the way to the ground. The planting arrangement and density allows for air to partly flow through the barrier. Barriers without airflow act like impermeable walls. The wind containing the spray drift is deflected up and over the top of the barrier which increases the effective release height and increases the far-field drift potential. Do not position barriers where airflow will be obstructed by adjacent objects such as turkey's nests.

The optimum height for a buffer is 1.5 times the release height of the spray. Trees and shrubs are able to act as an effective barrier for ground applied sprays from early in their development. Most guidelines suggest that the optimum width of the barrier is 20 m with a 10 m maintenance strip on either side.

BE ABLE TO MONITOR WEATHER CONDITIONS

Since sprays are released into the atmosphere, weather conditions at the time of application will have an effect on spray transport and deposition. Monitor weather conditions regularly during spray applications (this means at least every 20–30 minutes).

Handheld equipment is one option for monitoring weather conditions before and during spray applications. Photo: Graham Betts

Every grower should use an electronic weather meter to measure meteorological data at the site of application. This can be done with handheld equipment (e.g. Kestrel 3000, 3500, 4000 etc). Alternatively there are on board weather stations available utilising GPS input to provide weather information and logging whilst spraying (such as the Topcon or Watchdog systems).

Growers can also subscribe to websites that provide forecasts of conditions for spraying up to 10 days in advance. These sites evaluate all of the following factors to produce tables indicating times that would be suitable for spraying. You can access the websites at either Spraywisedecisions.com.au or Syngenta.com.au for more information.

MAINTAIN SPRAY EQUIPMENT

Calibrate spray equipment

- The output of each nozzle should be checked pre-season and regularly during the season. Nozzles that vary more than 10% from the manufacturer's specifications should be replaced.
- Regularly check wheel sensors and flow meters for accuracy.
- Check pressure across the boom for evenness.
- Cross check total spray volumes used against sprayed areas on your GPS logs to monitor whether application accuracy may have changed since your last calibration.

Decontaminate spray equipment

Application equipment that has been used to apply herbicides should be thoroughly decontaminated before being used to apply any product to a susceptible crop. Strictly follow the method of decontamination recommended on the label. No matter how much time is spent decontaminating the equipment there is always a risk of herbicides residues causing a problem.

UNDERSTAND THE INFLUENCE OF WEATHER CONDITIONS

Wind Speed

Wind speed affects the distance that a droplet will travel before deposition, impaction or evaporation. Wind speeds of 3–15 km /h are recommended (8–10 km /h are ideal) for spraying with a ground rig.

Higher wind speeds usually pose greater risk that product will evaporate quicker or be blown off target. At wind speeds of 11–15 km /h, use low drift nozzles or higher application volumes. Avoid spraying when wind speeds exceed 4.5 m /s or 16 km /h.

Scandinavian studies have suggested that an increase in wind speed from ~5 km /h to ~16 km /h at an air temperature of 10°C will require a 25% increase in buffer zone size for herbicide applications.

Mandatory wind speed range

Some pesticide labels already have a mandatory wind speed range, such as those on products containing 2,4-D, which state… 'wind speeds must be above 3 km /h and less than 15 km /h as measured at the site of application.'

This approach will be applied to all new labels, with the wind speed range varying depending on the level of risk associated with each product, and the method of application. In many cases the wind speed range will also be linked to the size of a no spray zone.

Temperature and humidity

Water-based sprays should not be applied under conditions of high temperature and low relative humidity (RH). Spraying should occur when the delta T (the difference between the wet bulb and dry bulb) is more than 2 and less than 10°C. For example, spraying can be carried out if the temperature is;

- 20°C and RH ≥24%
- 25°C and RH ≥33%
- 30°C and RH ≥40%
- 35°C and RH ≥45%.

