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COTTON RESEARCH & DEVELOPMENT CORPORATION

FINAL REPORT

DISEASES OF COTTON

DAN 48C

1989 - 1992

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NSW AGRICULTURE

DAN 48C - DISEASES OF COTTON - FINAL REPORT

CONTENTS

COTTON RESEARCH & DEVELOPMENT CORPORATION

DISEASES OF COTTON

FINAL REPORT

Project Number:	**DAN 48C**
Field of Research:	**Crop Protection - Diseases Field Code: 1-2**
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Project Commenced	**Project Completed**
1-7-89	**30-6-92**

Project Objectives:

(i) To monitor the effectiveness of steps being taken to eliminate the bacterial blight pathogen from cotton planting seed and to continue to monitor the races of the blight pathogen that are present in Australia.

(ii) To identify methods to improve plant establishment and reduce the impact of seedling diseases.

(iii) To consider the potential use of biocontrol agents for the control of seedling diseases and verticillium wilt.

(iv) To investigate the importance of alternaria leaf spot as a disease of cotton in Australia.

(v) To continue to collect field data on the effect of permanent bed systems, irrigation systems, dryland cropping, rotation crops etc. on the development of diseases of cotton.

SUMMARY

Disease Surveys.

Commercial cotton (*Gossypium hirsutum* L.) fields in the McIntyre, Gwydir, Namoi and Macquarie valleys of New South Wales were inspected in November and March each season. Commercial fields in the Bourke area were also inspected during March surveys.

The incidence and severity of bacterial blight on Deltapine cultivars has been significantly reduced in recent years. The disease was not observed during the November 1991 survey.

Verticillium wilt was present in a significant proportion of the fields inspected in all areas. The disease was most prevalent in crops in the Namoi valley where it was present in over 90% of crops and where the mean incidence for the last three seasons has been over 25%. The increasing incidence of verticillium wilt in individual fields that have been surveyed on several occasions during the last six seasons is of particular concern.

Seed/seedling losses have varied from 27.5% in the 1991/92 season to 41.2% in 1989/90 with the greatest losses occurring in the Macquarie Valley.

The incidence of Phytophthora boll rot has generally been low although wet conditions in February 1990 resulted in a mean incidence of 2.67% with up to 26% of bolls affected in one crop.

Alternaria leaf spot was rarely observed in New South Wales with the exception of some isolated areas. The disease was regularly observed causing some defoliation late in the season in crops on the property 'Red Mill' north-east of Moree. Low infestations of Alternaria leaf spot are often seen in the Maules Creek area east of Narrabri and the disease was also observed on crops of 'Pima' in the Bourke area in February 1992.

Over recent years and in most gin yards there has been an increasing occurrence of module rot associated with the entry of water into the module - especially around tarp ropes. The seed cotton becomes discoloured and a species of *Coprinus* (the 'inky cap' mushrooms) is often present.

Bacterial Blight

The success of the seed scheme for controlling blight in the Deltapine cultivars has been monitored by testing the level of seed infestation in commercial seed lots and by blight assessments during the disease surveys. The percentage of planting seed infested with the blight pathogen has decreased from 12.0% in 1985/86 to 0.016% in 1990/91. Consequently the mean incidence of blight on seedlings and bolls in commercial cotton crops has been reduced from 10.13% to 0.04% and from 19.56% to 0.29% respectively during the same period. The goal of the 'Blight Investigation Group' was achieved and the disease was not observed at all during the November 1991 survey.

Isolates of the blight pathogen have been collected whenever encountered during the disease surveys of commercial crops. Growth chamber experiments to identify the races of the pathogen have continued to indicate that Race 18 is predominant. No other races have been detected in these studies.

The use of 0.2% 'Pulse' (an organo-silicone surfactant) as an aid to inoculation with bacterial blight was evaluated in the field in December, 1992. The results show that 'Pulse' significantly improved the success of the inoculation even though applied under adverse environmental conditions. 'Pulse' has since been successfully used to aid inoculation with the blight pathogen in the Deltapine cotton breeding nurseries at Boggabilla.

Verticillium Wilt

The most significant development in the control of verticillium wilt of cotton in Australia has been the release of cultivars with improved resistance to the pathogen. The cultivar 'Sicala V1' has been shown to be significantly more resistant to verticillium wilt than the current commercial cultivars and it yields better than other cultivars when the incidence of verticillium wilt is high.

Six field experiments have so far indicated no consistent or significant advantage of raking and burning for the control of the verticillium wilt pathogen although this failure may be associated with the very high levels of inoculum already present in the soil at those trial sites that were used. It would appear that the pathogen is able to adequately survive in association with the finer crop residues (petioles, leaves, bracts etc.) that are not included in the raking and burning process.

Over 150 potential biocontrol agents have been isolated from the roots of healthy plants growing in areas with a high incidence of verticillium wilt, from cotton soils that appear to be suppressive to the disease and from infested crop debris from a previous season. The efficacy of these organisms is to be compared with that of agents being used in overseas work.

Seedling Diseases

Each year CSD with the co-operation of NSW Agriculture evaluate current and potential seed treatments at the Narrabri Agricultural Research Station. Several biological treatments have also been evaluated in recent years. No treatments have been shown to be consistently superior to the current standard seed treatment.

Hopper-box and in-furrow fungicide treatments have also been evaluated in all three seasons. Despite significant improvements in plant stand there has been no observed yield benefit resulting from the treatments. These experiments were planted early in the season thereby allowing plants time to compensate for reduced stand resulting from seedling disease. None of the experiments had levels of seedling disease which would require replanting.

Black Root Rot

Black root rot caused by *Thielaviopsis basicola* is an important disease of cotton in California where it causes significant yield losses. The disease was first reported in Australia in 1990 at two sites but has since been observed on specimens from a field at Dalby in southern Queensland and on specimens collected from four properties in the Wee Waa area of New South Wales.

Soil samples were collected from 30 commercial fields with a long history of cotton cultivation during November 1990 and assayed for the presence of *T. basicola*. Results showed that the pathogen is not widely distributed in cotton cropping areas. Apart from several fields in the Wee Waa area where the disease is common the distribution of the pathogen in cotton soils is limited. With the exception of the Wee Waa area, the pathogen was only found in soil from one field in the Macquarie Valley and one field in the McIntyre Valley. The population of *T. basicola* in the soil was low in both of these fields.

On the basis of these results, and considering the situation in California, it is important that the distribution and incidence of black root rot caused by *T. basicola* is monitored. Growers need to be warned that the disease can be spread in soil attached to farm machinery so that the necessary precautions can be taken.

Alternaria Leaf Spot

Several attempts have been made during the last three seasons to artificially generate epidemics of alternaria leaf spot in cotton at the Narrabri Agricultural Research Station. Despite the use of cv. 'Pima' which is very susceptible to the disease, overhead sprinkling, the spreading of diseased leaf material from an infected crop and inoculation with laboratory-grown spores no significant disease development has occurred.

Vesicular Arbuscular Mycorrhiza (VAM)

Very poor early season plant growth resulting from inadequate VAM establishment was observed in crops growing in newly developed fields near Warren, Burren Junction and Cryon in November 1992 and near Brewarrina in early 1989. The elapsed time between the initial clearing and the planting of the crop appears to be an important factor. Affected plants eventually grew rapidly and became rank with delayed maturity.

The elimination of VAM fungi by methyl bromide fumigation resulted in very poor, stunted early season growth in plots at the Narrabri Agricultural Research Station. The stunted plants in the fumigated plots eventually recovered and grew vigorously, becoming taller than plants in unfumigated plots. There was no significant difference in seed cotton yield from fumigated and unfumigated plots sown in early October. However, fumigated plots yielded 23.7% less seed cotton than did unfumigated plots for the early November sowing.

It was noted that cotton plants from fumigated soil in the field at the Narrabri Agricultural Research Station developed symptoms identical to those symptoms present on cotton plants growing in fields near the Galathera Creek. Subsequent studies showed that plants from the Galathera area had low levels of VAM infection.

Fumigation with methyl bromide improved early season growth of cotton on a Galathera site. It is possible that the fumigant removed deleterious rhizosphere microorganisms that inhibit VAM colonisation. Other effects could be due to reductions in specific cotton root pathogens.

Investigations Into Factors Associated With Fibre Damage In Cotton

The 1991 harvest was accompanied by very warm, dry conditions and most cotton was harvested by the middle of May although rainfall during late May, June and July delayed the harvest of some late crops until August.

An extensive study detected many samples with relatively high levels of fibre damage. However, this fibre damage was not accompanied by high pH which therefore suggested a physical cause of the observed damage. A comparison of the incidence of fibre damage in hand-ginned cotton and machine-ginned cotton indicated that the ginning and lint cleaning processes are responsible for a proportion of the damage that can be observed on fibres. The moisture content of the seed cotton may be a factor in determining the amount of physical damage that may occur. It has been suggested that very dry seed cotton is particularly prone to fibre damage during processing and much of the seed cotton delivered to gins early in the season had < 5% moisture . Problems in distinguishing between physical damage and damage as a result of microbial degradation made it difficult to identify the factors conducive to the development of cavitoma in cotton.

Cavitoma as indicated by the presence of fibre damage and high pH was only detected in lint from some late harvested crops exposed to rain and in lint from modules affected by coprinus module rot. Very high levels of fibre damage occurred when seed cotton in modules was exposed to local flooding and waterlogging, however, pH was found to be 'normal'.

Results of experiments with mini bales and mini modules appear to confirm the expected increase in pH and fibre damage as moisture content is increased. There was difficulty in obtaining and maintaining desired moisture contents within the mini-bales and mini-modules.

Plant Quarantine and Diseases of Cotton

The Australian cotton industry has developed rapidly since the early 1960's when irrigation became available. Bacterial blight, Verticillium wilt and Phytophthora boll rot have caused significant yield reductions but Australian production areas have been kept free of several potentially important plant pathogens which are present in other countries. The pathogens that cause bacterial blight and Verticillium wilt have been present in Australia for many years. More virulent races and strains of these same pathogens have developed in overseas production areas and the introduction of these new races and strains must be prevented. Standard plant quarantine procedures have achieved the level of protection required by the Australian cotton industry with the possible exception of the introduction of races of the bacterial blight pathogen by symptomless epiphytic transfer. The quarantine dilemma is whether to attempt to provide optimum conditions so that the pathogen, if present, can express symptoms in the host and be detected or to provide conditions that will minimise the growth and development of the pathogen and other epiphytic micro-organisms, if present.

The presence of soil and/or plant material on second-hand machinery imported from overseas constitutes a weak link in the effectiveness of quarantine attempts to prevent the introduction of exotic pathogens into Australia. Those involved in bringing second-hand machinery into Australia should ensure thorough cleaning of such equipment prior to importation. The inspection of this machinery by Quarantine officers also needs to be thorough and the efficacy and feasibility of fumigation could be considered.

BENEFITS OF RESEARCH

Field, glasshouse and laboratory studies and disease surveys completed as part of this project have:

- monitored the effectiveness and success of the clean seed scheme for blight control in Deltapine cultivars.
- established better methods for screening for blight resistance in breeding lines.
- identified and monitored the increasing distribution and incidence of verticillium wilt.
- quantified the level of resistance of Sicala V1 to verticillium wilt.
- showed that raking and burning by itself does not significantly reduce the incidence of verticillium wilt.
- established a programme to develop and evaluate biological methods for the control of verticillium wilt and seedling diseases.
- provided a reliable evaluation of cotton seed treatments for seedling disease control.
- identified the occurrence and distribution of black root rot in Australia.
- assessed the importance of alternaria leaf spot in New South Wales.
- demonstrated the role of Vesicular-Arbuscular Mycorrhiza (VAM) in early season growth of cotton.
- demonstrated VAM involvement in the Galathera syndrome.
- identified the micro-organisms involved and collected evidence that pre-harvest exposure to rain is a major factor in the development of cavitoma in Australia.

As a result of these studies the following co-operative links have been established and developed:-

- Dr. John Brown & David Nehl - University of New England - VAM
- Dr. Peter McGee - University of Sydney - VAM
- Dr. Bruce Lyons - University of Sydney - Verticillium wilt, VAM
- Fiona Murray - CSIRO Canberra - biocontrol of Verticillium wilt
- Dr. Mike Pailthorpe & Dr. Nigel Johnson - University of New South Wales - microbial damage to cotton fibres / cavitoma
- Dr. Joe Kochman & Graeme Harden - QDPI - Disease surveys etc.
- Dr. Peter Dart & Dr Helen Ogle - University of Queensland - biocontrol of seedling diseases

DISSEMINATION OF RESULTS TO INDUSTRY
(See also Publications Arising)

The results of this work have been presented in 10 extension articles in the 'Australian Cotton Grower' and the 'Cotton Irrigator'; in 3 presentations to National and State grower conferences; in 5 presentations to associations of consultants and agronomists; and in oral presentations at numerous field days and grower meetings at Moree(4), Narrabri-Wee Waa(5), Warren(4), Dalby(4), Gunnedah, Goondiwindi, St George, Theodore, Bourke and Emerald.

