FINAL REPORT
DAN 95C

Project Title: ***DISEASES OF COTTON - (V)***

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THIS PROJECT WAS PART OF THE CRC FOR SUSTAINABLE COTTON PRODUCTION
SUB-PROGRAM 2.5 - 'MANAGEMENT OF DISEASES AND MYCORRHIZAL FUNGI '

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SUMMARY

DAN 95C - DISEASES OF COTTON (V)

The results of disease surveys have indicated a declining incidence of Verticillium wilt and seedling diseases and an alarming increase in the prevalence of Fusarium wilt, black root rot and Alternaria leaf spot. Bacterial blight and Alternaria leaf spot have become significant problems for Pima growers in the Bourke area.

No new fungicide seed treatments have been significantly better than the current standard Quintozene Apron treatment and the use of planter-box or in-furrow fungicide treatments was not found to be warranted under Australian environmental conditions at planting.

An integrated control strategy which included resistant cultivars, removal/incorporation of crop residues and rotation with non-hosts resulted in a more rapid decline in the incidence of Verticillium wilt compared to the use of resistant cultivars alone. Repeated use of resistant cultivars in a field experiment at ACRI has resulted in the development of a possible new strain of the Verticillium wilt pathogen.

The widespread use of permanent bed systems and the introduction of legumes into cotton production systems has contributed to the increased prevalence of black root rot. No fungicide seed treatment, crop rotations or cultural practices that were evaluated provided adequate control of black root rot of cotton.

The incidence of Fusarium wilt in field E2 at 'Morella' near Boggabilla has fallen from 13.4% to 3.4% in three seasons as a result of the use of a more resistant cultivar. Summer flooding, trash management and crop rotation experiments have been established in commercial fields in the McIntyre and Gwydir valleys. Remote sensing by thermal imagery enabled quick location of possible Fusarium wilt infected plants when images were taken in January after full row closure from an altitude of 1500 'feet'.

BACKGROUND TO THE PROJECT

The objective of the plant pathology programme at the Australian Cotton Research Institute is : "to determine the distribution, incidence and severity of those diseases present in cotton in Australia and to develop economically viable and ecologically sustainable disease management strategies to minimise losses". For many years the plant pathology programme at Narrabri was the only pathology programme servicing the entire cotton industry in Australia. The Queensland Department of Primary Industries has recently commenced disease surveys and work on Fusarium wilt of cotton.

The results of annual disease surveys since the 1983/84 season have given basic direction to the plant pathology programme at Narrabri. An extensive database relating disease incidence and severity to cultivar, field history, cultural practices and seasonal conditions has been established.

The identification of Fusarium wilt of cotton near Boggabilla and Mungindi was confirmed in January and February 1995. Fusarium wilt is a major disease of cotton in many overseas cotton growing areas and has long been one of the main reasons for Australian Quarantine restrictions on cotton seed introductions. The disease was originally reported in Australia from crops growing in the Brookstead area of Queensland in 1993. The Brookstead and Boggabilla isolates of the pathogen appeared to be unrelated and both were distinctly different from overseas isolates of the pathogen. For these reasons it was essential that local field experimentation be used to develop control recommendations rather than the adoption of results from other areas with other strains.

Verticillium wilt was the most widespread and important disease of cotton in Australia with the potential to reduce yields by 20-25% in some fields when weather conditions were favourable. The widespread adoption of CSIRO cultivars with resistance to Verticillium wilt effectively reduced the incidence and importance of the disease. In California, where there are several different and more virulent strains of the pathogen, the use of resistant cultivars resulted in the selection of more virulent strains and an effective breakdown in the level of cultivar resistance to the disease. For this reason it was of great importance to monitor the incidence of Verticillium wilt with repeated cultivation of a resistant cultivar in Australia.

Effective control of seedling diseases is important so that the costs and problems associated with replanting can be avoided. Black root rot of cotton had become increasingly common in the previous few seasons and was causing considerable concern in parts of the Namoi and Macquarie valleys.

Research projects DAN 8L and DAN 26L focussed mainly on bacterial blight with the successful development and monitoring of a clean seed scheme and characterisation of the races of blight that were present on cotton in Australia. Work under DAN 48L concluded the work on bacterial blight and focus shifted to Verticillium wilt, seedling diseases and the importance of mycorrhizas. The main emphasis of DAN 69C was the use of resistant cultivars and cultural practices for Verticillium wilt control. This emphasis was continued under DAN 95C while also commencing a more concentrated effort on black root rot.

PROJECT OBJECTIVES

(i) To continue to evaluate control strategies for verticillium wilt and seedling diseases of cotton.

(ii)To develop and/or evaluate control strategies for black root rot and Fusarium wilt of cotton.

(iii) To monitor the distribution and importance of diseases in irrigated and dryland cotton by regular disease surveys.

Objectives achieved in each year of the grant:

(i) the inspection of commercial crops in all cotton growing areas of NSW during November and March of each season to quantify disease incidence and severity.

(ii) annual field experiments at two sites to compare and evaluate fungicide seed treatments for seedling disease control - in collaboration with Cotton Seed Distributors and Deltapine Australia.

(iii) annual assessment of long term field experiments to evaluate a) the effect of cultural practices for the control of verticillium wilt, and b) the effect of repeated cultivation of either resistant or susceptible cultivars on wilt incidence.

(iv) annual field experiments comparing cultivar reaction, fungicide efficacy and the effects of cultural practices on the incidence of black root rot.

(v) annual field experiments at the Boggabilla Fusarium site evaluating cultivar reaction, fungicide seed treatments and fertiliser treatments.

METHODOLOGY WITH JUSTIFICATION

Disease Surveys

Commercial cotton crops in all cotton growing areas of NSW were inspected in November and March of each season. Disease incidence and severity, cropping history, cultural practices, cultivar, sowing date etc were recorded and the information added to a database which was originally established in 1985. In the past these surveys have provided opportunities for: collecting soil and plant samples; collecting isolates of the blight pathogen for race determination; determining the distribution and abundance of nematodes and black root rot in cotton; collecting isolates of *Verticillium dahliae* and mycorrhizal fungi for university based studies and collecting potential biocontrol agents and growth-promoting bacteria from seedling roots. The surveys allowed further opportunities for monitoring the distribution, abundance and importance of black root rot, bacterial stunt (Galathera syndrome) and Fusarium wilt.

Verticillium wilt

Disease survey results have indicated a significant reduction in the incidence of Verticillium wilt as a result of the use of resistant cultivars. Davis *et al.* (1994) reported that the repeated cultivation of resistant potato cultivars for five years resulted in a 60 - 70% reduction in the inoculum density of *V. dahliae* in the soil. In a second experiment they showed that susceptible cultivars could be successfully grown after five seasons of a resistant cultivar. Conversely, Ashworth *et al.* (1983) showed that the repeated use of resistant cotton cultivars in California increased the amount of soil borne inoculum of the more aggressive strains of the pathogen and resulted in the demise of the resistant cultivars. The success of cotton cultivars with resistance to Verticillium wilt in Australia will depend on the strength and durability of that resistance and on the presence or absence of strains of the pathogen that can overcome the resistance.

Disease surveys in commercial crops will monitor the incidence of Verticillium wilt with repeated cultivation of resistant cultivars. A replicated field experiment in the Verticillium nursery at the Australian Cotton Research Institute monitored the incidence of Verticillium wilt with repeated cultivation of resistant and susceptible cultivars.

The verticillium nursery at the Research Institute was also used as a site for the evaluation of cultural practices for the control of verticillium wilt. Established, loug-term replicated field trials were used to compare the resistance/susceptibility of current Australian cultivars and evaluate the efficacy of a combined range of cultural practices for the control of verticillium wilt.

Seedling diseases

Annual seed treatment trials to compare the efficacy of current and potential fungicide and insecticide seed treatments were continued in collaboration with Mr Bill McDonnell from Cotton Seed Distributors and Mr Richard Leske from Deltapine Australia Pty Ltd. These trials were planted each season at a site on the Darling Downs of Queensland and at Narrabri. Replicated field trials at Narrabri were used to compare planter-box and in-furrow fungicide treatments with standard seed treatments under various conditions. The CRDC funded review in March 1997 suggested that further evaluation of the efficacy of hopper-box and in-furrow fungicide treatments for seedling disease control was unwarranted. Only one of nine field experiments over a five year period demonstrated a significant yield benefit from the use of these supplementary seedling disease control treatments.

Black root rot

Black root rot has been observed in commercial crops in the McIntyre, Gwydir, Namoi and Macquarie Valleys and the incidence of the disease has varied from a trace through to 100% of plants with symptoms.The fungicide Baytan, which is registered for the control of black root rot in the USA, has been evaluated for the control of black root rot in Australia with mixed results. This product was further evaluated in replicated field experiments in the Macquarie and Namoi Valleys.

Several authors (eg Kendig and Rothrock, 1991) have suggested that the incorporation of hairy vetch residues could suppress the pathogen. The widespread adoption of permanent bed systems has been suggested as a reason for the increased incidence of the disease in Australia. Field experiments evaluated cultivar resistance and/or susceptibility and the effects of hairy vetch residue incorporation and permanent bed systems on the incidence and severity of black root rot.

Fusarium wilt

The limited distribution of the pathogen has made it difficult to identify suitable sites for field experimentation in NSW and much of the work on developing a control strategy for Fusarium wilt of cotton is being done in Queensland under the supervision of Dr Joe Kochman. Where sites have been available it has been necessary to try and fit experiments within a strip so that plots have relatively even exposure to infection by the pathogen. For this reason Coefficients of Variation for some analyses were unacceptably high.

A small area of the infected field near Boggabilla was made available for replicated field experiments to evaluate, nutrition (nitrogen, phosphorus and potassium), cultivar reaction (current CSIRO and Deltapine cultivars) and fungicide seed treatments.

The incidence of Fusarium wilt in a field near Mungindi, which was flooded for 60 days during the 1995-96 summer, was monitored. A second 'summer flooding' experiment has been established in fields 5 and 6 at Tarcoola North near Moree. Assessment of disease incidence along an established transect in a commercial field was used to determine the impact of repeated use of less susceptible cultivars.

Remote sensing technology based on thermal imaging was introduced to the Gwydir Valley for irrigation scheduling during the 1996/97 season. The use of this technology allowed easy detection of new patches of diseased plants.