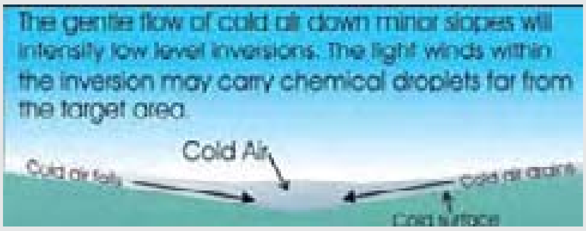
Higher ambient air temperatures and lower relative humidity conditions increase evaporation rates. Since droplet size of water-based sprays decreases rapidly with higher evaporation rates, drift tends to increase. Studies have shown that an increase in air temperature from 10°C to 20°C may require an increase of a few percent to over 100% in buffer zone size, depending on the accompanying wind speed.

When using coarse sprays at high water volume rates, evaporation may be lower, allowing application to continue in marginal delta T conditions.

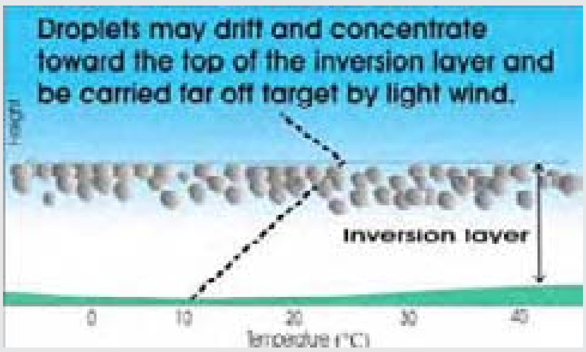
High humidity increases the drift hazard under inversion conditions – the more humid the air, the longer the life of small droplets (less than

What is an inversion layer?

An inversion exists when temperature increases with altitude instead of decreasing.



Inversions are the most hazardous atmospheric conditions for spray applications. **Do not spray in inversion conditions.**



Inversions usually occur on clear, calm nights and persist into the morning, until sufficient wind causes the air to mix, breaking the inversion layer.

100 microns). When spraying occurs in inversion conditions, droplets suspended within the inversion layer tend to travel parallel to the ground. The cool air drains to the lowest point in the landscape, carrying with it chemical that remains suspended.

Windy or turbulent conditions prevent inversion formation. Smoke generators can be used to detect inversion conditions. Under an inversion smoke will not continue to rise, but will drift along at a constant height under the inversion 'blanket'. **Do not spray in inversion conditions.**

Thermals are updrafts during the heat of the day cause rapidly shifting wind directions. Also avoid spraying in these conditions.

WIND SPEED AT NIGHT AND INVERSIONS

Still conditions or very light and variable winds greatly increase the risk of spray movement away from the target and so should be avoided for spray applications. Such conditions may indicate local surface inversion layers. Spray Drift that occurs under these conditions may travel long distances, often damaging large areas, with very uniform symptoms.

Figure 15. Effect of atmospheric stability on the dispersion of sprays in the atmosphere. Source: Bureau of Meteorology.