DIFFICULTIES ENCOUNTERED

The detection of barre and cavitoma in Australian cotton harvested in 1990 prompted immediate concern from the industry and necessitated that an investigation into factors associated with fibre damage in cotton be commenced. Consequently, considerable time and resources were allocated to this study during 1991 at the expense of some of the objectives specified in the original project proposal.

The Technical Officer appointed to the project developed health related problems which made it increasingly difficult for him to perform his assigned duties and provide the technical support required. He has since resigned and the position has been re-advertised.

RECOMMENDATIONS FOR FURTHER RESEARCH

(i) Continued development and/or evaluation of control strategies for verticillium wilt and seedling diseases of cotton and the development of a better understanding of those factors that slow down early season growth.

(ii) Continued monitoring of the distribution and importance of diseases in irrigated and dryland cotton by regular disease surveys.

(iii) Evaluation of potential biocontrol agents for seedling disease control.

(iv) The establishment of a programme to develop and compare strategies for the biocontrol of verticillium wilt.

(v) Investigation of those factors associated with the development of microbial fibre damage (cavitoma) in cotton.

NOTE:
These recommendations are currently being implemented under the new projects DAN 69C "Diseases of Cotton", DAN 70C "Biological control of verticillium wilt and seedling diseases of cotton" and a joint project with the School of Fibre Science and Technology, University of New South Wales "Microbial Deterioration of Cotton Fibres" which commenced in July 1992.

PUBLICATIONS ARISING

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Allen, S. J. (1992) The distribution, importance and control of diseases of cotton in Australia. *Proceedings of the 1992 Beltwide Cotton Conferences*, Nashville, Tennessee, January, 1992.

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RESULTS AND CONCLUSIONS

1. DISEASE SURVEYS

Introduction

Commercial cotton (*Gossypium hirsutum* L.) fields in the McIntyre, Gwydir, Namoi and Macquarie valleys of New South Wales were inspected in November and March each season. Commercial fields in the Bourke area were also inspected during March surveys. The incidence and/or severity of the diseases present were recorded for each crop as well as information on cultivar, planting time, growth stage, cropping history, cultural practices and method of irrigation. The amount of cotton debris from previous cotton crops that was present on the soil surface was also estimated during the November survey. The purpose of these surveys was to determine the distribution and relative importance of the various diseases of cotton that occur in New South Wales and to collect field data on various aspects of the epidemiology of these diseases.

Disease assessments were generally based on a step point method using 25 to 50 metres between samples depending on the size of the field. Care was taken to avoid sampling in areas of the crop adjacent to the head ditch or tail drain.

November surveys.

Debris from previous cotton crops was sampled using a quadrat ($0.1m^2$) that was thrown 10 times. The debris collected from within the quadrat was oven dried before weighing. The incidence of bacterial blight of seedlings (for the susceptible cultivar Deltapine 90) was estimated by inspecting 20 samples, each of 10 plants. It is difficult to assess the incidence of seedling diseases which occur as seed rots and pre and post-emergent damping-off. The viability of the seed and the activity of insects in the soil also have an effect on the final plant stand. An estimate of the combined effects of all these factors was derived from the sowing rate (supplied by the grower) and the final plant stand which was determined by counting the number of plants per metre of row at 20 sites in each field.

March surveys.

The incidence of Verticillium wilt (*Verticillium dahliae* Kleb) was estimated using 20 samples, each of 10 plants. Each plant was inspected by actually splitting the stem to check for the characteristic discoloration caused by *V. dahliae*. The incidence of boll rots and boll blight was estimated by inspecting 20 samples, each of 10 bolls. Cultivar trials organised by Cotton Seed Distributors Ltd of Wee Waa were also inspected during March of each season.

Bacterial blight

Bacterial blight of cotton caused by *Xanthomonas campestris* pv. *malvacearum* (Smith) Dye used to be recognised as the most widespread and important disease of cotton in Australia. The prevalence of blight was a major factor in the rapid decline in popularity of the Deltapine cultivars which are susceptible to the disease. Australian cultivars with immunity to blight derived from Tamcot SP37 were released in the 1985/86 season and now account for approximately 80% of the Australian cotton growing area.

Table 1.1. The percentage of planting seed infested with the blight pathogen and the incidence of blight(%) on seedlings and bolls in commercial Deltapine cotton crops 1984/85 - 1991/92 (NSW only).

Season	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92
in planting seed	3.30	12.00	2.10	0.95	0.25	0.29	0.016	-
on seedlings	3.00	10.13	17.11	2.67	0.21	0.35	0.04	0.00
on bolls	23.76	19.56	19.68	22.66	7.96	8.02	0.29	1.50

Verticillium wilt

The distribution and incidence of verticillium wilt in commercial cotton crops growing in NSW cotton growing areas has been assessed during disease surveys in March of each year since 1985. The results (*see Figures 1, 2 and 3)* reflect the effects of seasonal weather conditions and indicate that the disease is present in a significant proportion of the fields inspected in all areas. Verticillium wilt is most prevalent in crops in the Namoi valley where it is now present in over 90% of crops and where the mean incidence for the last three seasons has been over 25%. It has been suggested that the use of susceptible cultivars, the increased adoption of reduced tillage practices and favourable weather conditions have all contributed to the increased incidence of the disease that has been observed in recent seasons.

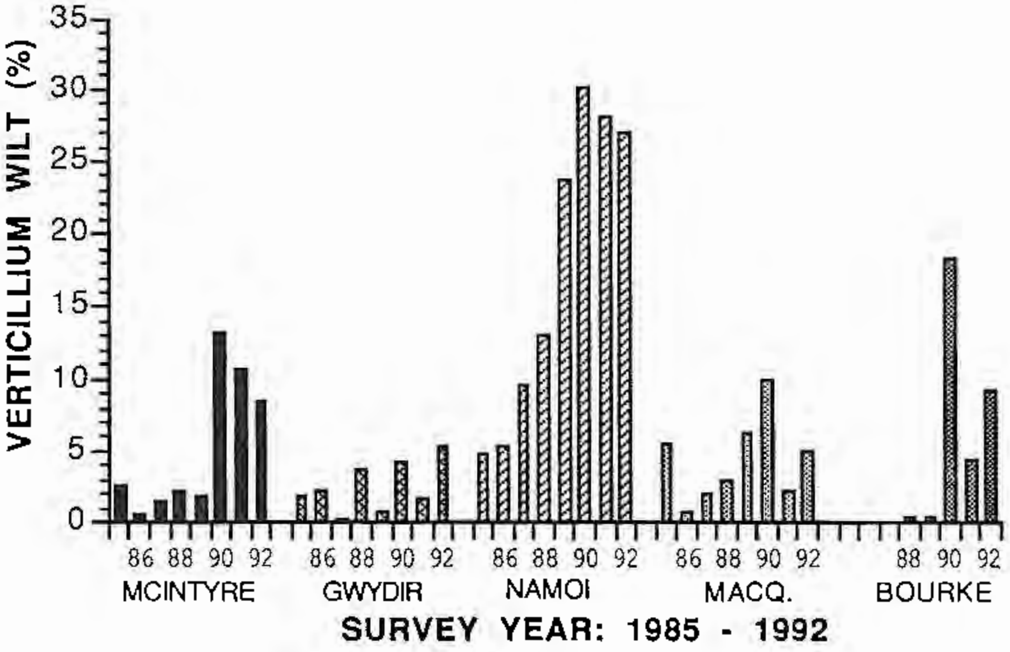

Figure 1.1. The mean incidence (%) of verticillium wilt in commercial cotton crops in the major production areas of New South Wales as determined during disease surveys in March of each season.

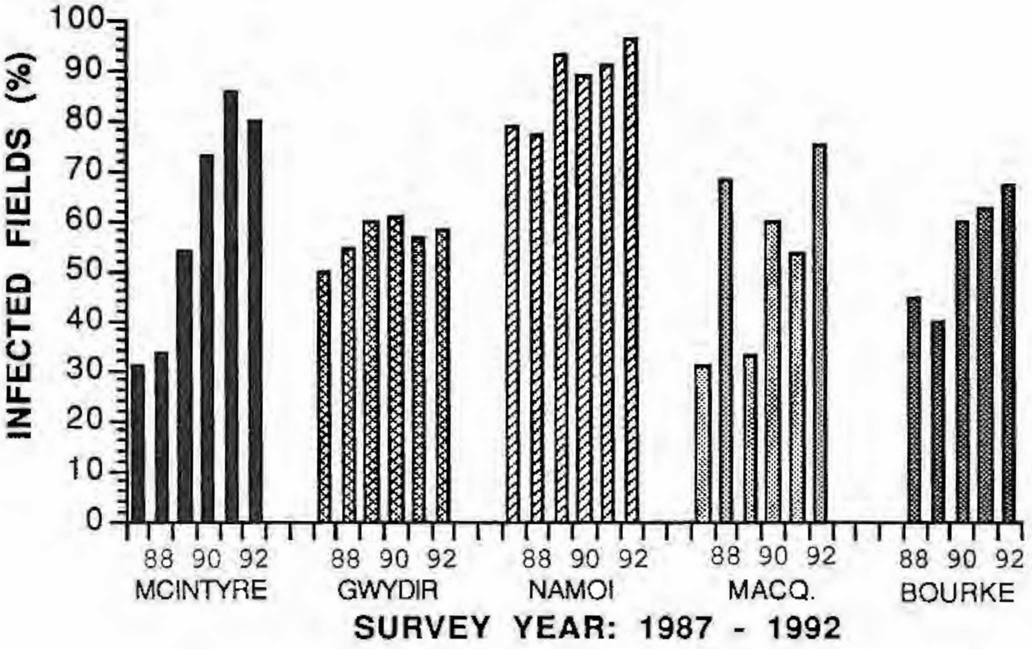

Figure 1.2. The percentage of fields inspected where Verticillium wilt was found to be present - in the major production areas of New South Wales as determined during disease surveys in March of each season.

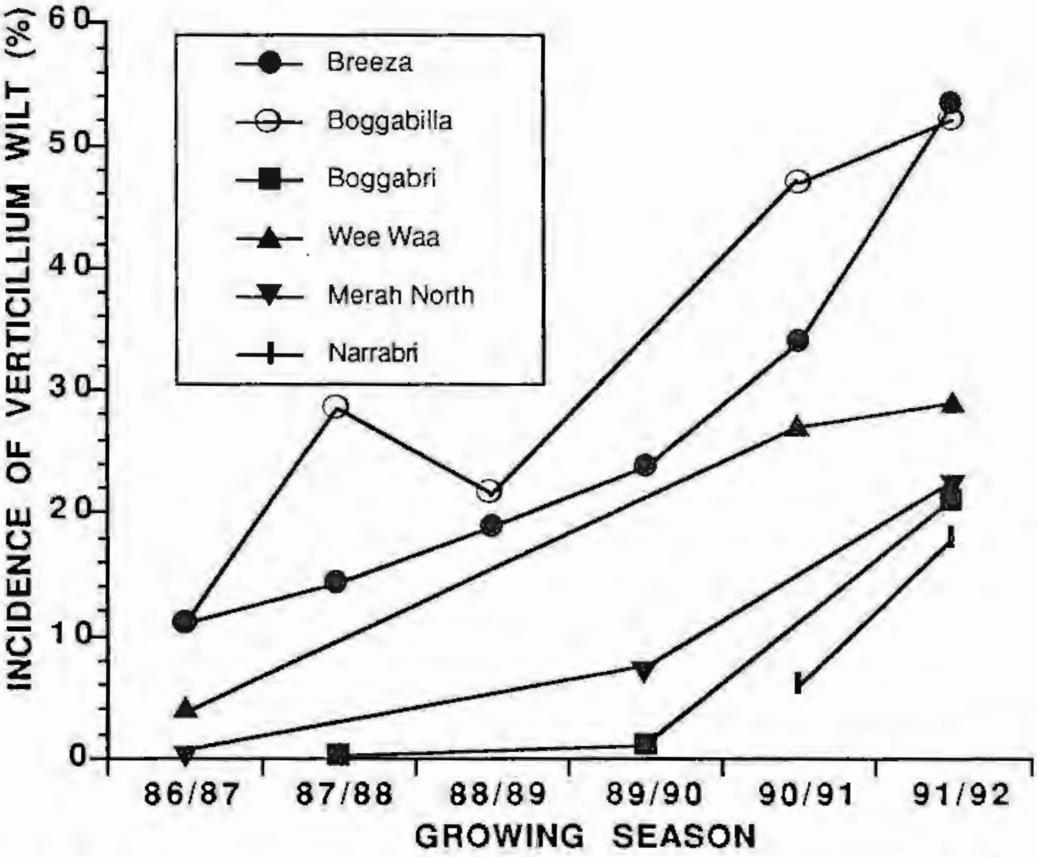

Figure 1.3. The increasing incidence of Verticillium wilt in selected commercial cotton fields as determined during disease surveys in March of each season.

The increasing incidence of verticillium wilt in individual fields that have been surveyed on several occasions during the last six seasons is of particular concern (See Figure1.3). These results demonstrate the capacity of the disease to increase from season to season in different areas under different farming practices.