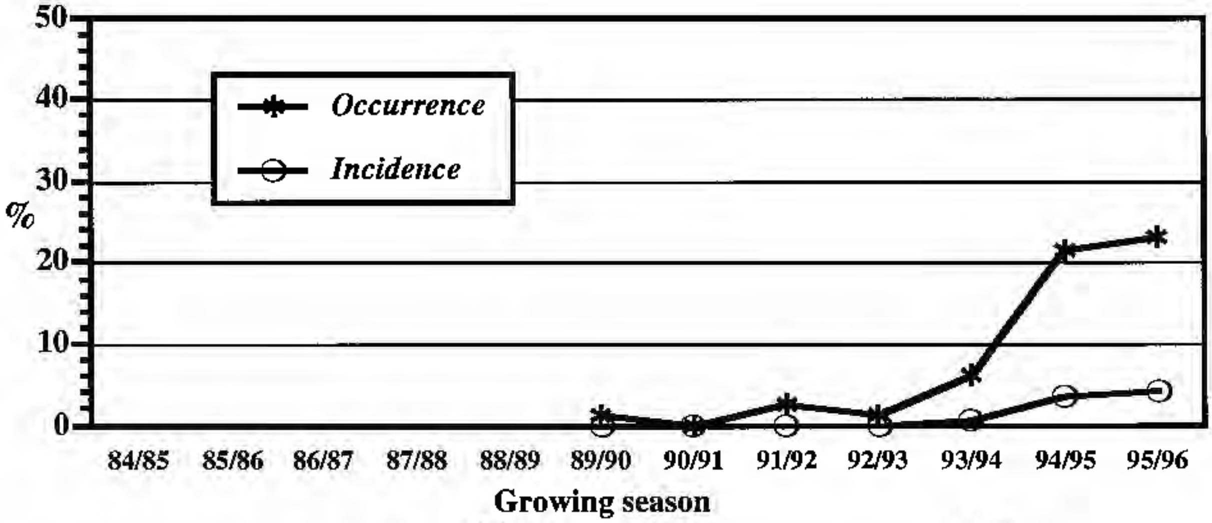
DETAILED RESULTS

Disease Surveys - 1995/96

Weather conditions in most cotton growing areas during the 1995/96 season were ideal for disease development. Cool weather early in the season favoured black root rot and seedling diseases. Wet, cool weather in January allowed the development of significant epidemics of Alternaria leaf spot and was conducive to infection by the Verticillium wilt pathogen. January flooding throughout the Darling Downs and in the McIntyre Valley where Fusarium wilt is a problem no doubt extended the distribution of the pathogen. The late harvest and the exposure of the seed cotton to wet weather prior to harvest caused concern for the potential degradation of the fibre by microbial activity. On a brighter note - the disease situation could have been considerably worse if the weather had not remained predominantly dry during February, March and April!

Black Root Rot

The disease was first reported on cotton in Australia in 1990. It has since been reported on farms in most cotton growing areas of NSW and on the Darling Downs of Queensland. Black root rot was observed in 21(22.3%) of the 94 commercial cotton fields that were inspected. The incidence of the disease exceeded 20% in 5 fields and 90% of plants were infected in one field in the Macquarie Valley.

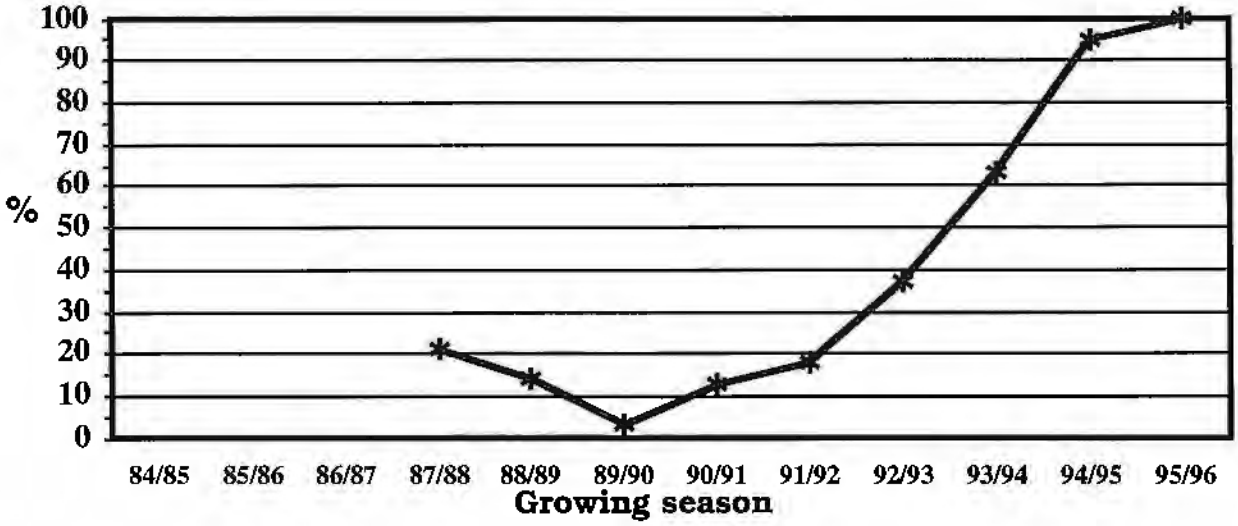


The occurrence (percentage of fields inspected where the disease was found to be present) and mean incidence (percentage of seedlings affected) of Black root rot of seedlings in commercial cotton crops in NSW.

Alternaria Leaf Spot

Alternaria leaf spot of cotton has been common in Queensland for many years . In 1966 its occurrence in Queensland was described as " general; slight to moderate, sometimes severe in dry crops". Prior to the 1987/88 season the disease had not officially been recorded on commercial cotton crops in NSW.

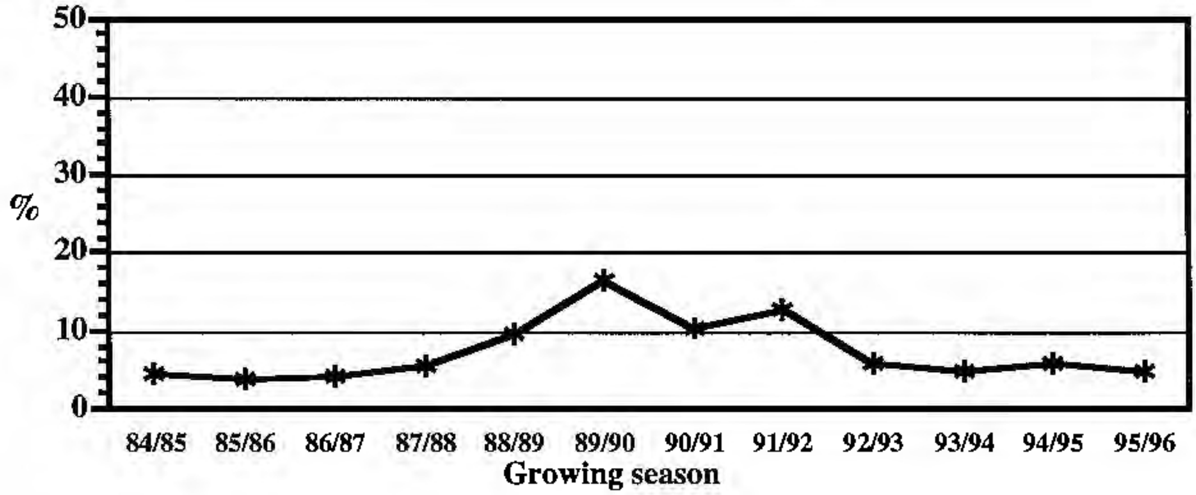
The results of disease surveys have shown an alarming increase in the occurrence of this disease in recent years. Alternaria leaf spot was found in all 64 commercial crops that were inspected in March 1996 and the mean incidence of the associated boll rot was 0.5%. In one crop 8.5% of bolls were affected.



The incidence of Alternaria leaf spot of cotton in NSW. (The percentage of fields of cotton inspected where the disease was found to be present)

Verticillium Wilt

Verticillium wilt has been one of the most common diseases of cotton in Australia for many years. The mean incidence of the disease reached a peak in the 1989/90 season and has since declined significantly with the advent of commercial cultivars with resistance to Verticillium wilt. However, the last four seasons have featured cool wet periods in January and/or February which have favoured the disease. The 1995/96 season has been ideal for the Verticillium wilt pathogen and the incidence of the disease in the western areas of NSW, where the Verticillium resistant cultivars have not been so commonly grown, was higher than that previously observed.



The mean incidence of Verticillium wilt in commercial cotton crops in NSW.

Fusarium Wilt

Fusarium wilt of cotton was first observed in a single field of cotton on one farm near Boggabilla in NSW in December, 1994. During the 1995/96 season the disease was found in four additional fields on three farms located near the original site. It would appear that all four of these fields may have been subject to inundation by water that had run-off the original infected field during local flooding that occurred more than five years ago. These same infested fields have again been subjected to local flooding during the 1995/96 season.

Disease Surveys - 1996/97

Once again, weather conditions in most cotton growing areas were ideal for disease development. Cool weather early in the season was favourable for the development of black root rot. The wet, cool weather in January enabled the development of significant epidemics of Alternaria leaf spot and was conducive to infection by the Verticillium wilt pathogen. Local flooding in many areas provided ideal conditions for effective dispersal of the Fusarium wilt pathogen.

Fusarium Wilt

Of great concern was the increasing distribution of Fusarium wilt. By the end of the season there were five areas in the McIntyre Valley and one area in the Gwydir Valley where the disease had been reported and confirmed. Of greater concern was the suggestion that some growers and consultants were not 'going public' and were not admitting to the presence of the disease on their farm! The disease is seed borne and if a pure seed crop is inadvertently taken from an area where Fusarium wilt is present then the disease could be very easily dispersed to all corners of the industry! Our seed producers can only avoid the areas that we know about ! If growers, consultants and contractors know that the disease is present in an area then they are more likely to take precautions which will limit its spread.

Verticillium Wilt

On a brighter note, the mean incidence of Verticillium wilt in cotton crops continued to decline despite the very conducive weather over the previous two seasons. The mean incidence of the disease in those crops surveyed in NSW during March 1997 was only 2.5% which was the lowest mean since surveys commenced in 1984/85 and considerably lower than the 16.6% recorded in the 1989/90 season. Similarly the mean incidence of the disease in those crops surveyed in the Namoi valley during March 1997 was only 3.9% which was the lowest mean since surveys commenced in 1984/85 and considerably lower than the 64.1% recorded in the 1989/90 season. This remarkable reduction in Verticillium wilt would appear to be the result of the widespread adoption of Verticillium wilt-resistant cultivars.

Where growers have persisted with the more susceptible cultivars the incidence and severity of Verticillium wilt was high. A comparison between the yields of three Verticillium wilt resistant cultivars and three susceptible cultivars in a CSD Ingard trial near Moree was interesting. The average yield of the resistant cultivars was 64.9% higher than that of the susceptible cultivars. It is probable that other factors such as variable plant stands and severe water logging partly accentuated the impact of the disease on yield in this trial.