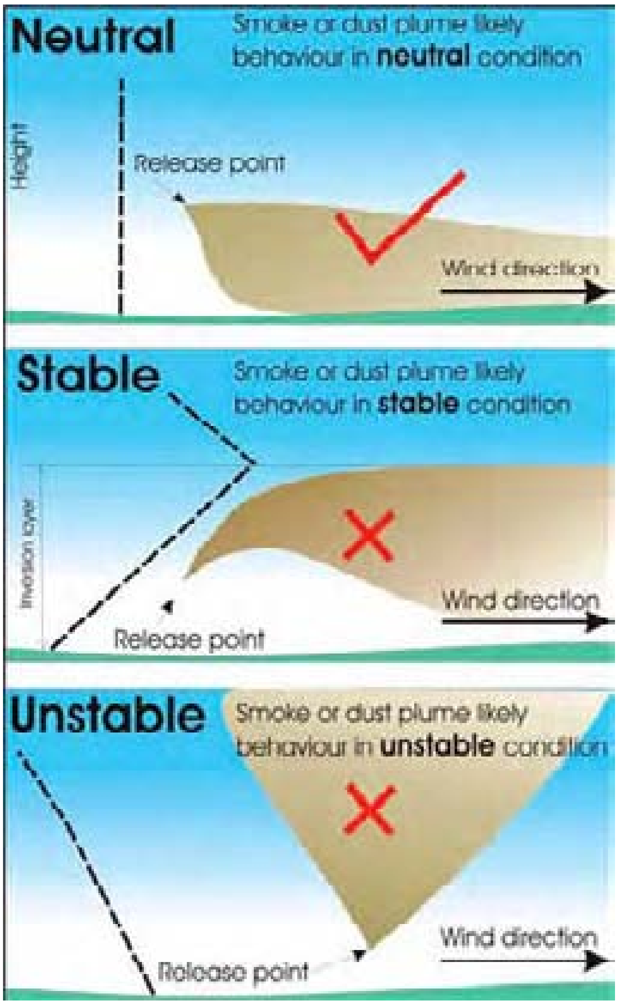


Figure 15 below shows the effect of atmospheric stability on the dispersion of sprays in the atmosphere. The behaviour of smoke or dust under various stability conditions may assist with selection of the preferred spraying conditions. Neutral atmospheric stability conditions (e.g. morning with a light cool breeze) are best for most applications.

Equipment to maximise efficacy

SET THE SPRAY RELEASE HEIGHT

The amount of chemical left in the air may double as nozzle height increases from 50 cm to 70 cm above the target or by a factor of 10 times as nozzle height increases from 50 cm to 1 m above the target. It is important to set the height of the boom at the minimum practical height to achieve the correct spray pattern for the nozzles.

Vertical movement of the spray boom should be minimised. Limit vertical movement by tuning the boom suspension and matching travel speed to release height. Alternatively consider fitting auto boom height.

Auto boom height devices use ultrasonic sensors to detect the height of the boom above the target. These adjust the boom hydraulically to maintain the nozzles at a constant height above the target. Generally these systems will require a machine with good hydraulic capacity. These systems allow the machine to maintain boom height at travel speeds up to 28 km /h.

FACTOR IN RISKS ASSOCIATED WITH TRAVEL SPEED

While the capacity of ground spraying equipment has improved significantly in recent years allowing more spraying to be carried out per unit of time, air velocity still has the same affect on the deposition of droplets onto the target. Increased operating speeds can cause spray to be diverted back into upward wind currents and vortexes behind the spray boom. Special care should be taken when using high speed, high clearance sprayers and some 'floaters' whose tires may become more like fans when driven at high speeds. Small droplets can become trapped in these air patterns and contribute to loss of product away from the target. Speeds above 15 km /h have been shown to increase the risk of drift for boom spraying and speeds above 10 km/h increase the risk from shielded sprayers.

OPERATE IN THE RECOMMENDED PRESSURE RANGE

Only ever operate nozzles within the pressure range recommended by the manufacturer. Higher or lower than recommended pressures changes the droplet spectrum and the spray pattern, affecting both the risk of drift and the efficacy of the spray application.

Be aware that many air induction nozzles will require slightly more pressure than the minimum indicated on the manufacturers spray chart. Always assess the spray pattern at various pressures, to determine an appropriate minimum operating pressure.

Where automatic rate controllers are fitted to the machine, carefully consider the true range of speeds the machine is likely to operate, from the slowest field to the fastest field. Identify what the pressure at the nozzle will be at your lowest speed and your fastest speed and identify a nozzle that will produce the required spray quality across that range of speeds.

Operating at recommended pressures can also minimise wear and tear on nozzles.