Seedling diseases

The activity of seedling disease pathogens and soil-inhabiting insects often results in poor stand establishment. During a disease survey in commercial fields it is difficult to distinguish between the effects of this activity and losses due to seed that is not viable. Consequently, seed/seedling mortality has been estimated by comparing the seeding rate (seeds/metre) used by the grower with the number of plants established (plants/metre). Seedling mortality therefore includes factors such as seed viability, seedling diseases, insect activity and herbicide effects. The results indicate direct losses in seed and do not estimate the costs of replanting, low or irregular plant stands and damaged root systems on surviving plants.

Table 1.2. The incidence of seed/seedling mortality in commercial cotton crops growing in NSW cotton growing areas, 1987/88 to 1991/92.

	SEED/SEEDLING MORTALITY (%)				
	1987/88	**1988/89**	**1989/90**	**1990/91**	**1991/92**
McIntyre	-	32.7	34.3	21.4	28.7
Gwydir	-	33.3	41.3	31.1	24.6
Namoi	-	39.8	39.0	39.2	27.2
Macquarie	-	41.2	48.0	39.4	31.1
TOTAL*	**49.7 (21)**	**37.1 (83)**	**41.2 (74)**	**33.3 (71)**	**27.5 (70)**

* *Number in brackets indicates the number of fields surveyed.*

The results indicate that seed/seedling losses have varied from 27.5% in the 1991/92 season to 49.7% during the 1987/88 season. Large areas of cotton needed to be replanted in the 1987/88 season. The highest incidences of seedling mortality have consistently occured in crops in the Macquarie Valley.

Black root rot

Black root rot of cotton caused by *Thielaviopsis basicola* (Berk. & Br.) Ferraris was first reported on cotton in Australia in 1990. The disease has only been detected in cotton crops on eight farms in New South Wales and one farm in Queensland. Over 90% of plants were infected in two adjacent fields on a farm near Narrabri in the 1990/91 season.

Phytophthora boll rot

Phytophthora boll rot caused by *Phytophthora nicotianae* Breda de Haan var. *parasitica* (Dastur) Waterh. was first reported in Australia in 1986. The disease develops when a period of wet weather coincides with the approaching maturity of low bolls (ie. rainfall in February). Soil containing the pathogen is splashed up onto the lower bolls and infection takes place. Losses of up to 26% have been observed under favourable conditions although the incidence of the disease is generally low (Table 1.3). Cultivars with bolls on low hanging branches are more prone to the disease than cultivars which produce bolls on shorter branches close to the stem. A dense, even crop canopy can minimise soil splash onto low bolls.

Table 1.3. The mean incidence of phytophthora boll rot in commercial cotton crops in New South Wales from 1987/88 to 1991/92.

Season	Mean incidence	Range	February rainfall[1]
1987/88	0.85%	0-10%	97.0mm
1988/89	0.11%	0-3%	17.8mm
1989/90	2.67%	0-26%	160.0mm
1990/91	0.48%	0-11%	55.4mm
1991/92	0.55%	0-11%	115.4mm

[1] *at Narrabri Agricultural Research Station*

Alternaria leaf spot

Alternaria leaf spot (*Alternaria macrospora* Zimm.) causes severe defoliation in cotton grown on less fertile soils when the crop is exposed to extended periods of wet weather. These conditions occasionally occur in some Queensland cotton growing areas. Plants senescing prematurely as a result of potassium deficiency appear to be most susceptible.

The disease is rarely observed in New South Wales with the exception of some isolated areas. Alternaria has regularly been observed causing some defoliation late in the season in crops on the property 'Red Mill' north-east of Moree. Low infestations of Alternaria leaf spot are often seen in the Maules Creek area east of Narrabri and the disease was also observed on crops of 'Pima' in the Bourke area in February 1992.

Module rot

Over recent years and in most gin yards there has been an increasing occurrence of module rot associated with the entry of water into the module - especially around tarp ropes. The seed cotton becomes discoloured and a species of *Coprinus* (the 'inky cap' mushrooms) is often present.

VAM's and early season growth

Very poor early season plant growth resulting from inadequate VAM establishment was observed in crops growing in newly developed fields near Brewarrina in 1989 and near Warren, Burren Junction and Cryon in November 1992. The elapsed time between the initial clearing and the planting of the crop appears to be an important factor. Affected plants eventually grew rapidly and became rank with delayed maturity.

The establishment of VAM and the importance of VAM to cotton are discussed in detail elsewhere in this report.

2. BACTERIAL BLIGHT

Seed Scheme for Blight Control

Bacterial blight of cotton caused by *Xanthomonas campestris* pv. *malvacearum* (Smith) Dye used to be recognised as the most widespread and important disease of cotton in Australia. In 1985, in response to the severe losses being experienced by growers, Cotton Seed Distributors Ltd (a grower-controlled company that was responsible for the production of all cotton planting seed in Australia) co-ordinated the formation of the 'Blight Investigation Group' with the objective to "reduce the level of blight infestation of planting seed to less than 0.03% within 5 years". A seed scheme was developed and implemented in order to achieve this objective.

This scheme included the following:

(i) the isolation of cultivar nurseries from susceptible commercial crops,
(ii) the use of copper sprays in cultivar nurseries to reduce the spread of the disease early in the season,
(iii) the location of pure seed production areas in drier western areas,
(iv) blight assessments on pure seed crops and the use of blight incidence and severity as a criteria for rejection of crops from the pure seed production program,
(v) the processing of blight-immune cultivars through gins prior to the processing of seed cotton of susceptible cultivars for planting seed production ('gin sweeping'), and
(vi) the storage of seed for one season prior to planting.

The success of the scheme has been monitored by testing the level of seed infestation in commercial seed lots and by blight assessments during the disease surveys. The percentage of planting seed infested with the blight pathogen has decreased from 12.0% in 1985/86 to 0.016% in 1990/91. Consequently the mean incidence of blight on seedlings and bolls in commercial cotton crops has been reduced from 10.13% to 0.04% and from 19.56% to 0.29% respectively during the same period. The 'Blight Investigation Group' goal was achieved (Table 1.1) and the disease was not observed at all during the November 1991 survey.

Bacterial Blight Race Identification

Isolates of the blight pathogen have been collected whenever encountered during the disease surveys of commercial crops. Growth chamber experiments to identify the races of the pathogen have continued to indicate that Race 18 is predominant. No other races have been detected in these studies.

Blight inoculation

As a result of earlier studies (Final report DAN26L) cotton breeders have used high pressure spray inoculation early in the day to aid the field selection of bacterial blight resistant material.

A reference (abstract only) in a US journal to the use of an organo-silicone, 'stomate flooding' surfactant which was being used to enhance the inoculation of weeds with bacterial pathogens was noted. The surfactant known as 'Silwet L 77' in the USA is marketed in Australia as 'Pulse' by Monsanto.

The use of 0.2% 'Pulse' as an aid to inoculation with bacterial blight was evaluated in the field in December, 1992. Plants were inoculated during the hottest time of the day using a low pressure hand-held knapsack sprayer. The results (Table 2.1) show that 'Pulse' significantly improved the success of the inoculation even though applied under adverse environmental conditions. 'Pulse' has since been successfully used to aid inoculation with the blight pathogen in the Deltapine cotton breeding nurseries at Boggabilla.

Table 2.1. The effect of the organo-silicone, 'stomate-flooding' surfactant 'Pulse' on the inoculation of cotton cv. Deltapine 90 with the bacterial blight pathogen.

	Bacterial blight symptoms (percentage leaf area infected)	
Treatment	After 2 weeks	After 4 weeks
Bacterial blight inoculum **without 'Pulse'**	0.02%	1.92%
Bacterial blight inoculum **with 'Pulse'**	15.7%	49.8%

3. VERTICILLIUM WILT.

Introduction

Verticillium wilt has been recognised as an important disease of cotton in Australia for many years, especially in the older established cotton growing areas. However, in recent years there has been an alarming increase in the incidence of this disease (Figures 1.1, 1.2, 1.3). Possible reasons for this increase include: the increased adoption of reduced tillage practices and permanent bed systems; the use of very susceptible cultivars; a sequence of three wet winters which have prevented the early incorporation of crop debris and the occurrence of cool weather periods during summer.

A verticillium nursery has been established at the Narrabri Agricultural Research Station using gin trash from modules harvested from cotton fields with a high incidence of verticillium wilt. This site is now being used to (i) evaluate cultural control practices, (ii) compare the resistance of current commercial cultivars and (iii) screen new breeding lines for resistance to the disease.

Comparison of current cultivars

The most significant development in the control of verticillium wilt of cotton in Australia has been the release of cultivars with improved resistance to the pathogen. CSIRO (Commonwealth Scientific and Industrial Research Organisation) cotton breeders at Narrabri have released the cultivar 'Sicala V1' which is significantly more resistant to verticillium wilt than the current commercial cultivars (Table 3.1). Sicala V1 has been shown to yield better than other commercial cultivars when the incidence of verticillium wilt is high (Tables 3.2, 3.3). The mechanism of this resistance is not presently understood and it is not known if the type of resistance present in Sicala V1 is the same as that which is widely utilised in Californian cultivars with resistance to verticillium wilt.

Table 3.1. A summary of the results of eight field trials over three seasons comparing the relative resistance/susceptibility of current commercial cultivars to verticillium wilt of cotton.

	89/90	89/90	89/90	90/91	90/91	91/92	91/92	91/92	
Cultivar	Myall Vale	Auscott N'bri	CSD N'bri	CSD Dalby	CSD N'bri	CSD N'bri	CSD Merah	Auscott N'bri	Mean
Sicala V1	28.2	-	35.3	19.5	41.4	13.9	48.3	41.8	32.6
CS-189	-	64.0	44.8	48.0	72.8	19.5	87.7	54.0	55.8
DPL 90	46.6	68.6	44.3	57.7	73.4	24.4	89.1	56.6	57.6
Sicala 33	57.3	72.4	63.2	48.0	84.8	16.3	86.3	71.0	62.4
Siokra 1-4	58.5	85.5	61.3	68.9	85.0	22.3	95.7	72.9	68.8
LSD	11.5	7.0	8.8	12.1	8.0	6.1	9.4	8.2	

Table 3.2 Results of the 1990/91 field experiment comparing the yield of current cultivars when exposed to a high incidence of verticillium wilt (The verticillium nursery at the Narrabri Agric. Research Station).

Cultivar	**Incidence of Verticillium Wilt**	**Seed Cotton Yield**
	(%)	***(Kg/ha)***
Sicala V1	74.3	5,497
Sicala 33	98.0	5,223
Siokra 1-4	97.4	4,969
Deltapine 90	92.9	4,731
Namcala	83.0	4,560
	LSD = 8.05	LSD = 441.0

Table 3.3 Results of the 1991/92 field experiment comparing the yield of current cultivars when exposed to a high incidence of verticillium wilt (The verticillium nursery at the Narrabri Agric. Research Station).

Cultivar	Vert %	s. c. yld. kg/ha	turnout %	lint yld kg/ha	length in	strngth g/tex	uni. %	micro.
Sicala V1	83.7	6622	40.2	2592	1.16	32.4	47.7	4.12
DPL 90	77.5	5575	40.5	2251	1.16	30.4	48.8	4.20
Siokra 1-4	95.0	4803	39.7	1921	1.19	30.2	44.7	3.62
Siokra L22	92.5	5500	40.7	2228	1.21	29.5	46.3	3.62
CS 7S	65.0	5959	42.1	2498	1.12	31.7	49.8	4.22
CS 50	87.5	5734	41.5	2370	1.15	28.0	45.0	4.07
CS189	81.3	5484	37.1	2035	1.17	28.8	46.1	3.95
Acala C32	70.0	5444	27.2	1484	1.21	35.3	52.6	3.97
L.S.D.	18.1	616	5.8	407	0.02	1.8	1.6	0.32

Stalk-pulling, raking and burning

The development of stalk-pullers, stubble mulchers and trash rakes has, in recent years, increased the range of trash management options available to cotton growers. If the conditions during winter are relatively dry then all alternatives can be considered. However, in seasons similar to those experienced in recent years the options are considerably reduced and it is under these conditions that the practice of raking and burning has become more prevalent.

Six field experiments (Table 3.4) have so far indicated no consistent or significant advantage of raking and burning for the control of the verticillium wilt pathogen although this failure may be associated with the very high levels of inoculum already present in the soil at those trial sites that were used. It would appear that the pathogen is able to adequately survive in association with the finer crop residues (petioles, leaves, bracts etc.) that are not included in the raking and burning process.

Table 3.4 A summary of the results of six field experiments comparing the effect of stubble mulching/slashing and stalk-pulling, raking and burning on the incidence of verticillium wilt in the subsequent cotton crop.

			Incidence of Verticillium wilt (%)	
Site	Field history	Season	Slashed	Stalk-pulled
NARS Old2	cotton/cotton	90/91	60.2	76.6
NARS Old2	wheat rotation	91/92	59.4	58.1
NARS Old2	long fallow	91/92	51.9	48.1
Auscott 4	cotton/cotton	89/90	51.1	51.0
Auscott 4	wheat rotation	91/92	54.5	53.0
Auscott 32	cotton/cotton	91/92	33.7	28.7

Cultural control of verticillium wilt

Long term experiments have been established at two sites to evaluate the effectiveness of combining all available cultural practices with the use of the resistant cultivar 'Sicala V1' for the control of Verticillium wilt. Consequently the two treatments include:

(i) "standard practice" - slashing, direct sown cereal, fallow, minimum cultivation and the use of a susceptible cultivar.