Alternaria Leaf Spot

This disease was common again in the 96/97 season especially in Pima cotton which is more susceptible. Despite being widespread the severity of the disease was generally not as great as in the previous season.

Black Root Rot

Black root rot was again common early in the season. It was found throughout the Namoi and Macquarie production areas causing blackening of the root system and stunting of early season growth.

Seedliug Diseases

Stand counts completed as part of the regular November disease surveys of commercial crops in the Macquarie, Namoi, Gwydir and McIntyre valleys were compared with the growers' estimates of sowing rate and 'Seedling mortality' was calculated. Seedling mortality represents the difference between the number of seeds sown per metre of row and the number of plants established. It includes the effects of seed quality or viability, seedling diseases and the effects of some insect pests that attack seedlings. The results show that there had been a decline in mean seedling mortality over the previous ten seasons (see figure). Factors contributing to this decline have not been determined. They could include better ground preparation and planting practices, better seed quality, better seed treatment formulations, reduced impact of pre-emergent herbicides, better soil insect control etc. etc..

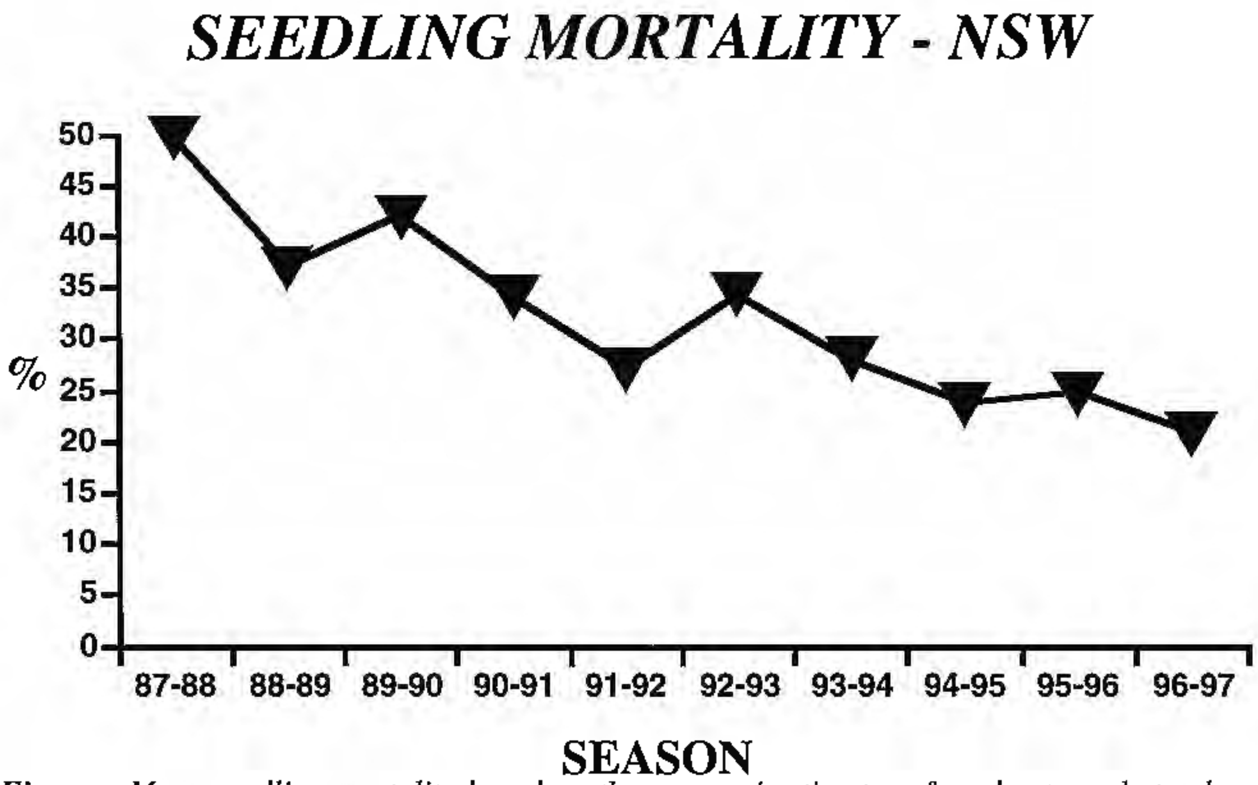


Figure *- Mean seedling mortality based on the growers' estimates of seed rate and stand counts determined during the November disease survey of commercial cotton crops in the Macquarie, Namoi, Gwydir and McIntyre valleys of NSW. Seedling mortality represents the difference between the number of seeds sown per metre of row and the number of plants established. It includes the effects of seed quality or viability, seedling diseases and the effects of some insect pests that attack seedlings.*

Disease Surveys - 1997/98

Commercial cotton fields in the Macquarie, Namoi, Gwydir and McIntyre Valleys and in the Bourke area were again inspected in November 1997 and February-March 1998 and the incidence and severity of those diseases present were assessed. Field history, trash carryover, ground preparation, cultivar, planting date and seed rate were also recorded for each of the 89 fields surveyed. This represented the fifteenth year of disease surveys in NSW.

Fusarium Wilt

Fusarium wilt was reported and confirmed at three new sites in NSW during the 1997/98 season. All three of these sites had connections via floodwater or vehicle and machinery movement to areas where the disease had previously been reported. Dr Joe Kochman also reported Fusarium wilt in new areas of Queensland at Warra and Theodore.

Of some concern was that the disease was quite severe in two fields of Sicala V2 and a field of DeltaGEM- cultivars that were considered to be among those that are least susceptible to Fusarium wilt. On a positive note the incidence of Fusarium wilt in a field near Boggabilla had declined over the previous three seasons from 13.4% in 1994/95 (Siokra L23) to 3.4% in 1997/98 (Sicot 189).

Verticillium Wilt

Verticillium wilt is favoured by cool weather conditions. The hot start to the 1997/98 season and the hot, dry finish to the season were not conducive to the development of this disease. However, the week of overcast wet weather in late summer was ideal! The incidence of the disease in a susceptible cultivar, in a field at Bourke was found to be 70%. Where resistant cultivars are being used the incidence of the disease continues to decline.

The incidence of the disease was assessed in several fields at Auscott Narrabri where the incidence had exceeded 60% in previous disease surveys. The results (see Table) show a considerable decline in the significance of Verticillium wilt on this farm.

***Table** - The effect of repeated use of resistant cultivars on the incidence of Verticillium wilt of cotton at Auscott Narrabri.*

Field No.	Incidence (season)	Incidence in 1997/98
12	70% (1988/89)	4.5%
31	67% (1988/89)	6.5%
4	64% (1989/90)	18.5%
33	74% (1990/91)	7.0%
21	72% (1993/94)	22.5%

Phytophthora Boll Rot

This disease occurs when wet soil is splashed up on to low bolls that are about to open or when mature bolls are temporarily submerged either in water in the furrow or when water backs up from the tail drain. A well established and closed canopy minimises the chance of soil splash onto low bolls.

The wet weather experienced in some areas in February, 1998 was conducive to the development of this disease. Phytophthora boll rot was found in 52 of the 89 fields inspected at the end of the season and incidence varied from a trace up to 5.5% in a field near Burren Junction.

Alternaria Leaf Spot

Alternaria leaf spot is favoured by wet weather conditions coupled with the use of susceptible cultivars, retention of crop residues from one season to the next and physiological stresses on the host crop such as those caused by a heavy fruit load or nutritional imbalances etc. The development of premature senescence and reddening can be associated with severe epidemics.

The hot, dry finish to the season did not allow significant development of Alternaria leaf spot although the disease was present at very low levels in many areas. There was some defoliation due to Alternaria leaf spot in crops of Pima cotton in the Bourke area.

Bacterial Blight

Nearly all cultivars of upland cotton grown in Australia are immune to the bacterial blight pathogen. However, Pima cultivars are very susceptible. Prior to the 1995/96 season bacterial blight was not observed in Pima cotton in the Bourke area. In 1996/97 the disease was observed in pure seed crops at low levels. In 1997/98 the incidence of bacterial blight was high especially in second-year fields where residues from the previous cotton crop had carried over. In one field near Bourke 72% of bolls were infected and significant defoliation had occurred. The disease was found in all Pima pure seed crops that were inspected.

Black Root Rot

Despite the warm start to the season black root rot was found in 11 of the 15 fields inspected in the Macquarie valley and in 8 of the 26 fields inspected in the Namoi valley as well as in the Gwydir and McIntyre Valleys. Symptoms of the disease included significant stunting and poor early season growth.

Seedling Diseases

The incidence of seedling diseases was generally low and the need to replant was most often associated with the cool, wet weather during that first weekend in October or with herbicide relocation or soil crusting resulting from the rain.

DISPERSAL OF COTTON PATHOGENS

We have emphasised the importance of minimising the transfer of soil and crop residues from farm to farm in order to restrict the spread of diseases and weeds. A recent exercise at ACRI supported this emphasis.

Soil was collected from underneath 16 visitor's vehicles parked at ACRI during the 1998 Namoi valley cotton field day. The samples were tested for the black root rot fungus, *Verticillium* sp. and *Fusarium* sp.

*3 of the 16 vehicles were carrying the black root rot pathogen !
*12 of the 16 vehicles were carrying *Verticillium* sp.!
*15 of the 16 vehicles were carrying species of *Fusarium* ! **Not the cotton fusarium!**
Samples were not tested for the presence of weed seeds.

SEEDLING DISEASES

EVALUATION OF FUNGICIDE SEED TREATMENTS

Two fungicide seed treatment trials were planted in the 1995/96 season. The Narrabri trial was completely wiped out by hail in November 1995 and only the Darling Downs trial was completed. Two fungicide seed treatment trials were completed during both the 1996/97 and 1997/98 seasons. These experiments were made possible by the collaboration of CSD (Seed, seed treatment application and packeting of seed), Deltapine Australia (Planting and assessment of the Darling Downs trial) and NSW Agriculture (Planting and assessment of the Narrabri trial).

The main objectives of these field experiments were to evaluate potential new fungicide seed treatments against the performance of the Standard (PCNB / Apron), to evaluate the activity of new formulations (Apron XL) and to compare the efficacy of the reduced rate of PCNB which is widely used in Australia with that of the much higher rate of PCNB used in the USA.

1995/96

The results of the Darling Downs trial, though significant, were discounted as a result of the very high Coefficient of Variation (26%). As mentioned previously the ACRI trial was destroyed by hail prior to assessment.