MATCH THE WATER VOLUME TO THE PRODUCT AND USE PATTERN

Always follow label recommendations for application water volumes. Typically in-crop applications to cotton will require application volumes of 100 L/sprayed hectare or more.
For fallow spraying with translocated herbicides (such as glyphosate and the phenoxys) equivalent efficacy has been shown for medium, coarse and even extremely coarse spray qualities at 50 L /ha.
For products with minimal translocation, such as Spray.Seed®, equivalent efficacy has been shown for medium, coarse and even extremely coarse spray qualities at 70 L /ha and greater.

When using coarser than a medium spray quality for translocated products, increasing water rate does not necessarily increase efficacy, and in some situations may actually reduce performance in the field. When a marginal rate of product is used, when water quality may be marginal or where diluting the adjuvants included in the product, higher water rates can reduce the performance of translocated products.

Describing nozzle size spectrums

Spray nozzles produce a range of droplet sizes called the droplet size spectrum. Nozzle manufacturers now use internationally recognised classifications for droplet size spectrums for nozzles. These are Very fine, Fine, Medium, Coarse, Very coarse and Extremely coarse. This classification system aims to provide an all-purpose description of the droplet size spectrum produced by the nozzle.

SELECT NOZZLES THAT ARE SUITED TO THE SPRAY SITUATION

For most farming enterprises it will not be possible to optimise the application of all pesticides to all crop and fallow situations using the same set of nozzles.

The droplet size spectrum from the nozzle influences the time it takes droplets to land on the target. Small droplets do not have as much mass to sustain their direction toward the target, so are more readily carried by horizontal and vertical winds, or in the vortices associated with sprayer wakes.

An increasing number of nozzle designs are available on the market that are specifically designed to produce less fine droplets and more droplets in the Medium and Coarse spectrums. They should be evaluated as part of your enterprise's BMP process and fitted if they are cost effective and result in better spraying.

Achieving coarse spray quality

Increasingly pesticide labels will state the specific spray quality (e.g. coarse) required for product application. Achieving compliance with the label with regards to spray quality is a function of nozzle selection and operating pressure.

Mandatory spray qualities

Some pesticide labels already have a mandatory spray qualities, such as those on products containing 2,4-D, which state… 'spray quality must not be smaller than a coarse to very coarse spray quality according to the ASAE Standard S-572'.

All new labels are likely to have a requirement for either a medium spray quality or a coarse to very coarse spray quality. This will be linked to a wind speed range and other measures for mitigating spray drift risk.

The spray quality produced by a particular nozzle can be manipulated by changing the operating pressure. For example, if a coarse spray quality is required when Turbo TeeJet® TT11002 nozzles are being used, reducing the operating pressure from ~4 bar to ~2 bar would change the droplet spectrum of the nozzle from medium to coarse and enable compliance with the label. However this strategy has implications for the application volume per hectare and operating speed, particularly if an automatic rate controller is being used. In the above example, if 50 L /ha was the desired output, at 4 bar the travel speed would be 22 km /h, while at 2 bar travel speed needs to be reduced to ~15.5 km /h to still be applying 50 L /ha. If an automatic rate controller is being used in the sprayer then variation in the travel speed, from ~15.5 km/h to 18 km/h during the operation would change the droplet spectrum back to medium. Where automatic rate controllers are being used, it is best to select a nozzle that produces coarse and very coarse spectrums over a range of operating pressures so that as the sprayer slows down to turn around or increases speed along straight runs, droplets are consistently being produced within the intended spectrum.

High pressure air induction nozzles such as AI Teejets, Hardi Injets and Agrotop Turbodrop TDs are types of nozzles that can produce coarse to very coarse droplet spectrums over wide range of pressures. Not all spray equipment however, has the capacity to consistently run at the high pressures required for these nozzle types. Most centrifugal pumps will struggle to operate consistently in the 5–8 bar range. Nozzles should only ever be operated within the manufacturer's recommended pressure range. When nozzles are operated at pressures below the recommended range, the fan angle may collapse and air flow into air induction nozzles is likely to be poor, leading to reduced pesticide efficacy and possible nozzle blockages.