(ii) Stalk-pulling, raking and burning, cultivation, double crop rotation (cereal-lablab or cereal-soybean), incorporation of rotation crop residues and the use of the resistant cultivar 'Sicala V1'.

These treatments will be continued for several seasons before the final assessments are made.

Biocontrol of verticillium wilt

Verticillium wilt is now recognised as the most important disease of cotton in Australia. As a result of its soil-borne habit, wide host range and its ability to survive for long periods, verticillium wilt is difficult to control by conventional methods.

There is increasing public concern about the use of pesticides in the cotton industry. Biocontrol methods are recognised as being more environmentally acceptable than the use of pesticides.

In the USA in recent years there has been some progress in the development of biocontrol methods for verticillium wilt.

Over 150 potential biocontrol agents have been isolated from the roots of healthy plants growing in areas with a high incidence of verticillium wilt, from cotton soils that appear to be suppressive to the disease and from infested crop debris from a previous season. The efficacy of these organisms is to be compared with that of agents being used in overseas work.

Experiments currently in progress are comparing the efficacy of several potential biocontrol agents when applied to infested crop trash.

4. SEEDLING DISEASES

Introduction

As a tropical crop being grown in a temperate climate cotton is particularly susceptible to seedling diseases and despite the extensive use of fungicide seed treatments some replanting is often required. The cost of seedling diseases to the cotton grower should take into account the reduced vigour of surviving stands as well as the costs associated with replanting where necessary.

Seedling diseases are generally caused by relatively weak fungal pathogens and symptoms may include seed rotting, pre- or post-emergent damping off, root pruning, 'soreshin' and 'nub root'. *Rhizoctonia solani* and *Pythium ultimum* are the most common causes of seedling disease of cotton in Australia.

The standard seed treatment currently in use is a combination of pcnb, metalaxyl and thiodicarb. The application rate being used for pcnb as a seed treatment in Australia is approximately 60% of the recommended rate in the USA. The use of fungicides as 'hopper-box' or 'in-furrow' treatments is not common although there has been an increased interest in these methods of application in the last three years.

CSD Seed treatment trials

Each year CSD with the co-operation of NSW Agriculture evaluate current and potential seed treatments at the Narrabri Agricultural Research Station. The results are shown in Tables 4.1, 4.2, 4.3.

1989/90 - (Table 4.1) - The 1989/90 trial included 30 treatments replicated 10 times with 100 seeds planted per plot on 26/9/89.

Table 4.1 Results of the 1989/90 CSD seed treatment trial comparing the efficacy of fungicide and insecticide treatments for seedling disease control and seedling vigour. (Plant stand at 40 days after sowing)

fungicide	+ nil	+ apron	+ apron + orthene	+ apron + semevin	+ apron + promet	(mean)
untreated	51.3	54.3	58.5	33.1	35.7	46.6
terraclor	59.9	62.5	61.2	65.5	60.5	61.9
rizolex	65.3	67.4	73.7	68.5	52.2	65.4
beret	54.8	62.6	65.4	52.4	44.3	55.9
CST89/1	58.8	66.0	69.7	62.1	62.0	63.7
baytan	70.6	67.6	69.9	71.0	62.5	68.3
(mean)	60.1	63.4	66.4	58.8	52.8	

SEEDLING VIGOUR (tops dry wt - 5m of row) at 7 weeks after sowing

no significant differences between fungicides

fungicide + apron + orthene	67.8g	a
fungicide + apron + promet	60.7	b
fungicide + apron + semevin	59.5	bc
fungicide only	56.5	cd
fungicide + apron	53.6	d

CONCLUSIONS:

(i) Baytan and rizolex treatments performed well.

(ii) Orthene treatments significantly improved plant vigour when compared with semevin or promet or with treatments without an insecticide.

(iii) the average stand for the "better" treatments was 34% better than the stand for untreated seed.

(iv) the relatively poor performance of promet could be associated with the ' stickiness' and consequent clumping of treated seed and then resulting planting problems.

1990/91 - (Table 4.2) - The 1990/91 trial included 32 treatments replicated 10 times with 100 seeds planted per plot on 4/10/90.

Table 4.2 Results of the 1990/91 CSD seed treatment trial comparing the efficacy of fungicide and insecticide treatments for seedling disease control and seedling vigour.

FUNGICIDES - stand counts assessed 42 days after planting.

fungicide	no. of plants per plot	% of control
RIZOLEX-APRON	49.3	119
PCNB-APRON	48.7	117
BERET-APRON	47.6	114
BAYTAN-APRON	47.2	113
MONCERIN COMBI	47.0	113
MONCUT-APRON	45.1	108
UNTREATED	41.6	100
APRON	39.2	94

L S.D. = 3.998

INSECTICIDES - stand counts assessed 42 days after planting

insecticide	no. of plants per plot	% of control
ORTHENE	47.5	101
UNTREATED	47.1	100
PROMET	44.5	94
SEMEVIN	43.7	93

L.S.D. = 2.874

VIGOUR - tops dry weight harvested 42 days after planting.

insecticide	tops dry weight (gm)	% of control
SEMEVIN	10.543	167
PROMET	9.382	149
ORTHENE	7.810	124
UNTREATED	6.308	100

L.S.D. = 0.692

No fungicide treatments were found to be significantly better than those seed treatments which are currently being used. Seedlings grown from seed treated with Semevin had a significantly higher tops dry weight at 42 days after planting than all other treatments.

1991/92 - (Table 4.3) - The 1991/92 trial included 26 treatments replicated 10 times with 100 seeds planted per plot on 26/9/91. Weather conditions early in the season were relatively mild and warm and not conducive to a high incidence of seedling disease.

The 91/92 trial included comparisons between flowable and powder formulations of both Apron and PCNB and also comparisons between the standard rate of PCNB used in Australia and the higher rate of PCNB which is used in the USA.

Table 4.3 Results of the 1991/92 CSD seed treatment trial comparing the efficacy of fungicide and insecticide treatments for seedling disease control and seedling vigour.

FUNGICIDES - stand counts assessed 42 days after planting.

fungicide	no. of plants per plot	% of control
PCNB-APRON-BAYTAN	62.4	118
BAYTAN-APRON	59.8	114
MONCUT-APRON	58.4	111
ROVRAL-APRON	58.3	111
PCNB(fl) Lo -APRON	58.1	110
RIZOLEX-APRON	56.0	106
PCNB(fl) Hi -APRON	55.4	105
PCNB Lo -APRON	55.2	105
PCNB Hi -APRON	54.7	104
PCNB(fl)-APRON(fl)	53.5	102
UNTREATED	52.6	100
APRON FL	51.8	98
APRON 35SD	51.1	97

L S.D. = 5.5

VIGOUR - tops dry weight harvested 42 days after planting.

insecticide	tops dry weight (gm)	% of control
SEMEVIN	12.34	115
UNTREATED	10.73	100

L.S.D. = 0.6

No significant differences between the various rates and formulations of PCNB and Apron were detected. Seedlings grown from seed treated with Semevin had a significantly higher tops dry weight at 42 days after planting than seedlings grown from seed not treated with insecticide.

Effect of seed treatments on yield

Field experiments in 1990/91 and 1991/92 were designed to determine the yield advantage resulting from the use of seed treatments. Treatments included untreated seed and the current standard seed treatment planted in 4 row plots with the two centre rows being used for stand and yield measurements. There were no significant differences between treatments in stand or seed cotton yield in the 1990/91 experiment (Table 4.4). Despite significant differences in stand between treatments in the 1991/92 experiment there were still no significant differences between the seed cotton yields of the various treatments (Table 4.5).

Both of these experiments were planted early in the season thereby allowing plants time to compensate for reduced stand resulting from seedling disease. Future experiments will include both early and late sowings. Neither of the experiments had levels of seedling disease which would require replanting.

Table 4.4 The effect of cotton seed treatments on stand and seed cotton yield (1990/91).

Treatment	Stand (/150) 42 days after sowing	Seed cotton yield (kg/ha)
Untreated seed	95.0	5429
PCNB	97.2	5367
Baytan	98.9	5634
Apron	87.5	5568
PCNB - Apron	98.6	5654
Baytan - Apron	98.4	5562
	N.S.	N.S.

Table 4.5 The effect of cotton seed treatments on stand and seed cotton yield (1991/92).

Treatment	Stand (/300) 42 days after sowing	Seed cotton yield (kg/ha)
Untreated seed	213.3	5450
PCNB(low) - Apron	232.2	5550
PCNB(high) - Apron	235.9	5450
PCNB Baytan Apron	223.1	5300
LSD	12.1	N.S.

In-furrow and hopper-box treatments

Additional protection against the seedling disease pathogens can be gained from the use of fungicide dusts mixed with the seed as it is placed in the planter boxes (hopper box treatments). The dust is distributed along with the seed during planting. This method results in a non-uniform distribution of fungicide but it nevertheless provides an improved level of disease control. Growers should be made aware that the addition of dust to the seed may reduce seeding rates by as much as 15% with some planters and the function of electronic seed monitors can be impaired.

Maximum protection may be achieved by combining seed treatment with the use of an in-furrow fungicide formulated as a spray or granule and applied at planting into the seed furrow and covering soil. In-furrow fungicides require more fungicide per hectare than other treatments but they are generally more effective in controlling seedling diseases. This method also requires specialised application equipment.

1989/90 field experiments. After consultation with pathologists in California the use of a cowpea green manure crop was adopted so that the presence of an active seedling disease pathogen population could be assured. A stand establishment trial investigated the efficacy of an in-furrow fungicide under different planting conditions (see Table 4.6). This trial was planted with a cone seeder so that the fungicide granules were applied with the seed in the seed furrow. The results (Table 4.6) showed that in-furrow fungicide treatments could significantly increase stand establishment especially under less favourable planting conditions.

Table 4.6 The efficacy of the in-furrow fungicide, Ridomil PC 11G for seedling disease control under different planting conditions.

	seedling establishment - 6 weeks after planting	
	planted into moisture well prepared beds	watered after planting poorly prepared beds
control	60.6%	52.0%
Ridomil PC 11G	63.9%	59.1%
LSD	2.15	3.10

1990/91 field experiments. The 1989/90 field experiment was repeated in 1990/91 with the inclusion of a hopper box treatment. The seed treatment, hopper-box treatment and in-furrow fungicide granule were all formulations of Terraclor and Apron so that a comparison of methods could be made. The trial was planted with a Kinze planter fitted with a Horstine granule applicator and modified cover plates so that the granules could be placed in the seed furrow. Rainfall soon after planting favoured seedling disease development and confounded the differences between the pre-watered, well prepared beds and the watered-up, poorly prepared beds (Table 4.7). The hopper box and in-furrow treatments significantly increased seedling survival. However, there were no significant yield differences between treatments.

Table 4.7 A comparison of methods for the application of fungicides for seedling disease control under two different planting conditions.

	seedling establishment - 4 weeks after planting (plants/ 20 metres of row)	
	planted into moisture well prepared beds	watered after planting poorly prepared beds
treated seed only	209.5	233.5
treated seed + hopper-box treat.	261.2	273.8
treated seed + in-furrow fungicide	241.8	258.7
LSD	15.7	17.6

1991/92 field experiments. The 1991/92 field experiments compared the efficacy of several potential hopper-box and in-furrow fungicide treatments. However, seasonal conditions did not favour seedling disease development (see Table 4.8). Despite significant differences in plant stand in the experiment planted into moisture, there were no significant yield differences in seed cotton yield.

Table 4.8 A comparison of hopper-box and in-furrow fungicide treatments for seedling disease control in cotton.

Treatment	Application	planted into moisture		watered after planting	
		Stand (/300)	S.C.Yield (kg/ha)	Stand (/300)	S.C.Yield (kg/ha)
Untreated		230.5	5175	232.5	5410
PCNB-Apron	seed treat.	228.8	5344	248.2	5411
Ridomil PC11G	in-furrow granule	233.3	5417	256.9	5476
Terraclor Super X	in-furrow granule	222.5	5260	255.6	5459
Rizolex	hopper-box treatment	239.5	4904	250.0	5310
P Pickle T	hopper-box treatment	247.8	5082	249.1	5391
Rizolex	in-furrow spray	182.9	5217	231.4	5468
Rovral - Aliette	in-furrow spray	227.3	5145	231.9	5367
LSD		26.8	N. S.	N. S.	N. S.

Evaluation of potential biocontrol agents

There are several potential biocontrol agents for seedling disease control already available. These agents have all given good control in laboratory and glasshouse studies and some have shown promise in field studies at locations in Australia and in the USA. In recent years three biological products have been registered for the control of seedling diseases of cotton in the USA.

No effort has been made to identify new biocontrol agents for seedling disease control in Australia. Experiments have concentrated on the evaluation of available biocontrol agents under field conditions.