Darling Downs site (planted and assessed by Deltapine)

Fungicide Seed Treatment	stand/100	% of mean
Vitaflo/Apron	53.95	123.0
Pcnb(US)/Apron	52.13	118.8
Pcnb(std)/Apron Amplify	51.79	118.1
Rizolex/Apron	46.95	107.0
ApronQ	45.86	104.5
Pcnb(std)/Apron Kodiak	44.96	102.5
Pcnb(std)/Anchor	44.94	102.5
Pcnb(std)/Apron Naturakelp	44.65	101.8
Nusan/Nuflow/Apron	44.16	100.7
Pcnb(US)/Anchor	44.04	100.4
Anchor	43.26	98.6
Pcnb(std)/Apron/Baytan	42.97	98.0
Vitavax Apron	42.95	97.9
Untreated	42.33	96.5
Vitavax/Pcnb/Apron	41.62	94.9
Baytan/Apron	39.62	90.3
Apron	39.55	90.2
Kodiak	38.18	87.0
Naturakelp	37.04	84.4
Pcnb(std)/Apron	36.36	82.9
Average LSD - 10.33		
Av. standard error of difference 5.1650		
F-ratio (19, 152 df)	1.7537	% prob 3.6
Coefficient of Variation	26.3286	

1996/97

The results (see Tables) show that (i) there was nothing significantly better than the PCNB/Apron standard, (ii) the higher rate of PCNB used in the USA did not improve survival compared with the lower standard rate used in Australia, and (iii) the new, more concentrated Apron XL formulation was similar in performance to the older formulation.

Darling Downs site (planted and assessed by Deltapine)		
Fungicide Seed Treatment	stand/100	% of mean
ApronTriple	64.24	109.1
Pcnb(std)/Apron	62.77	106.6
Pcnb(US)/Apronxl	62.23	105.7
Pcnb(std)/Apronxl	61.32	104.2
Pcnb(US)/Apron	61.27	104.1
Apronfdl	61.10	103.8
Vitavax/Thiram/Apron	60.56	102.9
Vitavax/Pcnb/Apron	60.45	102.7
Pcnb(std)/Apron/Baytan	59.68	101.4
Pcnb(std)/Apron/Kodiak	59.45	101.0
Nusan/Nuflow/Apron	59.06	100.3
Baytan/Apron	58.80	99.9
Vitaflo/Apron	58.47	99.3
Apron	57.80	98.2
Rizolex/Apron	57.51	97.7
Apronxl	56.41	95.8
Kodiak	50.52	85.8
Untreated	47.98	81.5
Average LSD - 7.384		
Av. standard error of difference 3.6922		
F-ratio (17, 133 df)	2.2693	% prob 0.5
Coefficient of Variation	13.9073	

Narrabri site (planted and assessed by NSW Agriculture)		
Fungicide Seed Treatment	stand/100	% of mean
Pcnb(std)/Apron	83.94	103.9
Vitavax/Thiram/Apron	83.41	103.3
Pcnb(std)/Apronxl	83.23	103.1
Vitaflo/Apron	82.51	102.2
ApronTriple	82.30	101.9
Baytan/Apron	81.84	101.4
Pcnb(US)/Apronxl	81.83	101.3
Vitavax/Pcnb/Apron	81.77	101.3
Nusan/Nuflow/Apron	81.61	101.1
Pcnb(US)/Apron	81.51	100.9
Pcnb(std)/Apron/Baytan	80.23	99.4
Rizolex/Apron	80.19	99.3
Untreated	79.58	98.5
Kodiak	79.46	98.4
Pcnb(std)/Apron/Gly5	79.23	98.1
Apron	79.21	98.1
Pcnb(std)/Apron/Gly7	78.82	97.6
Pcnb(std)/Apron/Kodiak	78.62	97.4
Apronxl	78.22	96.9
Apronfdl	77.49	96.0
NOT SIGNIFICANT		
Av. standard error of difference 2.4886		
F-ratio (19, 152 df)	1.1755	
Coefficient of Variation	6.8912	

1997/98

The results (see Tables) show that there were no significant differences between the treatments despite significant seedling mortality, especially in the Darling Downs trial. Treatments based on Apron alone and untreated seed showed the lowest emergence in both trials suggesting that *Pythium* sp. were not a significant component of the seedling disease microflora in this season.

Darling Downs site (planted and assessed by Deltapine)		
Fungicide Seed Treatment	stand/100	% of mean
Nusan/Nuflow/Apron	58.12	110.7
Pcnb(US)/ApronXL	56.06	106.7
Thifluzamide/Apron	56.04	106.7
Baytan/Thiraflo/Kodiak/Apron	56.02	106.7
Pcnb(std)/ApronXL	55.66	106.0
ApronTriple	55.15	105.0
Pcnb(std)/Apron	54.47	103.7
Pcnb(US)/Apron	54.11	103.0
Vitavax/Pcnb/Apron	52.65	100.2
Baytan/Apron	52.23	99.4
Vitavax 200FF/Apron	51.00	97.1
Rizolex/Apron	50.21	95.6
Pcnb(std)/Apron/Baytan	49.76	94.7
Vitavax/Pcnb/Apron/Thiram	49.66	94.6
Apron	49.32	93.9
Pcnb(std)/Apron/Kodiak	49.31	93.9
Apron XL	48.91	93.1
Untreated	46.72	88.9
NOT SIGNIFICANT		
Av. standard error of difference	3.5480	
F-ratio (17, 136 df)	1.6202	% prob 6.9
Coefficient of Variation	15.1052	

Narrabri site (planted and assessed by NSW Agriculture)		
Fungicide Seed Treatment	stand/100	% of mean
Vitavax/Pcnb/Apron/Thiram	75.12	108.5
Pcnb(std)/Apron/Kodiak	73.96	106.9
Baytan/Thiraflo/Kodiak/Apron	73.19	105.7
ApronTriple	71.95	104.0
Nusan/Nuflow/Apron	71.27	103.0
Pcnb(std)/Apron/Baytan	71.23	102.9
Baytan/Apron	70.59	102.0
Pcnb(US)/Apron	70.34	101.6
Pcnb(US)/ApronXL	69.22	100.0
Vitavax/Pcnb/Apron	67.95	98.2
Rizolex/Apron	67.90	98.1
Pcnb(std)/Apron	67.86	98.1
Thifluzamide/Apron	67.17	98.1
Vitavax200FF/Apron	66.68	96.3
Pcnb(std)/ApronXL	66.59	96.2
ApronXL	65.69	94.9
Untreated	65.61	94.8
Apron	63.47	91.7
NOT SIGNIFICANT		
Av. standard error of difference	4.0458	
F-ratio (17, 127 df)	1.3219	%prob 19.0
Coefficient of Variation	2.7404	

EFFECT OF SEED TREATMENTS ON SEED COTTON YIELD

The objective of these experiments was to demonstrate the economic (yield) benefit from the use of seed treatment fungicides and insecticides. Two field experiments were established in each of the three seasons of the project. The three treatments in each of the experiments included untreated seed, seed treated with fungicide only and seed treated with both fungicide and insecticide. Unfortunately the 1995/96 experiments were destroyed by hail.

Despite significant differences in established plant stand, in three of the four experiments, there were no significant seed cotton yield advantages to any of the treatments.

***Table** The results of four field experiments showing the effect of insecticide and fungicide seed treatments on plant stand and seed cotton yield*

Planting date	Parameter	Untreated	Fungicide only (PCNB Apron)	Fungicide + Insecticide (+ Semevin)	Average LSD
2/10/96	plants/20m	191.7	199.0	180.0	12.79
	yield	5073	4969	5083	n.s.
21/10/96	plants/20m	175.2	211.8	191.2	17.70
	yield	5594	5281	5219	n.s.
15/10/97	plants/20m	143.2	159.0	162.5	n.s.
	yield	5459	5396	5507	n.s.
3/11/97	plants/20m	132.3	186.2	177.5	26.77
	yield	4799	5084	5271	n.s.

IN-FURROW AND PLANTER-BOX TREATMENTS

Field experiments to evaluate a selection of hopper-box and in-furrow fungicides were planted in both the 1995/96 and 1996/97 seasons. These experiments were duplicated to include an early (late September/early October) and a late (late October) planting. Unfortunately the 1995/96 trials were destroyed by hail in November 1995 and no results were obtained for this season (See Table).

The CRDC funded review of Cotton Pathology in March 1997 suggested that further evaluation of the efficacy of hopper-box and in-furrow fungicide treatments for seedling disease control was unwarranted. Only one of nine field experiments over a five year period demonstrated a significant yield benefit from the use of these supplementary seedling disease control treatments.

***Table** The results of two field experiments showing the effect of various hopper-box and in-furrow fungicide treatments on plant stand and seed cotton yield*

Planting Date	Treatment	Plants/20m	Seed cotton Yield (Kg/ha
2/10/96	Treated seed	158.3	2610
	+ Terraclor Super X 20-5 HB dust -10g/kg seed	151.0	2545
	+ Apron Terraclor HB dust - 4.5g/kg seed	135.0	2722
	+ Rizolex HB dust - 40g/kg seed	134.7	2579
	+ Rizolex I-F spray - 60g a.i./ha	160.5	2742
	+ SM-9 I-F spray - 585ml/ha (8oz/acre)	168.5	2706
	Average LSD	16.39	N.S.
21/10/96	Treated seed	147.0	4708
	+ Terraclor Super X 20-5 HB dust -10g/kg seed	149.0	4806
	+ Apron Terraclor HB dust - 4.5g/kg seed	157.8	4688
	+ Rizolex HB dust - 40g/kg seed	144.3	4479
	+ Rizolex I-F spray - 60g a.i./ha	144.5	4493
	+ SM-9 I-F spray - 585ml/ha (8oz/acre)	137.3	4868
	Average LSD	N. S.	N.S.

THE US 'COTTON SEEDLING DISEASE POINT SYSTEM'

The 'Beltwide Seedling Disease Program' co-ordinated by Dr Don Blasingame and sponsored by the American Cotton Foundation through a grant from Rhone Poulenc Ag Company has developed a 'Cotton Seedling Disease Point System' to determine "if the use of an in-furrow-applied fungicide is likely to improve seedling stands, vigour and yields". This system allows a grower to allocate points on the basis of 3-day average soil temperature at 10cm; 5-day forecast; seed quality based on cold germination value; field history for seedling disease; tillage (No-till, min-till, conventional); seeding rate; and use of an in-furrow nematicide/insecticide. If the points total exceeds 13 then use of an in-furrow soil fungicide is recommended. This 'Point System' was applied to the conditions at Narrabri during the 1997/98 season. Results indicated that the use of an in-furrow soil fungicide would have only been advantageous during the wet October long weekend when growers were unable to plant because it was too wet!