'02' nozzles that will produce a coarse droplet spectrum over a range of operating pressures to achieve a spray output of 50 L/ha.

Nozzles		Operating Pressure (bar)						
		2.0	2.5	3.0	3.5	4.0	4.5	5.0
Type	Description	Travel Speed (km/h)						
		15		19		22		27
Hardi ISO Minidrift	Minidrift 02	C	C	C	C	C	C	C
Agrotop Airmix	TDAM11002	VC	C	C	C	C/M	M	M

Source: Nufarm 2008.

For a given nozzle, there are significant differences in the droplet spectrum data provided by Nufarm and some nozzle manufacturers. Nufarm data was generated in an independent wind tunnel facility in the UK in accordance with the ASAE S572 standard required by the APVMA, so can be used to make nozzle selection decisions.

Several nozzle types able to produce coarse and very coarse spectrums over a wide range of relatively low pressures include; AIC Teejet, Teejet AIXR, Hardi ISO Minidrifts and Agrotop AirMix® nozzles. If a desired spray volume of 50 L /ha for fallow weed control is required, then an '02' or '025' nozzle is the nozzle most likely to provide a coarse to very coarse droplet spectrum over a range of travel speeds and relatively low pressures. Examples of two nozzles are provided in the table below. If a different spray output (L /ha) is desired, then the required operating pressures and travel speeds need to be adjusted so as to produce coarse or very coarse droplets.

Consider specialised nozzle technologies

When ground spraying adjacent to sensitive areas, application to the crop can be improved by using off-center nozzles at the ends of spray booms. These emit the spray toward the crop only, i.e. pointing inwards as a half-plume only. This can avoid application beyond the edge of the field.

Controlled Droplet Application (CDA) and some ground spraying rotary atomizers can be used to reduce the range of droplet sizes in a spray. If used properly, such equipment can reduce the proportion of the spray contained in driftable small droplets.

Sometimes a trade-off will exist in choosing the nozzle option with the lowest drift potential. Wide angle (110°) flat fan nozzles will produce more fine droplets than those with a narrower angle (80°), but have the advantage of allowing the boom to be set at a lower height above the target. Optimum spray height is 75 cm above the target for 80° spray tips and 50 cm above the target for 110° spray tips for standard 50 cm nozzle spacings.

Interpreting information about spray nozzles

Nozzle manufacturers provide information on the droplet size spectrum performance of nozzles and atomizers under specific operating conditions. Most nozzle catalogues only provide such

Influence of droplet spectrum on time to deposition and distance travelled in a typical aerial application with a release height of 3 m.

Droplet spectrum category*	$Dv_{0.5}$ at emission (µm)	Time to deposition (s)	Distance travelled (m)	$Dv_{0.5}$ at deposition (µm)
Very Fine	100	25	80	30
Fine	200	5	20	185
Medium	300	3	12	295
Coarse	400	2	10	395
Very Coarse	500	2	7	496
Extremely Coarse	600	2	6	597

* Droplet size classifications are based on British Crop Protection Council specifications and are in accordance with the American Society of Agricultural Engineers (ASAE S-572)

information for applications of water underground spraying conditions. Real tank mixes may produce different spectrums than those suggested in nozzle catalogues. Tank mixes with lower surface tension and viscosity than water will tend to favour greater production of smaller droplets.

In aerial applications sprays tend to be much finer than the ground-based nozzle catalogue data would suggest. This is primarily due to air shear. Models are available for some nozzles and atomizers to indicate the droplet size classification under aerial conditions. A comprehensive set of such models and tables of droplet size information are available from the United States Dept. of Agriculture at http://apmru.usda.gov/downloads/downloads.htm and, for aerially-applied 2,4-D sprays, from wind tunnel droplet size research from www.aerialag.com.au

The table on previous page shows an example of the distance that water droplets from each of the droplet size spectrums would travel prior to deposition following release from a 3 m height in a typical aerial application. The example was generated using the AgDRIFT® model.