Full co-operation and encouragement have been extended to Mr. V. S. Putcha, a Ph.D. student with Dr. Peter Dart at Queensland University. Co-operative field experiments during two seasons at the Narrabri A.R.S. were designed to evaluate the efficacy of several isolates of the bacterium *Pseudomonas cepacia* for the control of seedling diseases and the stimulation of crop growth. Results of these experiments indicate that two of the treatments can 'sometimes' provide control of seedling diseases equal to or better than that provided by the standard fungicide treatment.

A field experiment at Narrabri during the 1991/92 season evaluated five bacterial seed treatments at two different planting dates. Two of the treatments were supplied by Incitec as part of the work they are doing with the University of Queensland.

Environmental conditions early in the 1991/92 season were not conducive to seedling disease development and significant differences between treatments were not observed (see Table 4.9).

Table 4.9 The effect of various biological seed treatments on seedling survival and seedling vigour, 1991/92.

Treatment	Seedling survival (%) 42 days after sowing		Tops dry weight (g/plant) 49 & 42 days after sowing	
	sown 26/9/91	sown 22/10/91	sown 26/9/91	sown 22/10/91
Untreated + peat	64.9	78.5	0.77	2.04
Incitec 32 gran.	61.6	80.0	0.83	2.64
Incitec 32 + peat	56.2	72.5	0.95	2.72
Incitec 102 gran.	58.6	70.3	0.97	2.79
Incitec 102 + peat	63.6	78.2	0.94	2.62
A 13 + peat	70.0	77.7	0.70	2.39
Pf 5 + peat	65.0	75.3	0.87	2.62
LSD (p=0.05)	N.S.	N.S.	N.S.	N.S.
C.V.(%)	19.2	14.6	20.2	14.3

5. BLACK ROOT ROT

Thielaviopsis basicola: A potentially important pathogen of cotton in Australia.

(A paper presented at the 'Second Graduate Seminar in Plant Pathology and Mycology' - University of New England, 1991)

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Abstract

Black root rot caused by Thielaviopsis basicola *is an important disease of cotton in California where it causes significant yield losses. The disease was first reported in Australia in 1990 at two sites but has since been observed on specimens from a field at Dalby in southern Queensland and on specimens collected from four properties in the Wee Waa area of New South Wales. The purpose of this study was to investigate the distribution and importance of* T. basicola *in commercial cotton fields throughout New South Wales.*

Soil samples were collected from 30 commercial fields with a long history of cotton cultivation during November 1990 and assayed for the presence of T. basicola. *Results showed that the pathogen is not widely distributed in cotton cropping areas. Apart from several fields in the Wee Waa area where the disease is common the distribution of the pathogen in cotton soils is limited. With the exception of the Wee Waa area, the pathogen was only found in soil from one field in the Macquarie Valley and one field in the McIntyre Valley. The population of* T. basicola *in the soil was low in both of these fields.*

On the basis of these results, and considering the situation in California, it is important that the distribution and incidence of black root rot caused by T. basicola *is monitored. Growers need to be warned that the disease can be spread in soil attached to farm machinery so that the necessary precautions can be taken.*

Introduction

Thielaviopsis basicola (Berk. and Br.) Ferraris causes disease in over 137 species of plants (Otani, 1962; cited in Meyer, Shew and Shoemaker, 1989) including cotton (*Gossypium hirsutum* L.), soybeans (*Glycine max* [L.] Merr.) and tobacco (*Nicotiana tabacum* L.). Affected plants are usually stunted during the seedling stage of growth resulting in delayed maturity and consequent loss of yield. The pathogen is able to survive in the soil for long periods of time as thick-walled, dark brown chlamydospores which are formed in chains.

Black root rot of cotton caused by *T. basicola* was first reported in Arizona in 1922 (King and Presley, 1942). It is now widely distributed in the south western United States and has also been reported in Peru, the

USSR and Egypt (Watkins, 1981). Black root rot was first recognised as a minor disease of cotton in California in 1956. However, in recent years the incidence and severity of the disease and the resulting yield losses have increased significantly. In 1983 and 1984 it was estimated that 15% of the total area planted to cotton in California was affected by black root rot with estimated yield losses of up to 250 kg per hectare (Garber *et al*, 1985; Hake *et al*, 1985).

Cotton seedlings are infected in the spring when the soil temperatures are low with 15-20°C being optimum (Watkins, 1981). The pathogen invades the root hair region and destroys the cortex of susceptible plants resulting in a blackened 'envelope' of infected tissue surrounding the healthy uninfected stele (Garber *et al*, 1985). Within a few days of infection endoconidia and chlamydospores are produced on the root surface. The unaffected pericycle continues to allow the passage of water and nutrients through the plant. As the soil temperature rises the vegetative growth of the seedling resumes and most of the blackened diseased tissue is sloughed off leaving little evidence of infection (Garber *et al*, 1985).

T. basicola has previously been recorded in Australia on numerous ornamentals, tobacco, New Zealand blue lupin (*Lupinus angustifolius* L.), bean (*Phaseolus vulgaris* L.), pea (*Pisum sativum* L.) and radiata pine and pinaster pine (*Pinus radiata* D.Don and *Pinus pinaster* Ait.) (Simmonds, 1966; Sampson and Walker, 1982; Warcup and Talbot, 1981). Black root rot of cotton caused by *T. basicola* was first reported in Australia in 1990 at only two sites (Allen, 1990). The disease has since been observed on cotton seedlings from a field at Dalby in southern Queensland and on seedlings collected from four properties in the Wee Waa area of New South Wales.

The purpose of this study was to investigate the distribution and importance of *T. basicola* in commercial cotton fields throughout New South Wales.

Materials and Methods

Soil samples were collected from 30 commercial fields with a long history of cotton cultivation (See Table 1) during November 1990. A trowell was used to sample soil from 0 - 15cm depth within the seedling row at ten randomly selected sites in each field. These sites were selected by a step-point method with 20 paces between each sample site. All of the soil sampled from a field was combined in a bucket and mixed thoroughly before the removal of a 300 to 400g sub sample which was taken back to the laboratory.

The population of *T. basicola* in each of the soil samples was estimated using the method described by Tabachnik *et al*, (1979). Fresh, clean carrots were aseptically cut into transverse sections (disks) approximately 5mm thick. Five disks were placed in a petri dish containing two sterile Whatman No. 1 filter papers and 5mL of 0.5% Streptomycin Sulphate (0.5g $100mL^{-1}$ water). Five petri dishes were used for each soil sample and the experiment was replicated three times.

A soil spoon was used to place 20mg of air dried soil on top of each carrot disk and a second carrot disk was quickly placed over the soil to prevent dessication.

The plates were incubated at room temperature (23°C) and 100% Relative Humidity for 10 days. Following incubation the carrot disks were examined for the presence of chlamydospores using a dissecting microscope. The number of carrot disks colonized by *T. basicola* was determined for each sample and an estimate of the number of propagules per gram of soil was calculated. This method is particularly suited for detecting the presence of the pathogen but provides an under-estimate of the population if chlamydospores of the pathogen are abundant.

Results

The results obtained from the laboratory assay using fresh carrot disks (Table 1) show that *T. basicola* is not widely distributed in cotton cropping areas. Apart from several fields in the Wee Waa area where the disease is common, the distribution of the pathogen in cotton soils is limited.

Table 1: *An estimate of the number of propagules of T. basicola per gram of soil in thirty samples collected from commercial cotton growing areas of New South Wales.*

Production area	Property name and field No.	Nearest town	*T. basicola* (propagules g^{-1} soil)
Namoi Valley	# Myalla	Wee Waa	24
	# Greenbah 1	Wee Waa	50
	# Merinda 6,7,42	Wee Waa	38
	Togo 89	Wee Waa	0
	Undoolya 3	Boggabri	0
	Auscott-N'bri 13	Narrabri	0
	Drayton 3	Breeza	0
	Kerribee 15	Merah North	0
	Warilea 1	Narrabri	0
	Waverely 2	Burren Junction	0
	Dundee 6	Burren Junction	0
	Maunder 1	Boggabri	0
Gwydir Valley	Tellerega Station 9	Moree	0
	Auscott-Midkin 24	Moree	0
	Collyfarms 37	Collarenebri	0
	Iffley 17	Collarenebri	0
	Topbox 43	Garah	0
	Benwerrin	Croppa Creek	0
	Biniguy 3	Biniguy	0
McIntyre Valley	Northcote 2	Boomi	0
	Teviot 10	Mungindi	0
	Korolea 4	Boggabilla	0
	Cleland 2	Boggabilla	2
	Strathgyle 2	Garah	0
Macquarie Valley	Byron 14	Trangie	0
	Auscott-Macq.28	Warren	0
	Buttabone 4	Warren	0
	Twenty-stone 2	Mt. Foster	2

 # - fields included because the disease had already been recognized as present on the basis of host symptoms.

With the exception of the Wee Waa area the pathogen was only found in soil from one field in the Macquarie Valley and one field in the McIntyre Valley. The population of *T. basicola* in the soil was low in both of these fields. The pathogen was not detected in the seven soil samples from the Gwydir Valley.

Discussion

Despite the limited distribution of *T. basicola* in cotton growing areas the results of this study show that the pathogen can attain significant populations under Australian soil and climate conditions. Over 90% of seedlings from several fields on the property Merinda near Wee Waa featured completely blackened tap roots with few or no lateral roots remaining. This correlates with the relationship between the pathogen population in the soil and the disease severity (see Table 2) as described by Tabachnik *et al.* (1979).

Table 2 *The relationship between the population of T. basicola propagules present in soil, the 'disease index' and the severity of the disease on cotton seedlings (from Tabachnik et al., 1979).*

Propagules g-1 soil	Disease index	Disease severity
0 - 1	1	up to 25% of the tap root blackened
5 - 10	1 - 2	up to 50% of the tap root blackened
25	2 - 3	26% to 75%of the tap root blackened with few lateral roots blackened
50 - 100	4	76% to 100%of the tap root blackened with few or no lateral roots remaining

Until recently there were no satisfactory methods available for the control of this disease in cotton. However, seed treatment with the fungicide triadimenol (Baytan^R) has been shown to provide control in field experiments in the U.S.A. and registration is expected for the U.S. 1991 planting season. This will be the first product registered for the control of cotton seedling disease caused by *T. basicola* .

On the basis of these results and considering the situation in California it is important that the distribution and incidence of black root rot caused by *T. basicola* should be monitored. A more intensive sampling of commercial fields in the Wee Waa area should be undertaken in order to provide a more complete picture of the distribution of the pathogen and the evaluation of triadimenol as a seed treatment for the control of black root rot of cotton in Australia needs to proceed. Growers need to be warned that the disease can be spread in soil attached to farm machinery so that the necessary precautions can be taken.

Acknowledgements

The financial support of the Australian Cotton Research and Development Corporation and the co-operation of numerous cotton growers are gratefully acknowledged.

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6. ALTERNARIA LEAF SPOT

Manipulating epidemics

Several attempts have been made during the last three seasons to artificially generate epidemics of alternaria leaf spot in cotton at the Narrabri Agricultural Research Station. Despite the use of cv. 'Pima' which is very susceptible to the disease, overhead sprinkling, the spreading of diseased leaf material from an infected crop and inoculation with laboratory-grown spores no significant disease development has occurred.

It would appear from the literature and from the results of the work done at Emerald in Central Queensland by Graeme Harden, that epidemic development is correlated with either nutritional or physiological stresses in the plant eg. those stresses and symptoms associated with potassium deficiency.

7. VESICULAR ARBUSCULAR MYCORRHIZA (VAM)

Introduction

Mycorrhizas are symbiotic associations between the roots of plants and fungi. They come into existence when the plant's root system becomes infected with an appropriate fungus.

In most types of mycorrhiza the fungus utilizes carbohydrate that has been produced by the plant as a result of photosynthesis. It is likely that the fungus also obtains other nutrients from the plant such as amino acids and vitamins. The host plant also provides the fungus with a habitat that is free from competition from other micro-organisms, antagonists and predators. The fungal mycelium grows out from the infected root into the surrounding soil and acts as an extension of the plant's root system absorbing nutrients such as phosphorus and zinc as well as water from the soil and translocating these through the fungal hyphae into the plant. Mycorrhizal plants with their "extended fungal root system" can therefore explore and exploit a much greater volume of soil than non-mycorrhizal plants. This often results in mycorrhizal plants being healthier and more vigorous than those that are non-mycorrhizal.

There are several different types of mycorrhiza, however the most common type is called a **V**esicular-**A**rbuscular **M**ycorrhiza (**VAM**). This type of mycorrhiza occurs in 60 - 70% of plant species.

It is now known that many usual cropping practices such as cultivation, the use of fertilisers and fungicides, fallowing and the growing of crops like canola reduce the population of VAM fungi in the soil. In most cases the effects of these practices are un-noticed because sufficient fungi survive. However, these farming practices are placing VAM fungi under a selective pressure towards longer periods of dormancy and slow response to the presence of crops.

Intensive agriculture must include management of the population of VAM fungi in soils if productivity is to be maintained. At present there is little basic information on which farm management decisions can be based.