"ALTERNATIVE" SEED TREATMENTS

Numerous nutrient (Calcium, Zinc, Potassium) based, or microbial, seed treatments are promoted as being effective seedling disease control treatments and 'stimulants' of early season growth of cotton. These have been subjected to preliminary evaluation. Products evaluated in the past three seasons include Stand, MR Microbes, Super Symcoat, Teprosyn and KKomplex. No seedling disease control has been demonstrated by any of these products.

VERTICILLIUM WILT

THE DEVELOPMENT OF NEW STRAINS OF *VERTICILLIUM DAHLIAE* IN AUSTRALIA

Verticillium wilt of cotton is caused by *Verticillium dahliae* Kleb.. Work by Schnathorst and Evans (1971) and Bell (1994) showed that strains of the pathogen isolated from cotton in Australia cause mild symptoms (vegetative compatibility group 4) when compared to those strains that occur overseas (vegetative compatibility groups 1 and 2). The severe defoliating strain of *V. dahliae* is not known to be present in Australia.

When cultivars with some resistance to *V. dahliae* were released by CSIRO in 1990 they were widely adopted. By 1996/97 the area sown to resistant cultivars had increased to 85 per cent of the area sown to cotton in NSW. The new cultivars are not immune to the verticillium wilt pathogen and their resistance is indicated by reduced disease incidence and reduced disease severity.

The adoption and repeated use of cotton cultivars with resistance to *V. dahliae* in California resulted in the selection and increased prevalence of more virulent strains of the pathogen and consequently an increased incidence of disease in successive years (Ashworth et al., 1983). Their observations had confirmed the earlier work of Schnathorst and Mathre (1966) who had suggested that the 'demise' of verticillium wilt tolerant cotton cultivars in California was caused by a build-up of more virulent strains of the pathogen in the soil as a result of host selection pressure.

The objective of the study reported here was to evaluate the durability of the resistance to Verticillium wilt in commercial Australian cotton cultivars. A field experiment was established to investigate the effect of six consecutive cotton crops on the incidence of verticillium wilt.

Materials and methods

A Verticillium wilt 'nursery' was established in 1991 in a field at the Australian Cotton Research Institute by incorporating gin trash collected during the processing of cotton harvested from fields where the incidence of the disease was known to be high. The development of disease symptoms in the 'nursery' was further encouraged by delaying the sowing date, increasing the irrigation frequency and using higher nitrogen fertiliser rates (El-Zik, 1985). These practices effectively delayed crop maturity and favoured the pathogen.

A susceptible cultivar, Siokra 1-4 was grown over the entire area prior to starting the long term experiment. The trial area was subsequently divided into six plots with each plot being eight rows wide and 45m long. Three plots were planted to the cultivar Siokra 1-4 for the next six seasons and the remaining three plots were sown with the partially resistant cultivars Sicala V1 or Sicala V2. The cultivar Sicala V2 was a selection from the original Sicala V1 and was released commercially in 1994.

The incidence of verticillium wilt was assessed on the basis of vascular discoloration at the end of each season after cutting the stem with secateurs at ground level. Prior to 1997 assessments were based on ten groups of of ten plants selected along a zig-zag path from one end of the plot to the other using only the four centre rows (100 plants/plot). In March of 1997 and 1998 four groups of ten plants were assessed in each of the eight rows of each plot (320 plants/plot).

Results and discussion

The incidence of verticillium wilt in the susceptible cultivar, Siokra 1-4, was 95 per cent in the first year and increased to over 99 per cent in each of the last three seasons (See Figure). The incidence of the disease in the resistant cultivar, Sicala V2, declined significantly during the first three seasons. However, the decline ceased during the last three seasons (See Figure). Closer examination of the plots revealed that there were areas within the plots where the incidence of verticillium wilt had increased (See Figure). Consequently the assessments of disease incidence in the Sicala V2 plots were more detailed in the 1996/97 and 1997/98 seasons.

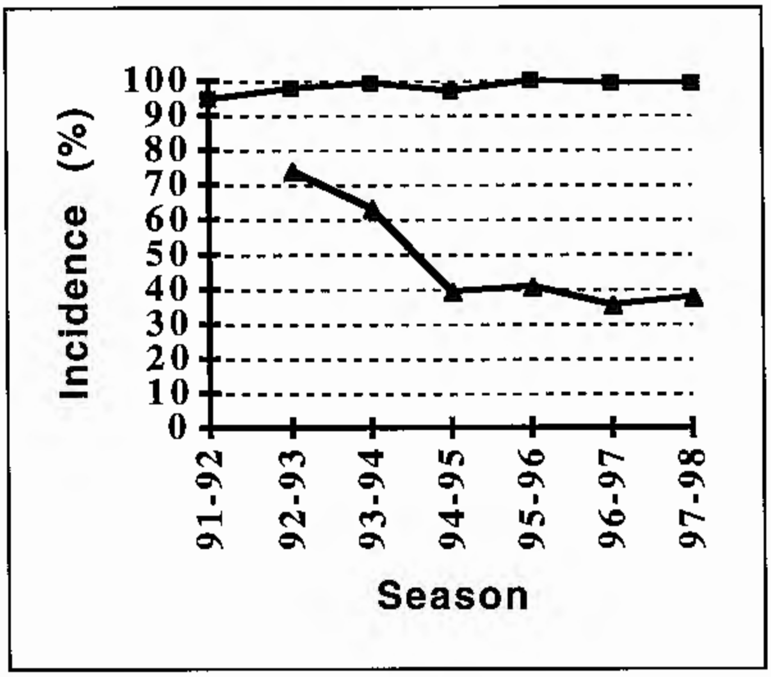


Figure *The incidence of verticillium wilt of cotton in a resistant (s) and a susceptible (n) cultivar when grown repeatedly in the same plots for six consecutive seasons.*

In the 1996/97 season, when the mean incidence of verticillium wilt across the three replicates of the resistant cultivar was 35 per cent, there were seven areas where the incidence was greater than, or equal to, 70 per cent. In the 1997/98 season, when the mean incidence of verticillium wilt across the three replicates of the resistant cultivar was 37.5 per cent, there were thirteen areas where the incidence was greater than, or equal to, 70 per cent (Figure 2). There appeared to be no increase in the severity of the disease symptoms in plants where the incidence of verticillium wilt was high.

Conclusion

Schnathorst and Mathre (1966) and Ashworth et al. (1983) in California found that the repeated use of cotton cultivars with resistance to *V. dahliae* resulted in the selection of more virulent strains of the pathogen and a consequent breakdown in the level of cultivar resistance. Despite the widespread and repeated use of resistant cultivars in Australia there has been no evidence of the development of more virulent strains of the pathogen in commercial cotton fields to date.

However, the occurrence of small areas in the verticillium wilt nursery experiment, where the incidence of disease is increasing, has indicated that the selection of more virulent strains of the pathogen may be possible under Australian conditions. It should be remembered that the environmental conditions provided in this experiment favoured the pathogen and there were no crop rotations included with either treatment.

Isolates of the pathogen collected from within these areas of higher incidence need to be characterised. It is essential that the incidence of verticillium wilt in commercial cotton crops should continue to be monitored.

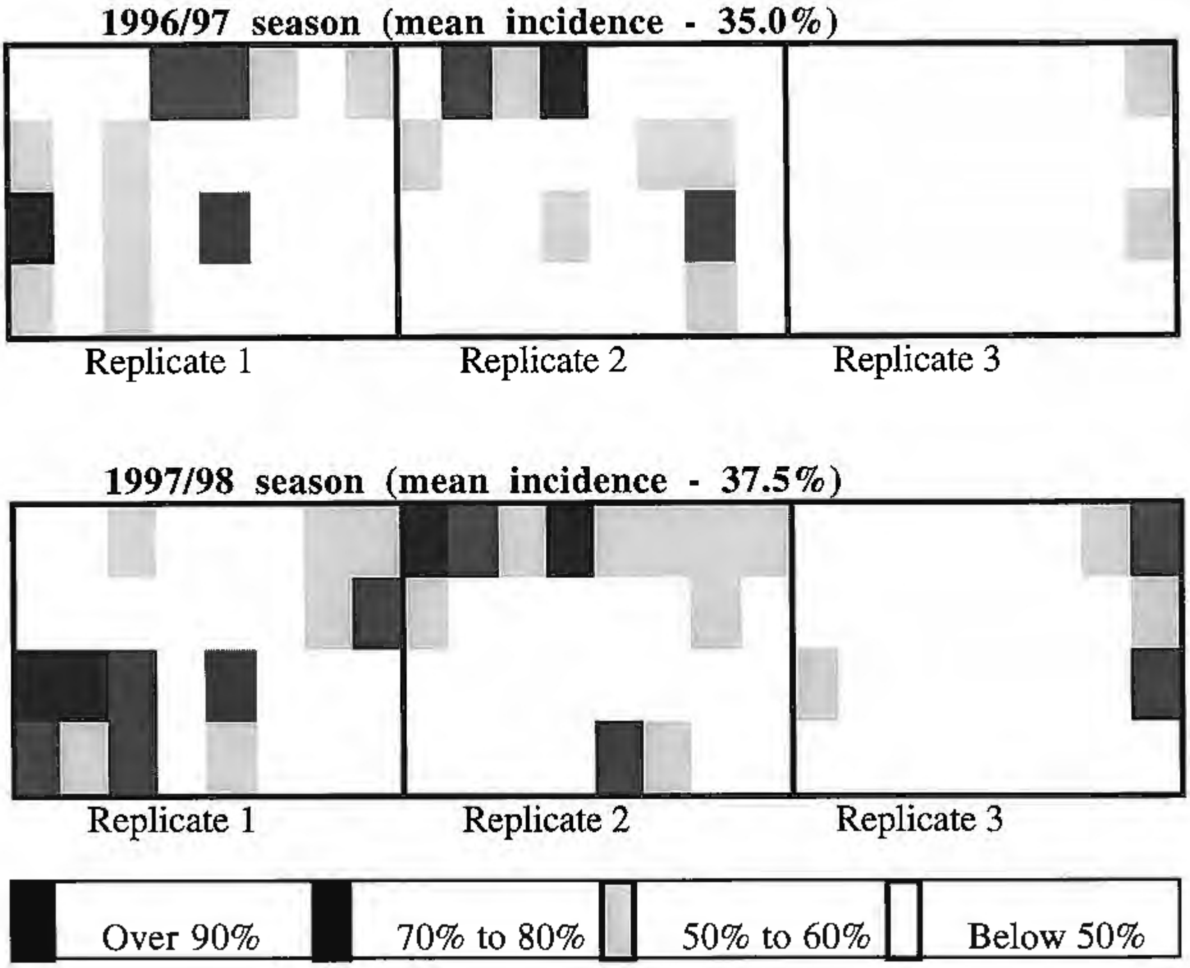


Figure *Trial plan showing areas within the trial plots where the incidence of verticillium wilt has increased in the last two growing seasons. Plots were eight rows wide by 45 metres long and four groups of ten plants were assessed in each row at the end of each season.*

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INTEGRATED CONTROL STRATEGY - VERTICILLIUM WILT

Two long term trials have also compared the repeated use of the resistant and susceptible cultivars with the addition of Integrated Pest Management (IPM) practices. The incidence of Verticillium wilt in a susceptible cultivar grown in either a cereal fallow rotation or back-to-back with retention of trash is being compared to the incidence of the disease in a resistant cultivar grown in either a double crop rotation or back-to-back with removal of crop residues and extra cultivation.