ADDITIONAL CONSIDERATIONS FOR AERIAL APPLICATIONS

Boom Length

The forces that provide lift and flight of aircraft also produce wake and vortex effects of the air into which spray droplets are released. If droplets become entrained in these airflows, their trajectory and path can change. To minimise this effect, boom length should not exceed 65 to 75% of the wingspan.

The strength of vortices tends to increase when a slower flight speed or greater weight is used and when the lift increases, for example when the aircraft climbs at the end of a flight line. Therefore, spray should not be applied when the aircraft is climbing, but only when the aircraft is level over the target. Also, if helicopters are flown very slowly, the airflow behaviour can cause droplets to be carried up by the rotor vortices, with an increase in spray drift potential.

Air Shear

The production of small droplets that may be more prone to drift can be reduced by minimizing air shear at the nozzle tip where the liquid meets the airblast from the aircraft motion. Reducing flight speed (e.g. using slower helicopters rather than higher speed fixed wing aircraft) can reduce this shear, but may affect productivity rates and optimal operation. Reducing the nozzle angle is an effective way to reduce air shear. In the case of deflector nozzles, the nozzle angle and the deflector angle can be reduced to provide minimal air shear conditions. The lowest air shear occurs for nozzle angles which are 0° straight back.

Pressure

The relative velocity of the air and liquid is important in affecting droplet size. For most nozzles, lower liquid pressure produces coarser sprays, within the optimal operating range for the nozzle. However, with very narrow angle sprays such as those from solid stream and narrow angle flat fan nozzles, higher pressure generally produces coarser sprays. Consult nozzle manufacturer information for specific recommendations on pressure range settings for optimal droplet size and application criteria.

Rotary Atomizers

Some rotary atomizer manufacturers provide models for predicting droplet size with their equipment based on operational parameters such as rotation rate, flight speed and liquid flow rate for specific product types.

Coarser droplets can be produced by increasing the drag on the atomiser to lower the rotation rate. Using windmill blade-driven atomizers allow selection of rotation rate through changing the blade angle. Droplet size also tends to increase with higher flow rates. There may be a change in the mode of atomization from direct droplet through ligament and sheet breakup as flow rate increases, each of which tend to produce progressively coarser sprays.

Special Aerial Equipment

Some spray equipment allows in-flight optimization of application conditions. For example,

- booms can sometimes be lowered after take-off, allowing spray release height to be reduced with lower drift potential;
- chambers are being developed for reversing the venturi effect where the nozzle can be positioned in a relatively lower airstream velocity reducing the number of small droplets;
- wing tip modification devices can reduce vortices and modify wake effects to prevent spray from drifting, but under some circumstances could also affect aircraft handling and airframe lifetimes;
- electrostatic spraying systems may help with droplet wrap-around onto lower leaf surfaces, but drift reduction will ultimately depend more

on droplet size than forces such as electrostatic charge. 'Spray Drift Management Principles, Strategies and Supporting Information'.

PRODUCT TYPE

The selection of product may affect the tank mix physical properties, which can affect droplet size and likelihood of off-target losses.

The impact of a given amount of drift off-target will depend on the product's toxicity to what is present in the affected areas. Alternative pest control methods (e.g. cultural, mechanical, biological) may allow pesticides to be avoided or used at lower rates in conjunction with other methods. Where chemicals are used, preference should be given to products which offer the lowest effects on non-target organisms and the environment. To compare the relative toxicities of insecticides to non-target insect species such as beneficials and bees, refer to Table 3, page 40.