Slow early season growth on virgin country

When new fields are developed, the established native population of VAM fungi are completely disrupted and are actually removed from 'cut' areas of the field. The longer the period between first clearing and planting the first crop the more depleted the population will become. VAM fungi are unable to survive long periods in the absence of living host plants. Severe depletion of the VAM fungi population may result in very slow and stunted early season growth which can be accompanied by yellowing and the development of severe zinc deficiency symptoms. These symptoms often occur in irregular patches across the field reflecting 'cut' and 'fill' areas and the distribution of weeds that grew during the land development process.

In December, 1989 samples were received from a property in the Brewarrina area. Plants from a newly developed field exhibited very poor early season growth when compared with plants from a nearby field which had been planted with cotton for the fourth successive year. Field history, planting dates, an estimate of VAM infection and the results of tissue analyses are shown in Table 7.1. Stunting and a lower level of VAM infection were accompanied by reductions in phosphorus, zinc, sodium, chloride and sulphur and increases in aluminium, iron and boron when compared with apparently healthy plants. Nitrogen, potassium, calcium, magnesium, copper and manganese showed small differences between healthy and unhealthy plants.

Table 7.1. A comparison between plants from two fields on a property near Brewarrina at eight weeks after planting.

field history	cotton cotton cotton	cleared of timber land levelling bare fallow
planting date	12-14/10/89	10-12/10/89
plant height	>25cm	<15cm
% VAM infection	61%	16%
sulfur (%)	0.53	0.34
phosphorus (%)	0.19	0.11
sodium (%)	0.21	0.09
chloride (%)	1.35	0.58
zinc (ppm)	15	5
iron (ppm)	44	75
boron (ppm)	53	66
aluminium (ppm)	25	65

According to the grower the stunted plants eventually recovered and grew vigorously. The observed differences in the levels of phosphorus, zinc, sodium, aluminium, iron and boron were consistent with those differences induced by soil fumigation in the experiment at the Research Station (Table 7.2).

Several commercial fields affected by these conditions were also observed during routine disease surveys in November 1991. The level of infection by VAM fungi in these fields varied from 4% to 16% in the roots of stunted plants and up to 58% in the roots of healthy plants. Healthy or less affected plants were two or three times the size of affected plants.

Observations indicate that the shorter the period between clearing and planting the first crop the better for subsequent crop establishment. Two adjacent fields on a property west of Burren Junction were developed and first cropped to cotton in 1991/92. One field was developed, listed up and left bare for nearly 12 months prior to planting while the other was developed quickly and planted almost immediately. The early season growth of cotton in the well prepared field was severely retarded while growth in the other field was relatively unaffected.

Observations on another property suggest that several crops of wheat, although less dependent on mycorrhizas than cotton, can alleviate mycorrhizal problems in newly developed fields.

These comments have been derived from observations only and there is a need for basic research to provide more informed answers to the problems associated with the establishment and/or maintenance of VAM fungi in soil.

Studies at Narrabri Agricultural Research Station

Methyl bromide was used to fumigate eight plots (each 2m X 10m) in an area (16 rows X 75m) of a field at the Narrabri Agricultural Research Station in September, 1989. Half of the area was planted with cotton on 5th October, 1989 and the other half was planted on 2nd November, 1989. The growth of seedlings in the fumigated plots was significantly reduced in comparison with the seedlings in the unfumigated area. Apart from being stunted the seedlings from the fumigated plots exhibited a range of symptoms which included pronounced zinc deficiency, death of leaf margins and dropping of cotyledons. Estimates of VAM infection and the results of tissue analyses are presented in Table 7.2. The greatest differences induced by soil fumigation and the consequent inhibition of VAM formation were reductions in phosphorus, zinc, copper and sodium and increases in manganese, iron, boron and aluminium. Nitrogen, sulphur, potassium, calcium, magnesium and chloride showed smaller differences associated with the fumigation treatment.

Table 7.2. An estimate of VAM infection (6 weeks after planting) and results of tissue analyses of cotton seedlings from fumigated and unfumigated plots in a field at the Narrabri Agricultural Research Station.

planting date	5/10/89		2/11/89	
fumigated	**yes**	**no**	**yes**	**no**
% VAM infection	**0.5**	**72.0**	**8.1**	**56.0**
phosphorus (%)	0.16	0.36	0.11	0.36
sodium (%)	0.06	0.12	0.05	0.06
copper (ppm)	11	15	9	12
zinc (ppm)	20	27	15	30
manganese (ppm)	90	52	100	62
iron (ppm)	170	88	173	96
boron (ppm)	109	47	120	41
aluminium (ppm)	104	39	72	46

The stunted plants in the fumigated plots eventually recovered and grew vigorously, becoming taller than plants in unfumigated plots. There was no significant difference in seed cotton yield from fumigated and unfumigated plots sown in early October. However, fumigated plots yielded 23.7% less seed cotton than did unfumigated plots for the early November sowing.

The greatest differences induced by soil sterilization have been reductions in P and Zn, and increases in Mn, Fe and B. VAM infection was least on plants in sterilized soil.

The Galathera syndrome

The Galathera Creek is a small occasional stream that has a few branches starting east of Edgeroi. During flood times, it pushes north-west through to the Moomin Creek (it can overflow into the Bobbiwaa Creek to the south). It is therefore part of the Gwydir catchment, even though it is only 5 km north of the Namoi River. There are occasional trees in the Creek, but adjacent country has always been treeless.

Cotton growing on fields adjacent to Galathera Creek has exhibited problems for many years. Seed germination and emergence in October is normal, but subsequent seedling growth is very slow, with delayed squaring. Plant growth is stunted, with small leaves and short internodes. Leaf symptoms include cupping, interveinal chlorosis, and burning, browning or bronzing of the leaf margins. In December, plant vegetative growth speeds up, ultimately producing normal-sized plants but with delayed maturity and low yield.

It was noted that cotton plants from sterilised soil in the field at the Narrabri Agricultural Research Station developed symptoms identical to those symptoms present on cotton plants growing in fields near the Galathera Creek. Sterilising the soil eliminates all biological activity, including the VAM fungi. Subsequent studies showed that plants from the Galathera area had low levels of VAM infection. Further studies were needed to determine the role of the VAM fungi in the Galathera syndrome.

A field experiments in 1990/91 utilised soil sterilisation with methyl bromide (and solarisation in 1990/91) in Auscott field 20 which is affected by the Galathera syndrome. The VAM treatments consisted of soil sterilization, combined factorially with VAM inoculation and zinc + phosphate fertilizer treatments. Plot size was restricted to 1 m. Assessment of treatments in the experiment were based on plant height.

Plant height measurements showed that soil sterilization with methyl bromide allowed cotton plants to grow faster. Home-grown VAM (soil from under cotton at NARS - used to grow maize) produced taller plants with no soil sterilization. High fertilizer rate and *Glomus mosseae* treatments also gave plant height increases on sterilized soil (Figure 7.1).

Sterilization with methyl bromide improved early season growth of cotton on a Galathera site. It is possible that MeBr has removed deleterious rhizosphere microorganisms that inhibit VAM colonisation. Other effects could be due to reductions in specific cotton root pathogens. Sterilization with MeBr on a non-Galathera site reduces cotton growth due to reductions in VAM (and possibly plant growth promoting rhizobacteria).

Further investigations of Galathera syndrome are being carried out at postgraduate level in the Department of Botany at the University of New England as part of the Cotton R & D Corporation funded project UNE7C..

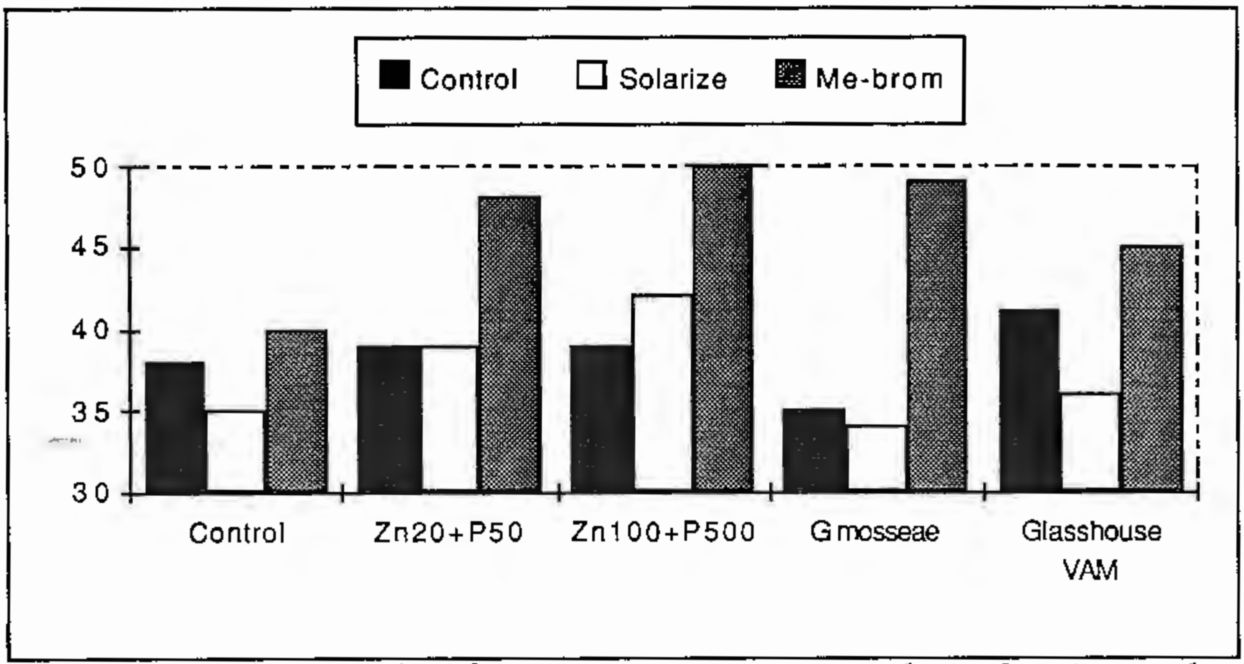

Figure 7.1. Plant height of cotton in response to soil sterilization and a range of zinc + phosphate fertilizer or VAM inolulation treatments. Measurements taken on January 7, 1991.

8. A SUMMARY OF INVESTIGATIONS INTO FACTORS ASSOCIATED WITH FIBRE DAMAGE IN COTTON - 1991

SUMMARY AND CONCLUSIONS

The 1991 harvest was accompanied by very warm, dry conditions and most cotton was harvested by the middle of May although rainfall during late May, June and July delayed the harvest of some late crops until August.

An extensive study detected many samples with relatively high levels of fibre damage. However, this fibre damage was not accompanied by high pH which therefore suggested a physical cause of the observed damage. A comparison of the incidence of fibre damage in hand-ginned cotton and machine-ginned cotton indicated that the ginning and lint cleaning processes are responsible for a proportion of the damage that can be observed on fibres. The moisture content of the seed cotton may be a factor in determining the amount of physical damage that may occur. It has been suggested that very dry seed cotton is particularly prone to fibre damage during processing and much of the seed cotton delivered to gins early in the season had < 5% moisture . Problems in distinguishing between physical damage and damage as a result of microbial degradation made it difficult to identify the factors conducive to the development of cavitoma in cotton.

Cavitoma as indicated by the presence of fibre damage <u>and</u> high pH was only detected in lint from some late harvested crops exposed to rain and in lint from modules affected by coprinus module rot. Very high levels of fibre damage occurred when seed cotton in modules was exposed to local flooding and waterlogging, however, pH was found to be 'normal'.

Results of experiments with mini bales and mini modules appear to confirm the expected increase in pH and fibre damage as moisture content is increased. There was difficulty in obtaining and maintaining desired moisture contents within the mini-bales and mini-modules.

FUTURE RESEARCH

A field experiment to be established at the Narrabri Agricultural Research Station for the 1992 harvest will allow a couple of defoliation and harvest dates with and without overhead sprinkling to simulate rain. The production of mini-modules and mini-bales will enable storage related factors such as time and moisture content to be investigated. Mini-modules and mini-bales will be made immediately after the addition of moisture and sealed polythene bags will be used instead of freezer bags in an attempt to better control moisture content.

Future research will therefore concentrate on the development of cavitoma under controlled conditions and on the importance of coprinus module rot. Mini-modules and mini-bales will be made from seed cotton and lint from wet modules, hot modules, modules affected by coprinus module rot and from crops exposed to long periods of wet weather, if available.

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The dedication and enthusiasm of Miss Suzanne Young who undertook most of the sampling and counting was greatly appreciated.

INTRODUCTION - A REVIEW

In Australia cotton is usually harvested in the period between March and May. However the 1988, 1989 and 1990 harvests were prolonged by wet weather with some crops harvested as late as August. As a result mature cotton was exposed in the field to repeated periods of high moisture and/or relative humidity. While colour and trash problems arose due to these conditions no other significant effects on the fibre were recorded except in 1990 when some spinning mills reported problems in blending associated with finer cotton counts and circular knitted fabric production. Blending procedures had to be revised and the mills undertook an analysis of the fibre in order to isolate the problem. A spray test using a pH indicator was instituted to detect cavitoma if present. One whole delivery of cotton tested positive and several bales with either spots or layers of cavitomic cotton were subsequently detected.