The results indicate an initial dramatic reduction in disease incidence followed by slight increases in the last three seasons. These results show similar trends to those reported earlier.

Table *The effect of different crop rotation and IPM strategies on the incidence of Verticillium wilt of cotton in a field experiment at Narrabri. The mean incidence of the disease in a susceptible cultivar grown over all plots in the 1991/92 season was 95%.*

	Treatment	92/93	93/94	94/95	95/96	96/97	97/98
Repeated cotton	Stalk-pull and remove trash, cereal green manure, heavy cultivation, resistant cotton cv.	47%	-	13%	19%	22%	26%
Repeated cotton	Stubble-mulch, permanent beds, winter fallow, susceptible cv.	95%	-	98%	100%	99%	99%
Rotation (cotton every second season)	Stalk-pull and remove trash, cereal-summer legume double crop rotation, heavy cultivation, resistant cotton cv.	33%	-	15%	-	18%	-
Rotation (cotton every second season)	Stubble-mulch, permanent beds, cereal fallow, susceptible cv.	72%	-	85%	-	94%	-

VERTICILLIUM WILT IN INGARD COTTON

A small field experiment with eight replications was established in October 1996 in the Verticillium nursery to determine if the addition of the Ingard gene affected a cultivar's resistance or susceptibility to verticillium wilt. The cultivars CS 50 and CS 50i were planted in single row plots that were 20m long and disease incidence was assessed in March 1997. No significant difference was observed with 88% and 85% of plants being infected in the two treatments.

COMPOSTED GIN TRASH AND VERTICILLIUM WILT

There has been increasing interest in composting gin trash and reapplying it to cotton fields, instead of burning it, as a means of disposal. One of the major concerns is the carryover of pathogens such as *Verticillium dahliae*. Previous work has shown that this pathogen is very common in gin trash. According to the results obtained from studies in the USA the temperatures achieved during the composting process are sufficient to kill the pathogen.

Compost samples from Warren and Goondiwindi have been submitted for testing for the presence of *V. dahliae* using Ethanol Streptomycin Agar as a selective medium.

The composting process at Warren involves placement of the gin trash in windrows with regular addition of water and regular turning. Test results indicated that the majority of the compost was free of the pathogen. However the pathogen could still be recovered from the small amounts of incompletely composted material from the edge of the piles. It was recommended that more care be taken to 'fold in' the gin trash along the edge of the windrows when turning the compost.

Samples received from Goondiwindi were from an undisturbed pile of gin trash. Samples from well within the pile were relatively free of the pathogen but samples from the surface of the pile contained up to 30 propagules of *V. dahliae* per gram of material.

The results confirm the need to compost the gin trash thoroughly in order to eliminate the carryover of the Verticillium wilt pathogen.

BLACK ROOT ROT

Cotton seedlings affected by black root rot are stunted and slow-growing with blackened tap-roots and poorly developed, blackened secondary roots - often occurring in distinct patches across the field. The blackened tissue that encases the root can be easily removed to show a healthy white centre. As the soil temperature rises the vegetative growth of the seedling resumes and most of the blackened, diseased tissue is sloughed off - eventually leaving little evidence of infection. The disease causes slow early-season growth and consequent delayed maturity. SOMETIMES - the disease continues to affect the plant through to maturity resulting in pale, unthrifty plants with a layer of blackened tissue (an internal ring rot) within the swollen crown region of the stem.

The pathogen that causes black root rot of cotton (*Thielaviopsis basicola*) has previously been recorded in Australia on numerous ornamentals, legumes, tobacco and radiata and pinaster pine. Overseas reports indicate that it can cause disease in over 137 species of plants. The fungus survives in the soil for long periods as dark, thick-walled resistant spores. Weeds in the crop rotation may also assist in survival. The use of permanent bed systems may be contributing to the increasing prevalence of the disease by retaining high numbers of spores in the top of the hills directly beneath the germinating seeds of the following cotton crop. The spores may be dispersed in association with crop trash or in soil carried by flood water, machinery or muddy boots! The development of disease symptoms is favoured by cool, damp, spring conditions with 15 - 20^{0}C being optimum.

FUNGICIDE TREATMENTS AT PLANTING

Until recently the only recommended control measure for black root rot was to avoid early planting in affected fields. At least two seed treatments have now been registered for the control of this disease in the USA. These treatments have been evaluated in Australia with mixed results. **However, it should be noted that the level of pathogen inoculum in the soil at the 'Merinda' trial site was up to 8 times that required to give severe symptom development.**

The six treatments evaluated in the 1995/96 experimemt at 'Merinda' near Wee Waa included a fungicide seed treatment, a hopper-box treatment and a product which is reported to initiate Systemic Induced Resistance in other plants. In addition to these treatments the fungicide seed treatment Celeste (= Apron Q = metalaxyl + fludioxonil) was tested in small handplanted plots at the end of the trial area. None of the treatments significantly reduced the incidence or severity of black root rot (see Table).

In the 1996/97 season two field experiments were established at 'Merinda' near Wee Waa to evaluate the efficacy of (i) seed treatment fungicides and (ii) in furrow fungicides, on the severity of Black root rot of cotton. None of the seed treatments gave adequate control of the disease (see Table). All three in-furrow rates of Baytan (triadimenol), applied with or without a Baytan seed treatment, caused significant delays in seedling emergence and the severity of Black root rot was unaffected.

Table *The effect of various treatments on the severity of black root rot of cotton at 'Merinda near Wee Waa in the 1995/96 season.*

Treatment	Black root rot rating #	% site mean
1. Untreated seed	3.60	104.5
2. Baytan (triadimenol) - a fungicide seed treatment	3.57	103.6
3. Kodiak AT (a hopper-box formulation of *Bacillus subtilis*, pcnb and metalaxyl)	3.55	103.1
4. Baytan + Kodiak AT	3.33	96.8
5. SIR (Novartis Systemic Induced Resistance product applied as spray to cotyledons)	3.33	96.8
6. Baytan + Kodiak AT + SIR	3.28	95.3
Average standard error of difference	0.1351	
F-ratio (5,20 df)	2.2114	% prob 9.3
Coefficient of Variation	6.7949	

\# - Black root rot was assessed on a scale of '0' to '4' where '0' = healthy and '4' = 75-100% of the tap root blackened with few or no lateral roots remaining.

Table *The effect of fungicide seedtreatments on the severity of black root rot of cotton at 'Merinda near Wee Waa in the 1996/97 season.*

Treatment	Black root rot rating #	% site mean
1. Quintozene-Apron (pcnb - metalaxyl - Standard)	3.95	101.4
2. Quintozene-Apron + Kodiak (*Bacillus subtilis*)	3.92	100.6
3. Baytan 1 (1.5ml/Kg seed- triadimenol)	3.95	101.4
4. Baytan 2 (3.0ml/Kg seed)	3.77	96.7
5. Apron Triple (metalaxyl, fludioxonil, difenconazole)	3.90	100.1
6. Real (triticonazole)	3.88	99.7
Average standard error of difference	0.0771	
F-ratio (5,29 df)	1.6107	% prob 18.9
Coefficient of Variation	3.3794	

\# - Black root rot was assessed on a scale of '0' to '4' where '0' = healthy and '4' = 75-100% of the tap root blackened with few or no lateral roots remaining.

IPM STRATEGIES FOR BLACK ROOT ROT CONTROL

It would appear that no single control practice will provide adequate control of black root rot and that an integrated control strategy is required. This strategy may include a fungicide seed treatment, the use of a rotation crop and a treatment to reduce the survival of inoculum in the planting line in the middle of the bed. Work under the previous project showed that there is no host plant resistance currently available.

Research in Arkansas has shown that the incorporation of a hairy vetch (*Vicia villosa*) green manure crop results in the production of ammonia in the soil. This ammonia is toxic to the spores of *T. basicola* and the amount of viable inoculum in the soil is reduced. Successful establishment of hairy vetch requires early planting(April-May) and sufficient rainfall, or an irrigation, during winter. Experience has shown that late planting does not allow time for sufficient growth (1995) and planting vetch near cereal crops which are sprayed for broadleaf weed control can be disastrous (1996)

Since ammonia is the 'active component' of the hairy vetch green manure crop strategy it was decided to test the application of either ammonium sulphate or anhydrous ammonia into the middle of the bed along the planting line where the spores of *T. basicola* are concentrated. It was estimated that 6-8g ammonium sulphate per metre of row would produce a concentration of approximately 10ppm ammonia (I. A. Rochester - pers. comm.)

A small plot experiment with 6 replicates was established in field 35 at 'Merinda' near Wee Waa. Ammonium sulphate was applied by hand at 10-15cm on 25/9/96 at rates of 0, 5, 10, and 15g/metre of row. Cotton was planted with a commercial planter 15/10/96 and assessments of Black root rot severity were made on 11/1196. No significant control of black root rot was apparent in any of the treatments. Future evaluations of this method should consider timing and placement of the ammonium sulphate.

An attempt to evaluate onions as a rotation crop in collaboration with Auscot Warren was aborted when a herbicide applied to the rest of the field severely affected the area of onions in the trial. Dr Richard Garber from California had suggested that onions may have a negative effect on the survival of the Black root rot pathogen. Extensive sampling of soil from this trial site showed that there was considerable variation in inoculum levels within plots in the trial area.

Two field experiments were set up in fields 2 and 2A at Agrilands Byron during the 1997/98 season to evaluate combinations of fungicide seed treatment and either incorporation of a hairy vetch green manure crop or shallow application of 50 units of anhydrous ammonia direct into the middle of the bed prior to planting. Inoculum concentration in the beds, seedling growth and the severity of black root rot symptoms on seedlings were monitored in both trials. No significant differences were observed.