(HL5) Herbicides with volatile active ingredients

If using volatile herbicide products, special care must be taken to avoid vapour drift issues. Vapours may arise directly from the spray or from the target surface after the spray has been deposited. Volatilisation from the target surface can occur hours or days after the herbicide is applied. The risk of vapour drift can be avoided by choosing active ingredients with low volatility. The ester forms of 2,4-D and MCPA have high volatility while the amine and salt forms have low volatility. However the propensity for a product to volatilise is influenced by temperature. High ground temperatures in summer can increase the risk of volatilisation. Additionally, active ingredients with low volatility are still susceptible to droplet and particle drift. Some examples of vapour drift risk from some different products are shown in the table on this page.

Specific Testing and Calibration

Sprayers should be operated according to the manufacturer instructions and be calibrated for proper performance. Sprays should be observed for correct appearance and uniformity of coverage.

Nozzles need to be checked regularly for possible wear or leaks. Nozzles that vary more than 10% from the manufacturer's specifications should be replaced. Replacement of warn nozzles prevents undue wastage of chemical and prevents changes in the spray discharge patterns and droplet size spectra that could reduce efficacy or increase the risk of drift.

RELATIVE HERBICIDE VOLATILITY

Active Ingredient	Product Example
HIGH VOLATILITY*	
2,4-D ethyl ester	Estercide® 800
2,4-D isobutyl ester	2,4-D Ester® 800
2,4-D n-butyl ester	AF Rubber Vine Spray®
SOME VOLATILITY	
MCPA ethylhexyl ester	LVE MCPA
MCPA isooctyl ester	LVE MCPA
2,4-D isooctyl ester	Low Volatile Ester 400
triclopyr butoxylethyl ester	Garlon® 600
picloram isooctyl ester	Access®
LOW VOLATILITY	
MCPA dimethyl amine salt	MCPA 500
2,4-D dimethyl amine salt	2,4-D Amine 500
2,4-D diethanolamine salt	2,4-D Low Odour 500
2,4-D isopropylamine salt	Surpass® 300
2,4-D triisopropylamine	Tordon® 75-D
2,4-DB dimethyl amine salt	Buttress®
dicamba dimethyl amine salt	Banvel® 200
triclopyr triethylamine salt	Tordon® Timber Control
picloram triisopropylamine	Tordon® 75-D
picloram triethylamine salt	Tordon® Granules

From Mark Scott, Agricultural Chemicals Officer, Industry & Investment NSW.

* The APVMA has taken the decision to continue to suspend the registration of products containing high volatile ester forms of 2,4-D, namely the ethyl, butyl and isobutyl esters. Refer to page 108 for more information.

Types of drift

Sprayed pesticides can drift as droplets and particles or as vapours.

Droplet and particle drift

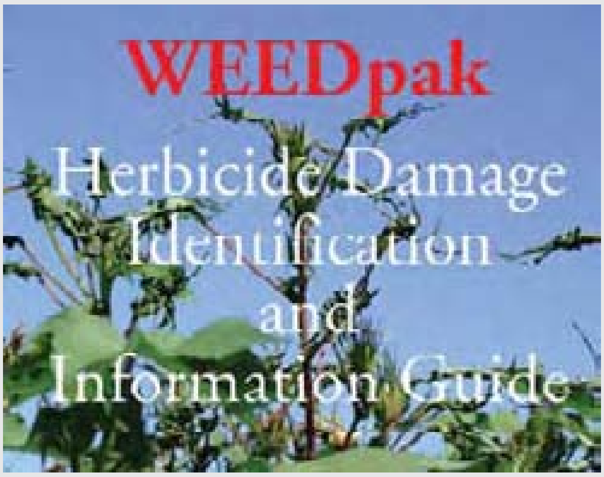
Droplet and particle drift is the most common cause of off-target damage from pesticides. It is particularly obvious where herbicides drift onto susceptible crops.

It occurs when any form of pesticide is applied in unsuitable weather conditions and/or with inappropriate application parameters. Water in the spray droplets evaporates resulting in finer droplets and particles of herbicide. As the size of the droplet declines, so too does their rate of fall towards the ground. Smaller droplets remain airborne longer and hence are susceptible to further evaporation and drift away from the intended target. Herbicide particle drift damage to susceptible crops has been reported up to 30 km from the spray source.