Initially cavitoma was noted only in cotton from the 1990 harvest and not in cotton from the previous two wet harvests. The wet conditions in April 1990 featured a period when rainfall was recorded on 16 consecutive days (see Table). Cavitoma had not previously been reported in Australian cotton which has been successfully sold in overseas markets because of its high fibre quality characteristics.

The Australian Cotton Research & Development Corporation quickly formed a group to co-ordinate an investigation into the causes of the problem so that future occurrences could be avoided or minimised.

Number of days per month on which rain fell(maximum No. of consecutive days) for Myall Vale via Narrabri, 1985 - 1990 (February to August only).

MONTH	1985	1986	1987	1988	1989	1990
FEB.	7(2)	3(1)	8(2)	6(2)	4(2)	7(2)
MARCH	4(2)	1(1)	9(5)	4(1)	12(4)	5(5)
APRIL	5(2)	4(2)	2(1)	18(8)	10(5)	*19(16)*
MAY	5(2)	4(3)	6(3)	11(5)	11(4)	9(4)
JUNE	5(4)	3(2)	8(3)	6(2)	12(5)	7(2)
JULY	5(4)	12(5)	5(2)	12(6)	12(4)	12(3)
AUGUST	10(4)	7(2)	15(9)	11(4)	5(2)	8(4)

Possible causes

Overseas studies have suggested that the initial fibre condition, time, temperature and moisture were the principal factors affecting the microbial degradation of cotton in storage. A moisture content of 9% is generally considered the minimum for growth in cotton although some workers found evidence of fibre damage progressing in the 6% to 7% range.

Possible causes of cavitoma in cotton from the 1990 harvest therefore include: exposure to a long period of wet weather in April 1990; high moisture content of seed cotton as a result of harvesting before the fibre had dried sufficiently; length of time in the module prior to ginning; moisture content of bales after ginning; length of time bales were stored prior to use; and bale storage conditions.

A survey of the diseases present in commercial cotton crops in March of each season showed that the incidence of phytophthora boll rot was particularly high in March 1990 compared to the previous two seasons. Phytophthora boll rot is caused by *Phytophthora nicotianae* var. *parasitica* which attacks mature cotton bolls as they begin to open.

A significant problem in gin yards over the last few years has been a module storage rot caused by water getting into the module around ropes which are used to fasten tarpaulins over the module. The seed cotton becomes discoloured, overheats and a species of *Coprinus* ('inky cap' mushroom) is commonly associated.

Preliminary observations from the spinning mills.

Records and observations from the spinning mills suggested that:

(i) cavitomic and non-cavitomic cotton could be present in the same bale.

(ii) the cavitomic spots spread quickly through the bale when the cotton was stored in a humidified atmosphere.

(iii) bales which contained cavitomic cotton had a higher moisture content than bales without cavitoma.

(iv) some pre-rain cotton had no cavitoma; some pre-rain cotton had spots or layers of cavitoma; all post rain cotton had cavitoma.

(v) all bales which had cavitoma had unusually high micronaire; micronaire as determined at the spinning mill was much higher than that indicated by the cotton supplier.

Preliminary studies at Narrabri ARS.

Two samples from the one bale of lint were provided from a spinning mill. One sample was 'normal' and the second sample was found to be cavitomic on the basis of the pH indicator spray test. Fibre tufts from each sample were mounted on a slide in 18% sodium hydroxide and reference lines were scribed onto the slide. The fibres were classed as either cavitomic or non-cavitomic at the point of intersection between the fibre and a reference line. Approximately 500 fibre-intersects were assayed for each sample. The incidence of fibre damage in the normal sample was found to be 13.4% compared to 31.6% for the cavitomic sample. This result indicated that some fibre damage was present in all samples with cavitomic cotton having a higher incidence of damage.

Lint samples were obtained from bales of cotton harvested from 8 commercial fields where the incidence of Phytophthora boll rot had been previously determined. No apparent relationship was found between the incidence of the boll rot and the incidence of fibre damage.

An Australian spinning mill provided a collection of lint samples that had been identified as cavitomic by the pH indicator spray test. The incidence of fibre damage (cavitoma) was assessed as previously indicated. Fibre tufts were also incubated at room temperature on 2% water agar and on sterile filter paper on 1% water agar so that the causal organisms could be identified. The results (See Table) showed that cavitoma had been present in some of the cotton harvested in 1989 and the associated fungal species were similar for most samples despite being taken from different geographic areas and different seasons. Four unidentified fungi and a yellow bacterium were also commonly isolated from the cavitomic cotton samples. Those fungi found to be associated with cavitoma in Australia were similar to those identified in overseas studies.

Lint samples were obtained from bales of cotton harvested from commercial fields that were picked before and after the wet period in April and the incidence of fibre damage and the pH were determined. The presence of cavitoma as indicated by fibre damage and high pH (pH>8.0) was confined mainly to that cotton that was harvested after the rain in April. However, cotton picked late in the season after exposure to a second period of wet weather at the end of May was not as severely affected as cotton picked in early May (Figure 1). It is interesting to note the relatively high levels of fibre damage associated with a neutral pH (6.0 - 8.0) which possibly indicates physical rather than biological damage. There was no clear relationship between the presence of cavitoma and the length of time the seed cotton was stored in a module (Figure 2).

The incidence of fibre damage (%) and the associated microflora of cavitomic lint samples from an Australian spinning mill.

YEAR	CV.	GRADE /TYPE	AREA GROWN	NO. OF SAMPLES	% CAVITOMA		ASSOCIATED MICRO-ORGANISMS
					MEAN	RANGE	
1989	SIOKRA	M	??	4	29.75	17.8-40.0	Rhizopus, Fusarium, Alternaria, Aspergillus niger
1990	DPL 90	S.M	EMERALD	2	27.7	21.1-34.3	-
1990	DPL 90	M+	BILOELA	5	37.82	28.5-42.6	Rhizopus, Fusarium, Alternaria, Aspergillus niger, Stachybotrys
1990	SICALA	SLM+	G'WINDI	5	29.92	24.2-38.1	Alternaria, Penicillium
1990	DPL 90	M+	NW NSW	4	46.5	34.2-58.5	Rhizopus, Fusarium, Alternaria, Aspergillus niger, Curvularia, Cladosporium, Chaetomium
1990	SIOKRA	M+	NW NSW	4	30.2	23.9-46.3	Rhizopus, Fusarium, Penicillium, Aspergillus niger
1990	SICALA	M+	NW NSW	6	40.5	27.7-53.9	Rhizopus, Fusarium, Alternaria, Aspergillus niger, Curvularia, Cladosporium,

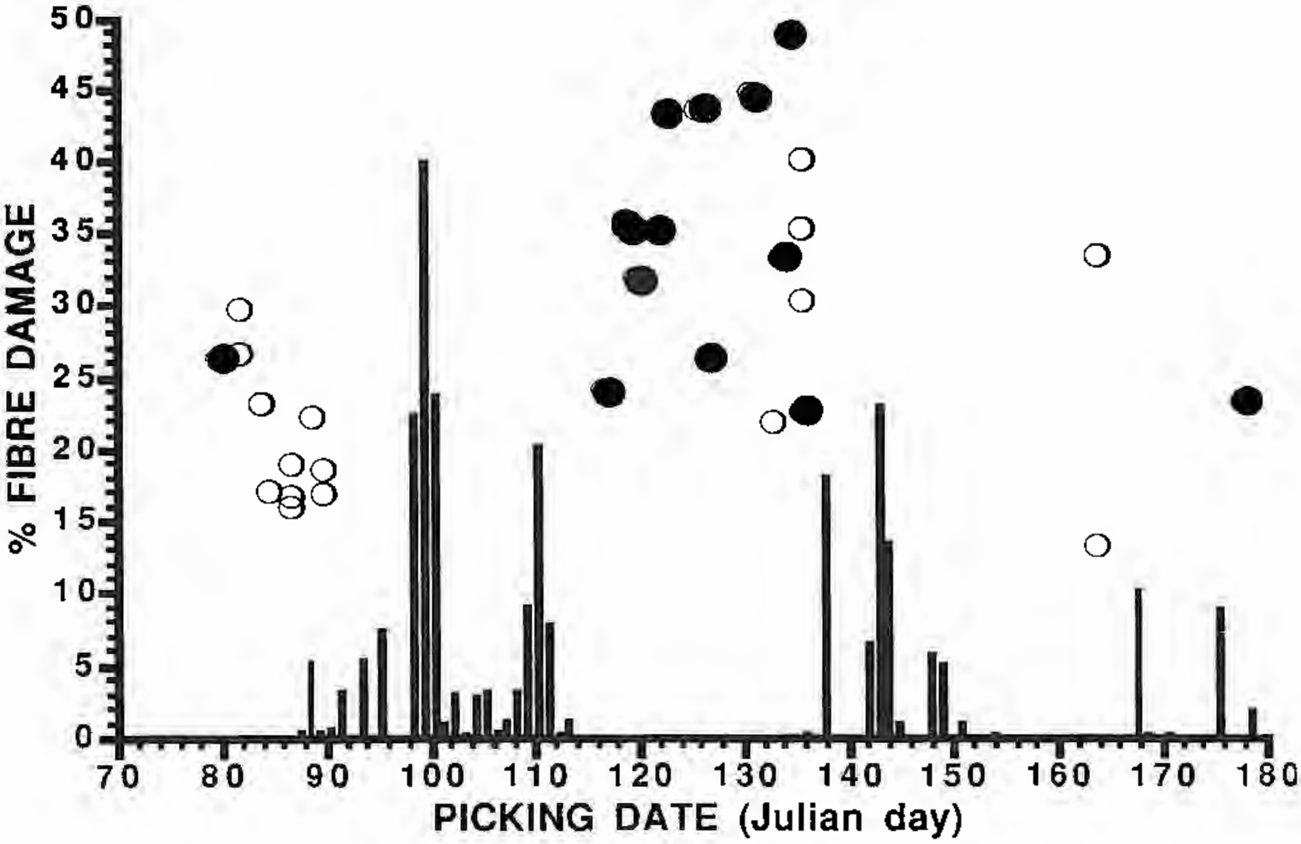

Figure 1. The incidence of fibre damage in lint samples from cotton harvested in 1990 as related to the picking date and daily rainfall (bars) at Narrabri. Closed circles indicate pH > 8.0.

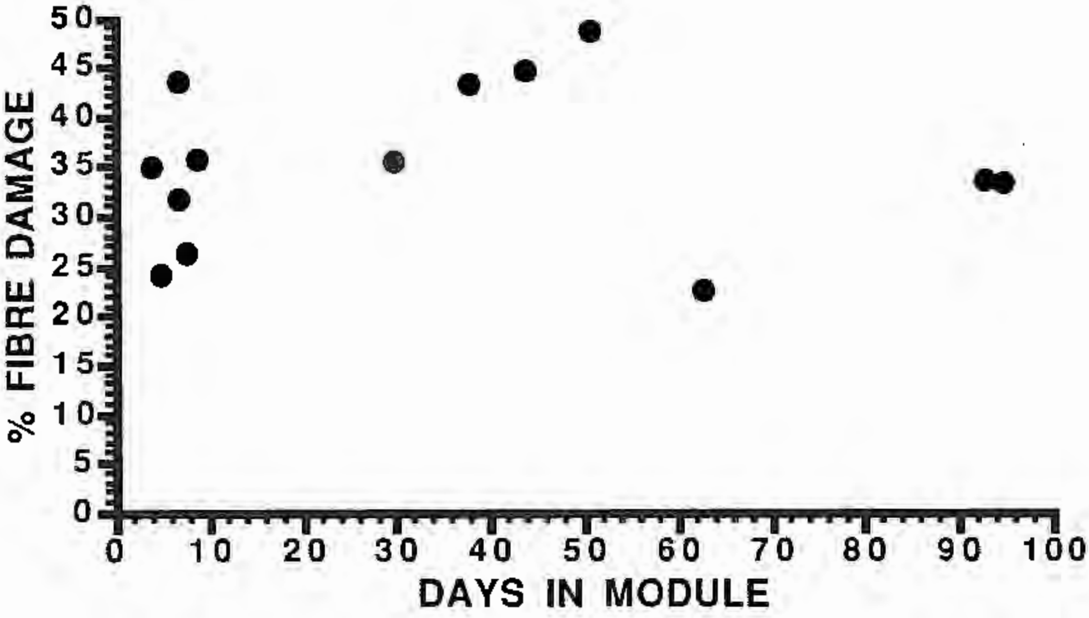

Figure 2. The relationship between the incidence of fibre damage and the number of days stored in a module for lint samples with pH > 8.0.

OBJECTIVE - 1991 HARVEST : *TO DETERMINE BY EXTENSIVE FIELD SAMPLING AND TESTING THOSE FACTORS ASSOCIATED WITH THE DEVELOPMENT OF FIBRE DAMAGE IN COTTON.*

METHODS

Hand-picking

Hand-picked samples were obtained by removing all lint from mature bolls on plants selected by a step-point method while traversing both diagonals of a section of the field.

Sampling modules

A 'module sampler' was designed and constructed at the Research Station to enable seed cotton samples to be withdrawn from within the module thereby avoiding edge effects. The sampler consists of a sharpened steel rod, 1 metre long and fitted with two sets of four 'barbs' situated just behind the point - and a pipe handle. Samples were obtained by plunging the sampler into the module. When withdrawn a small amount of seed cotton becomes trapped in the barbs Modules were sampled at three points along each of the opposite diagonals from opposite sides of the module and the six sub-samples thus obtained were combined to give a composite sample for each module.