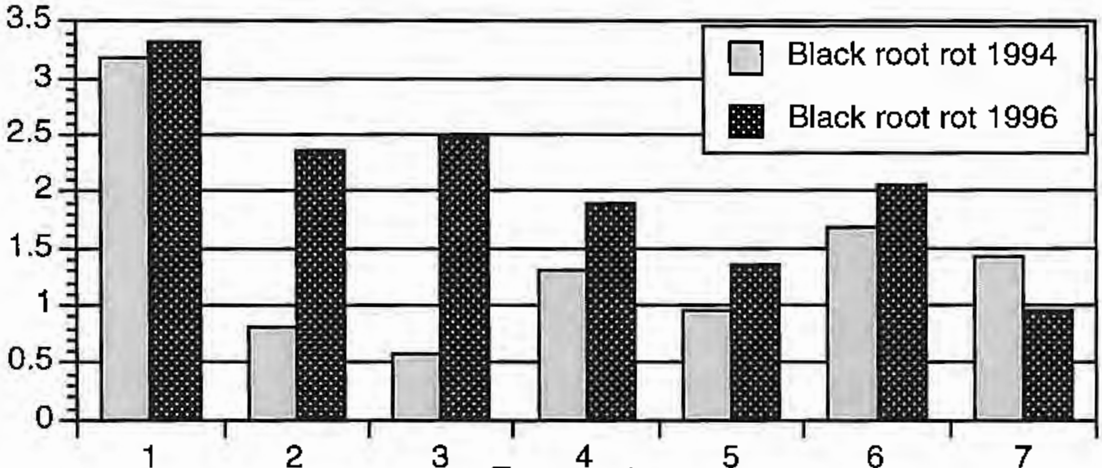
THE WARREN FARMING SYSTEMS EXPERIMENT

The severity of black root rot has been assessed at the Warren Farming Systems site in both November 1994 and November 1996. The seven treatments included in this farming systems experiment were as follows:

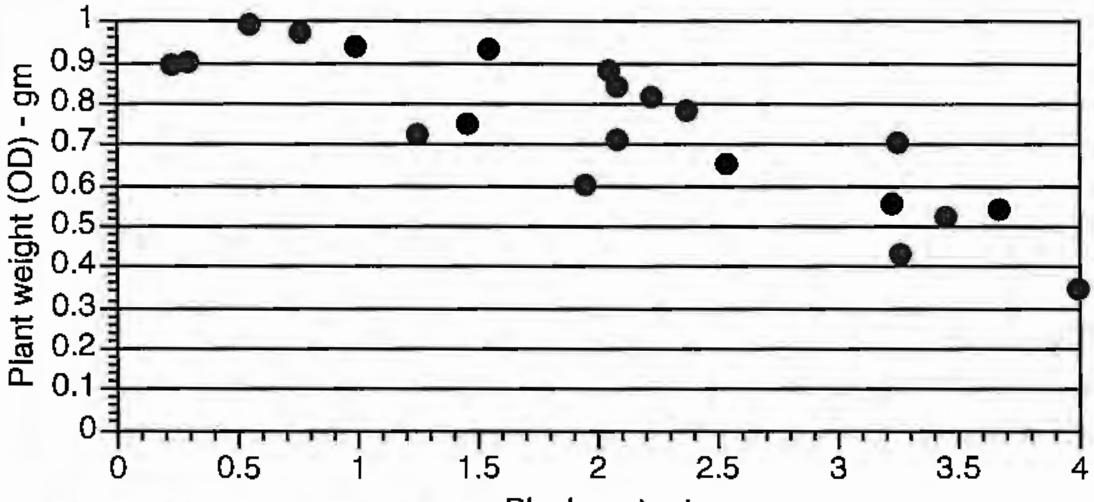
1. Cotton-cotton-cotton
2. Cotton-long fallow-cotton
3. Cotton-field pea-cotton
4. Cotton-low input wheat-cotton
5. Cotton-high input wheat-cotton
6. Cotton-wheat-lab lab-cotton
7. Cotton-wheat-lab lab-cotton with extra N, P & K fertiliser

The distribution of the disease in the field remained similar - however symptoms were more severe in the 1996 assessment for six of the seven treatments. This may have been due in part to the conducive environmental conditions experienced in the 1996/97 season as well as to the rotation treatments involved. The highest incidence of the disease occurred in those plots where cotton had been grown each season ("1"). The incidence of the disease had increased most in treatments "2" (+190%) and "3"(+327%) and declined in treatment "7"(-32%).

Black root rot was assessed on a scale of '0' to '4' where '0' = healthy and '4' = 75-100% of the tap root blackened with few or no lateral roots remaining.



The mean incidence of Black root rot for each of the seven treatments in the Warren Farming Systems trial as assessed in 1994 qnd 1996.



Relationship between Black root rot severity and plant weight at six weeks after planting. Healthy plants were approx. 3 times the size of the most severely affected plants (Warren Farming Systems - November 1996)

FUSARIUM WILT

Fusarium wilt of cotton is caused by *Fusarium oxysporum* f.sp. *vasinfectum* (*Fov*). The known distribution of the pathogen in NSW is limited to just 10 farms (as at September, 1998). The Boggabilla strain of the pathogen is confined to five farms in the Boggabilla area and to one of the farms in the Moree area where it occurs along with the Downs strain of the pathogen. The Downs strain occurs throughout Queensland and on five farms in NSW.

The limited distribution of the pathogen has made it difficult to identify suitable sites for field experimentation in NSW and much of the work on developing a control strategy for Fusarium wilt of cotton is being done in Queensland under the supervision of Dr Joe Kochman. Where sites have been available it has been necessary to try and fit experiments within a strip so that plots have relatively even exposure to infection by the pathogen. For this reason Coefficients of Variation for some analyses were unacceptably high.

HOST PLANT RESISTANCE

Since the strain of the pathogen in the Boggabilla area was distinctively different from the strain that occurred in other areas it was considered necessary to repeat the evaluation of available host plant resistance that was being completed elsewhere. The results were similar to those obtained by Joe Kochman and indicate that Sicot 189 and DeltaEmerald are the most resistant commercial cotton cultivars currently available in Australia (See Table).

***Table** The results of three field experiments over three seasons comparing the level of resistance/susceptibility to Fusarium wilt that is present in current commercial Australian cotton cultivars.*

1995/96		1996/97		1997/98	
Cultivar	plants/10m	Cultivar	plants/10m	Cultivar	plants/m
Sicot 189	72.95 a	Sicala V2	77.36 a	Sicot 189	11.74 a
DeltaGem	71.04 a	Sicot 189	76.94 a	DeltaEmerald	10.27 b
CS 8S	70.28 a	DeltaGem	55.36 b	Sicala V2	8.68 c
Sicala V2	66.95 b	DeltaPearl	53.38 b	CS 50	5.33 d
DeltaPearl	63.78 c	CS 50	46.35 b		
Siokra L23	58.57 d	CS 8S	46.18 b		
DPL 90	58.08 d	DPL 90	34.57 c		
CS 50	37.36 e	Siokra L23	33.75 c		
	C of V=23.8		C of V=22.4		C of V=10.34

Values in each column that are followed by the same letter are not significantly different (P=0.05)

FUNGICIDE SEED TREATMENTS

Field observations have shown that *Fov* causes significant death of seedlings early in the season. Replicated, hand planted, small-plot field experimennts were established at 'Morella' near Boggabilla to evaluate the efficacy of possible fungicide seed treatments and in-furrow and hopper-box treatments. As indicated previously large variation across the trial area contributed to high Coefficients of Variation and no significant differences were observed. Those treatments that were tested included the following:

Quintozene - Apron (pcnb, metalaxyl)
Panoctine - Apron (guazatine, metalaxyl)
P-Pickle T (thiabendazole, thiram)
Vitavax-PCNB FF - Apron (carboxin, pcnb, metalaxyl)
Rizolex - Apron (tolclofos-methyl, metalaxyl)
Apron Triple (metalaxyl, fludioxonil, difencoazole)
Quintozene - Apron - Kodiak (pcnb, metlaxyl, *Bacillus subtilis*)

SUMMER FLOODING

Reports from California indicate that flooding in summer for 30 days is effective in reducing the incidence of black root rot, Verticillium wilt and seedling diseases for up to 5 or 6 years. The incidence of the disease appears to have been significantly reduced in a field near Mungindi which was fallowed and flooded for two months in summer prior to planting with one of the more resistant cultivars in the 1996/97 and 1997/98 seasons. No disease was observed in the 1996/97 season and only 4 plants with disease symptoms were observed in the 1997/98 season.

Fusarium wilt was found in fields 5 and 6 at 'Tarcoola North' near Moree in 1996/97. These fields are located in a floodway next to the river. In order to try and eliminate the pathogen and reduce the further chances of spreading the pathogen down stream during flood events, the grower, with co-operation from his neighbour, decided to try summer flooding as a control strategy. He invested $20,000 in completing the necessary earthworks and the Department of Land and Water Conservation provided the required water in response to a request and project proposal from NSW Agriculture. The two fields were flooded during the 1997/98 season and the intention was to plant a resistant cultivar of cotton for the 1998/99 season. The incidence of the disease in these two fields is to be monitored in the future.

Although summer flooding, if effective, will not be an option that is generally available to growers, it is possible that some growers will have the opportunity during wet seasons to take advantage of this strategy.

FERTILISER TREATMENTS

There is evidence from the results of overseas studies which indicates that nitrogen, phosphorus and potassium nutrition can have a significant influence on the degree of resistance or susceptibility expressed by a particular cotton cultivar. The first report of Fusarium wilt in the Boggabilla area of NSW was in an organically grown crop of Siokra L23 following a green manured lablab crop. Consequently the disease first occurred, and was widespread, in a field where 'normal' applications of N, P and K fertiliser had not been made.

A field experiment was established in the 1995/96 season to evaluate the resistance or susceptibility of eight commercial cultivars when grown with or without the application of CK 88 fertiliser (a Crop King NPK product) and Nitrogen applied as 40 units of Urea, 180 units of Urea or 180 units of anhydrous ammonia per hectare. There was a significant interaction between cultivars and fertiliser treatments. Generally increased resistance was associated with the application of 180 units of anhydrous ammonia and increased susceptibility was associated with the use of the CK 88 fertiliser. These observations were confirmed by the results of Bo Wang's assessments of the soil population of *Fov* in the same experiment.

An attempt to repeat the experiment in the 1996/97 season was aborted when a death in the collaborator's family prevented application of the fertiliser treatments. A second attempt to repeat the experiment in 1997/98 was again aborted due to problems setting up the treatments.