Droplet and particle drift is the easiest form of drift to prevent. Under good spraying conditions, droplets are carried down by air turbulence and gravity to collect on the intended plant surfaces.

Vapour drift

Vapour drift is the movement of volatile components of herbicides in air currents during or after application. Volatility refers to the likelihood that the herbicide will turn into a gas. Vapours may arise directly from spray or from the target surface after droplet deposition. Volatilisation from the target surface can occur hours or days after application. The risk of vapour drift can be avoided by choosing active ingredients with low volatility. The ester forms of 2,4-D and MCPA have high volatility, while the amine and salt forms have low volatility. Actives with low volatility are still susceptible to droplet and particle drift. Some examples of vapour drift risk from some different products are shown in the table in above.



When herbicide drift occurs, sensitive crops may be up to 10,000 times more sensitive to the herbicide than the crop being sprayed. For information about the impact of herbicide damage on subsequent growth and yield of cotton, visit the Cotton CRC web site. Herbicide damage images have been generated by applying a known rate of herbicide over-the-top of cotton at a given growth stage and recording the impact of the herbicide on the crop grow.

www.cottoncrc.org.au/content/Industry/Publications/Weeds/Herbicide_Damage_Identification_and_Information.aspx

Where possible, validate the chosen spray setup in field conditions. Field testing can verify the on-target performance as well as recognise where off-target losses are ocurring. A good technique available to farming groups or individuals is the use of water or oil sensitive papers. These can be placed in and beyond the spray swath and analyzed using camera/ scanner/ image analysis and software packages such as Stainalysis.

CONSIDER THE INFLUENCE OF ADJUVANTS ON DROPLET SIZE

More can be done to manipulate droplet size with nozzle selection, than with the addition of an adjuvant.

Some adjuvants can increase droplet size, but care should be taken in assuring that there is a decrease in small driftable droplets with diameter below 100–200 µm, and not just an increase in the average or volume median diameter of the spray.

When considering adjuvants, compatibility with the tank mix and spraying system should also be considered, since some adjuvants do not perform as well with some combinations of other factors. For example, many polymers cause a decrease in spray angle from cone nozzles which may adversely affect spray formation and coverage. Emulsion-based adjuvants often perform better for reduction in small droplets than solution-based adjuvants for the same surface tension. However, actual performance is specific to the conditions.

MONITOR TANK MIX TEMPERATURE

Recent research has shown that the temperature of the tank mix relative to the air may have an effect on the droplet size spectrum produced at atomization. Often a temperature difference where the liquid is greater than 6°C warmer than the ambient air can reduce the small droplet proportion of the spray.

FURTHER INFORMATION

'Spray Drift Management Principles, Strategies and Supporting Information', www.publish.csiro.au/pid/3452.htm

SPRAYpak – Cotton Growers' Spray Application Handbook, 2nd Edition, available from CRDC.

Spraywise – Broadacre Application Guide – Available through Croplands Distributors.

The spray drift model 'AgDRIFT', is available for free download from www.agdrift.com. Fact sheets on droplet size classification, and drift management in aerial and ground applications are also available at this website.

For more information about using vegetative barriers in spray drift management, see the *Queensland guidelines: Anon (1997) Planning Guidelines: Separating Agricultural and Residential Land Uses. Dept of Natural Resources, Queensland and Dept of Local Government and Planning, Queensland. DNRQ 97088.* Available for free download at www.nrm.qld.gov.au/land/planning/pdf/public/plan_guide.pdf

Comprehensive information about droplet spectrums of nozzles under aerial application conditions is available from the United States Dept. of Agriculture at http://apmru.usda.gov/downloads/downloads.htm. For aerially-applied 2,4-D sprays, from wind tunnel research, see www.aerialag.com.au

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Cotton Catchment Communities CRC full page colour

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