ROTATION CROPS

Results of work by Bo Wang at the University of Queensland indicated that there was less build up of the pathogen in the soil when a resistant cotton cultivar was grown than when either sorghum or soybean were used as rotation crops. The results of research in California showed that even though barley was not a host of *Fov*, the pathogen was still able to colonise barley crop residues after harvest and thereby increase soil inoculum levels.

Fusarium wilt was detected in a strip extending from the head ditch to the tail drain of Field 5 on the property 'Korolea' near Boggabilla. The field was to be planted to a cereal fallow rotation with cotton to be planted again in 1999. A field experiment was established with three replicates of three treatments with plots eight rows wide and 74m long. The three treatments were barley, wheat and bare fallow.

The soil population of *Fov* was assayed by Dr Natalie Moore and Mr Wayne O'Neill of the QDPI, Indooroopilly at the commencement of the experiment and this assay will be repeated at the time of cereal harvest and immediately prior to planting cotton. Cotton seedling establishment and the incidence of fusarium wilt of cotton will be monitored in the 1999/00 cotton crop.

MANAGEMENT OF CROP RESIDUES

One of the recommended control strategies for Verticillium wilt of cotton was to incorporate crop residues as soon as possible after harvest. However, evidence suggests that the Fusarium wilt pathogen is able to exist as a saprophyte on buried crop residues and further increase the inoculum load in the soil.

Fusarium wilt was detected in a strip extending from the head ditch to the tail drain of Field 10 on the property 'Mundine' east of Boggabilla during the 1997/98 season. The field was to be planted again in 1998. Following the 1998 harvest the whole field was pulled and mulched. A field experiment was established with three replicates of three treatments with plots eight rows wide and 50m long. The three treatments were incorporation of mulched residues immediately and incorporation of residues after one and two months exposure on the soil surface. The soil population of *Fov* was assayed by Dr Natalie Moore and Mr Wayne O'Neill of the QDPI, Indooroopilly at the commencement of the experiment and this assay will be repeated immediately prior to planting cotton. Cotton seedling establishment and the incidence of fusarium wilt of cotton will be monitored in the 1998/99 cotton crop.

FIELD TRANSECTS

By monitoring the incidence of Fusarium wilt in successive seasons it is possible to determine if those control strategies that are being applied are having a positive or negative effect. The position of transects across four fields in the McIntyre valley was determined and the incidence of Fusarium wilt was assessed by inspecting 10 plants on every tenth row along each transect during late February 1998.

Fusarium wilt was first detected in 'Morella' field E2 in the 1994/95 season. An assessment along a transect 300m from, and parallel to, the tail drain indicated that 13.4% of plants of the cv. Siokra L23 were infected. The field has since had three crops of Sicot 189 which is considered to have some resistance to the pathogen. An assessment along the same transect in February 1998 indicated that only 3.4% of plants were infected. The field has again been planted to cotton in the 1998/99 season.

Fusarium wilt was first detected in 'Alcheringa' field C4 and 'Carbucky' field 17N in the 1996/97 season and in 'Mundine' field 10 in the 1997/98 season. All three fields were in cotton in 1997/98 and all three fields have been planted to a resistant cultivar of cotton for the 1998/99 season. Disease incidence along the transects was determined in February 1998 and will be monitored over the next few years.

REMOTE SENSING BY THERMAL IMAGERY

It is almost impossible to detect the presence of plants infected by *Fov* in large commercial fields or pure seed crops when the incidence of the disease is very low. However, it is essential that the disease be detected if present so that the possibility of dispersal in the seed to other cotton-growing areas can be avoided.

Agrometrics Pty Ltd introduced an irrigation scheduling service, based on thermal imagery, to growers in the Gwydir valley of NSW in 1996/97. Images taken from an altitude of 6000'feet' quickly allowed the detection of three previously unrecognised patches of Fusarium wilt-infected plants in fields 5 and 6 at 'Tarcoola North'. Bare ground and infected plants appeared "hotter" than healthy plants.

Funds were obtained to have images of cotton crops on 'Korolea' and 'Morella' taken from 1500'feet' in January 1998 after full canopy closure. When images are taken from this altitude then pixel size is approximately 73cm by 73cm and groups of two and three infected plants could be detected. These two farms are adjacent to each other and the disease was known to be present in several of the fields. The use of a differentially corrected portable GPS allowed direct access to 'hot spots' so that 'ground-truthing' could be completed. Gaps in the stand due to human error (planter or cultivator) and areas where plants are stressed by waterlogging or weed growth also appeared as hot spots.

It is suggested that this technology has a potential use in the checking of pure seed crops prior to maturity. Seed companies would need to provide GPS reference points to the corners of each pure seed crop. Agrometrics could take the images and steps have been taken to obtain the software for manipulating the images and determining those areas that need to be inspected. The use of images taken from an altitude of 1200'feet' may give increased precision.

DISCUSSION OF RESULTS

The results of disease surveys continue to assist in the development of priorities for the pathology research group at Narrabri. The declining incidence of Verticillium wilt and seedling diseases is encouraging while the increasing prevalence of Alternaria leaf spot, black root rot and Fusarium wilt is cause for concern. It would appear that the significant changes in cotton production systems, such as the move to permanent bed systems and reduced tillage practices and the introduction of legumes into rotation sequences, have contributed to increasing disease problems. In other words our attempts to improve sustainability have been counter productive in terms of disease incidence and severity.

The increasing distribution and prevalence of the 'new' diseases have made the industry aware of the need to 'come and go clean' and considerable effort is now directed at minimising the transfer of diseases in crop residues and dirt attached to vehicles and machinery. Although this emphasis has been developed with reference to Fusarium wilt the principles apply to several other pathogens as well as weeds.

The declining incidence of Verticillium wilt with repeated cultivation of resistant cultivars has been significant. However, the possible development of new strains of the pathogen is of great concern. It is essential that the incidence of this disease in commercial crops should continue to be monitored.

Black root rot is now widespread in the Macquarie and Namoi valleys and is becoming increasingly common in other areas. Attempts to identify resistant cultivars, effective seed treatments and cultural practices that reduce disease incidence or severity have all failed. There is a need for a more concerted effort to develop control strategies for this pathogen.

The control of Fusarium wilt is a major concern for affected growers. There is an urgent need for proven advice on residue management and crop rotation strategies. Commercial Australian cultivars with some resistance have been identified. However, even the most resistant of these cultivars still suffers significant seedling losses and a high proportion of plants that survive to maturity exhibit vascular browning.

TECHNICAL SUMMARY OF SIGNIFICANT OUTCOMES

DISEASE SURVEYS

* The incidence of verticillium wilt in commercial cotton crops has declined significantly. The mean incidence of the disease recorded in the March 1997 survey was the lowest since surveys commenced in 1984.
* Alternaria leaf spot has become widespread and can now be found in almost all crops approaching maturity. Alternaria leaf spot has been associated with the defoliation of Pima crops in the Bourke area.
* Bacterial blight has become a major disease in Pima crops in the Bourke area and all seed crops were found to be infected late in the 1997/98 season.
* Black root rot is now widespread in the Macquarie and Namoi valleys and is becoming increasingly common in other areas.
* The distribution of Fusarium wilt is increasing and the disease has now been recorded on 10 farms in the Gwydir and McIntyre Valleys of NSW.
* The pathogens that cause Black root rot and Verticillium wilt and *Fusarium* spp. were readily isolated from dirty vehicles parked at ACRI during the Namoi Valley Field Day.

SEEDLING DISEASES

* No new fungicide seed treatments have been significantly better than the current standard Quintozene Apron treatment.
* The use of fungicide and insecticide seed treatments did not significantly increase seed cotton yield.
* The use of planter-box or in-furrow fungicide treatments was not warranted under Australian environmental conditions at planting.
* None of the nutrient based or microbiological seed treatments that were evaluated provided any significant benefits in seedling disease control and stand establishment.

VERTICILLIUM WILT

* Repeated use of resistant cultivars in a field experiment at ACRI has resulted in the development of a possible new strain of the Verticillium wilt pathogen. Isolates of the pathogen have been collected from areas where the incidence of Verticillium wilt is increasing and these need to be compared with isolates from elsewhere in the trial area.

* An integrated control strategy which included resistant cultivars, removal/incorporation of crop residues and rotation with non-hosts resulted in a more rapid decline in disease incidence compared to the use of resistant cultivars alone.
* The insertion of the Ingard gene into cultivar CS 50 did not increase or decrease the cultivars susceptibility to Verticillium wilt.
* Thorough composting of gin trash with the regular addition of water and turning of the windrows eliminates the Verticillium wilt pathogen. The pathogen survived in gin trash near the surface of undisturbed piles and in loose material between the windrows.

BLACK ROOT ROT

* No fungicide seed treatment, crop rotations or cultural practices that were evaluated provided adequate control of black root rot of cotton.
* Growing cotton year after year and the inclusion of field peas in the rotation increased the incidence of black root rot in subsequent cotton crops.

FUSARIUM WILT

* Cultivar reaction to the Boggabilla strain of *Fusarium oxysporum* f.sp. *vasinfectum* was similar to the reaction to the Downs strain of the pathogen. Sicot 189 and DeltaEmerald appear to be the most resistant.
* The use of a NPK fertiliser in one field experiment near Boggabilla was associated with increased disease incidence. There was a significant interaction between cultivar and fertiliser treatment.
* Summer flooding, trash management and crop rotation experiments have been established in commercial fields in the McIntyre and Gwydir valleys.
* Field transects have been determined so that the impact of control strategies on disease incidence can be monitored. The incidence of Fusarium wilt in field E2 at 'Morella' near Boggabilla has fallen from 13.4% to 3.4% in three seasons as a result of the use of a more resistant cultivar.
* Remote sensing by thermal imagery enabled quick location of possible Fusarium wilt infected plants when images were taken in January after full row closure from an altitude of 1500'feet'.

RECOMMENDATIONS:

* Disease surveys should be continued with emphasis on Verticillium wilt, black root rot and Fusarium wilt along with continued emphasis of the need for good farm hygiene.

* A detailed evaluation of the possible new strains of the Verticillium wilt pathogen needs to be completed and the possible development of new strains in commercial fields should be monitored.

* The usefulness and economics of the application of thermal imagery for detecting Fusarium wilt in pure seed crops should be considered

* Field evaluation of trash management and crop rotation strategies should be completed as soon as possible so that practical recommendations for controlling Fusarium wilt of cotton can be made.

* A new project should be established to focus on the increasing prevalence of black root rot and the development of effective control strategies.

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OTHER EXTENSION ACTIVITY

Apart from participation in each of the Australian Cotton Conferences the author has made presentations at 39 grower meetings and field days and contributed several articles to local Grower Association Newsletters during the course of this project.