Determining moisture content

Moisture contents were determined by weighing the seed cotton or lint samples before and after 3 days in a dehydrator at 40°C. Samples for moisture determination were placed in sealed plastic containers as soon as they were collected so as to prevent changes due to ambient relative humidity.

Assessing fibre damage and pH

Fibre tufts were mounted on glass slides in 18% sodium hydroxide and reference lines were scribed onto the under-surface of each slide. The fibres were classed as either damaged or normal at the point of intersection between the fibre and a reference line. Between 300 and 500 fibre-intersects were assayed for each sample. Damaged fibres were characterised by irregular swelling in the caustic and the immature flat twisted fibres were not included in the counts.

A 5% solution of Universal Indicator was used to estimate pH.

Ginning

All the hand-picked samples and module samples were ginned on a small 10-saw gin at the Narrabri Agricultural Research Station. This gin has no facility for adding moisture and no lint cleaners. Commercially ginned samples were provided by courtesy of Auscott, the Namoi Co-operative and Dunavant Enterprises.

Mini-modules & Mini-bales

A small press was designed and constructed at the Research Station so that deterioration during storage could be studied under conditions similar to that within a module or bale. Compression is provided by a hydraulic ram mounted on the front of tractor. The press produces mini-modules and bales that are 15cm X 15cm X 25cm in size containing either 1.0kg seed cotton or 1.7kg lint - bound by three cable ties and enclosed in a tightly fitting freezer bag to prevent drying out or absorption of moisture.

Moisture content was adjusted by the addition of water as a fine spray. The amount of water to be added was calculated on the basis of sample size and original moisture content. The seed cotton or lint was thoroughly mixed after spraying and stored overnight wrapped in a 'poly' bag before being used to construct the mini-modules or mini-bales.

RESULTS

Early cf late harvest / with and without Prep / moisture content / module storage

Early maturing fields with and without Prep and later maturing fields were selected at both Auscott Warren and Auscott Narrabri. A module built early in the day and one built during mid afternoon (different moisture contents ?) were selected for each of the fields and put aside for sampling over an extended period. Seed cotton samples were obtained by hand picking prior to harvest and from modules after harvest. These samples were ginned at the Research Station and the pH and % fibre damage were determined. A composite sample from each module was collected during baling after ginning commercialy at the end of the experiment.

Auscott Midkin and Auscott Warren conducted experiments where all modules from a large field were divided into five groups and ginned at monthly intervals. All modules from both locations were sampled after harvest and at regular intervals until ginned.

All modules were picked under dry conditions and no fields were exposed to rain prior to harvest. Consequently there was little difference in moisture content and fibre damage between modules. Hand-picked samples collected up to 5 weeks prior to harvest did have higher levels of fibre damage than that observed in the modules after picking and this was possibly due to a predominance of cotton from low bolls nearer the ground and well down in the canopy. Bolls towards the top of the plant were not open at the time of hand-picking.

There was no obvious increase in fibre damage with storage time in the module and this probably reflects the very low moisture contents (3 - 5%). The level of fibre damage was higher in the commercially ginned bale samples than in the NARS ginned module samples.

AUSCOTT WARREN

Field No.	Prep	% fibre damage									
		Hand-picked samples		**picking date**	**module samples**						**Bale sample**
41	+	11.2 (4)		1/4/91	15.5 (10)	14.8 (23)	10.0 (39)	5.7 (57)	5.8 (73)	4.4 (87)	18.0 (125)
8	-	13.9 (4)		1/4/91	20.5 (10)	16.0 (23)	7.4 (39)	8.7 (57)	11.0 (73)	- (87)	15.5 (125)
39	-	17.2 (9)		6/4/91	13.1 (5)	22.2 (18)	9.0 (34)	8.6 (52)	5.0 (68)	7.9 (82)	12.1 (120)
26	-	17.1 (27)	14.6 (13)	24/4/91		7.5 (22)	11.2 (40)	7.0 (56)	8.3 (70)		16.3 (108)

No. in ( ) indicates number of days before or after commercial picking date
pH of all samples between 5.5 and 7.5

AUSCOTT NARRABRI

Field No.	Prep	% fibre damage									
		Hand-picked samples		**picking date**	**module samples**						**Bale sample**
22S	+	20.8 (20)	20.6 (9)	28/3/91		9.3 (21)	8.7 (39)	5.9 (68)			18.4 (110)
2N	-	25.1 (18)	15.2 (3)	7/4/91	16.1 (11)	18.4 (15)	6.4 (29)	15.0 (58)			18.6 (100)
5S	-	26.8 (25)	17.1 (10)	14/4/91		8.2 (22)		9.5 (52)			10.6 (94)
19S	-	29.2 (34)	18.4 (19)	23/4/91	8.6 (13)			8.2 (42)			9.5 (65)

No. in ( ) indicates number of days before or after commercial picking date
pH of all samples between 5.5 and 7.5

AUSCOTT WARREN

Field No.	Time of day picked	% moisture	Days in module	% fibre damage
41	9.30am	4.6	125	16.6
	4.00pm	3.5	125	20.5
8	am		125	13.5
	pm		125	17.4
39	am	5.4	120	10.4
	pm	3.5	120	13.8
26	9.30am	6.6	108	16.3
	4.30pm	3.0	108	16.3

Hand-picked & hand-ginned cf. machine-picked & ginned

Several of the samples collected and processed during the study were sub-divided and either machine-ginned or hand-ginned. Machine-ginned cotton consistently had higher levels of fibre damage than hand-ginned cotton.

Sample No.	Picking and ginning	% Fibre damage
1.	Hand-picked, Hand-ginned	9.6
	Hand-picked, Machine-ginned (NARS)	13.3
2.	Hand-picked, Hand-ginned	34.1
	Machine-picked, Machine-ginned (NARS)	51.7
3.	Hand-picked, Hand-ginned	2.7
	Hand-picked, Machine-ginned (NARS)	8.6
4.	Hand-picked, Hand-ginned	7.9
	Hand-picked, Machine-ginned (NARS)	17.4
5.	Hand-picked, Machine-ginned (NARS)	14.6
	Hand-picked, Machine-ginned (commercially)	28.5

Hot modules

Cotton Seed Distributors routinely monitor the temperature of all modules in the pure seed production programme. Modules that heat up are rejected.

CSD staff provided samples from modules where the temperature had exceeded 40°C and the pH and % fibre damage were determined. Results showed that none of these modules had high pH or excessive fibre damage. It is possible that hot spots were localised within the module and not included in the samples. In future samples for testing should be removed from the same point as the temperature probe.

Module No.	Picking date	Ginning date	Days in storage	Module Temp.(°C)	pH	% Fibre damage
453150	29/3/91	16/4/91	18	60+	6.5	16.5
453149	29/3/91	16/4/91	18	40 +	6.0	17.8
453151	29/3/91	16/4/91	18	40 +	6.3	15.7
*453150	29/3/91	16/4/91	18	-	6.0	24.0
521225	-	18/4/91	-	49	7.0	21.3
521246	-	18/4/91	-	49	6.0	10.2
521213	-	18/4/91	-	54	7.0	11.9
521214	-	18/4/91	-	37	6.0	21.6
521224	-	18/4/91	-	54	7.0	10.2
540060	24/3/91	29/4/91	36	49	-	12.7
540069	24/3/91	29/4/91	36	49	-	5.3
452235	5/4/91	3/5/91	28	49	7.0	9.5

* - a bale sample taken after ginning module 453150

Wet modules

As a result of extensive rainfall late in the 1991 harvesting season many modules were exposed to local flooding. A module on a farm near Narrabri was sampled at various heights above ground to cover the range from 'waterlogged' to 'unaffected'. Samples were dried and ginned at the Research Station. The waterlogged sample was very discoloured, with high fibre damage and low pH. Fibre damage decreased with decreasing moisture content. Microscopic observation showed prolific growth of bacteria over and within fibres from the waterlogged sample.

Sample description	pH	% fibre damage
wet module bottom (0-30cm)- 61% H_2O	5.0	86.9
wet module bottom (30-45cm)- 13% H_2O	7.0	35.7
wet module bottom (45-60cm)- 8% H_2O	7.0	11.6
wet module bottom (60-75cm)- 8% H_2O	6.0	9.5

Coprinus module rot.

Over recent years and in most gin yards there has been an increasing occurrence of module rot associated with the entry of water into the module - especially around tarp ropes. The seed cotton becomes discoloured and a species of *Coprinus* (the 'inky cap' mushrooms) is often present. Seed cotton samples were taken from 'near' and 'away from' an affected part of a module in the Midkin gin yard. A very discoloured sample and an unaffected sample were also collected from a partly built module on Cudgewa lane that had been 'flooded' when it was exposed to wet weather while still in the module builder. All samples were ginned at the Narrabri Agricultural Research Station.

High pH and substantial fibre damage were associated with the coprinus module rot in samples from the Midkin module. Substantial fibre damage and 'normal' pH were noted in the very discoloured cotton from the Cudgewa lane module.

Sample description	pH	% fibre damage
'near' module rot - Midkin	9.5	38.0
'away from' module rot - Midkin	7.5	13.4
Cudgewa module rot - very discoloured	6.5	55.7
Cudgewa module - unaffected	6.5	8.0

Boll rots.

A field on the property 'Richmond' near Pallamallawa was severely damaged/lodged by hail in February 1991. A disease assessment immediately prior to picking indicated 22% of bolls affected by phytophthora boll rot and 11.6% of bolls with symptoms of 'tightlock'. The field was picked on 14/3/91 and ginned the following day. pH was normal for both hand-picked and machine-picked samples. Fibre damage was higher in the commercially ginned sample which included lint cleaners.

Sample description	pH	% fibre damage
hand-picked, NARS ginned	6.0	14.6
machine-picked, commercially ginned	7.0	28.5

Alternaria leaf spot

A field of Sicala 33 on the property 'Red Mill' near Moree was exposed to an epidemic of alternaria leaf spot as it approached maturity. The field was picked on 14/3/91 and ginned 5 days later. Results indicated moderate fibre damage and slightly elevated pH. Epidemics of alternaria leaf spot are rare in NSW.

Sample description	pH	% fibre damage
hand-picked, NARS ginned	8.0	24.3
machine-picked, commercially ginned	7.5	26.6

Very late harvest after rain

Four late fields that had been exposed to lengthy periods of wet weather were sampled. Three of the four samples were cavitomic with high pH and high levels of fibre damage. The machine picked and ginned sample from Karinga/Smith had substantially more fibre damage than the hand picked and ginned sample.

Sample description	Harvest date	pH	% Fibre damage
Karinga / Smith, West of Wee Waa - HP-HG	late June	10.5	34.1
Karinga / Smith, West of Wee Waa - MP-MG	late June	10.5	51.7
Undoolya / Bullard, East of Boggabri - MP-MG	late June	6.5	12.9
Drayton / Hamparsum, Breeza - MP-MG	August	9.0	35.8
Rutter, Caroona - MP-MG	August	9.0	29.7

MP-MG = machine picked and ginned; HP-HG = hand picked and ginned.

Mini-modules.

Mini modules were made from seed cotton from two fields at the Research Station (See Table). Water was added to some to provide different moisture contents (approx. 4, 8 & 12%). Fibre damage, pH and moisture content were determined after 16 weeks storage in a field shed.

The results indicated that attempts to produce different moisture contents were unsuccessful with very little variation between the treatments. Consequently there was no apparent interaction or relationship between storage time, moisture content and fibre damage.

Sample description	No.	Desired moisture	AFTER 16 WEEKS STORAGE		
			Moisture content (%)	pH	% Fibre damage
NARS A1 Siokra 1-4, 5.8% moisture 39.9% gin out-turn	040	dry	6.9	6.5	9.7
	044	dry	6.7	6.5	9.3
	049	damp	7.5	-	-
	056	damp	7.0	-	-
	061	wet	8.1	6.0	12.1
	072	wet	8.3	6.5	9.2
NARS Old 2 DPL 90, 4.4% moisture 39.5% gin out-turn	005	dry	6.9	6.0	9.5
	011	dry	6.9	6.0	8.4
	017	damp	7.2	-	-
	019	damp	6.6	-	-
	026	wet	8.7	7.0	10.4
	035	wet	8.4	7.0	21.1

Initial assessment of fibre damage: NARS A1 - 8.4%; NARS Old 2 - 13.0%

Mini-bales.

Mini-bales were made from DPL 90 lint with water added to produce three levels of moisture content (4-6%, 8%, 12%). After 16 weeks storage in either a controlled environment shed at the Namoi Co-op. in Wee Waa or a field shed at the Research Station the moisture content, pH and % fibre damage were determined.

Results appear to confirm the expected increase in pH and fibre damage as moisture content is increased. There was apparent difficulty in obtaining desired moisture contents within the mini-bales. In a recent experiment to try and explain problems in establishing and maintaining different moisture contents dry cotton lint was placed in a freezer bag inside a humid chamber. Within 48 hours there had been a 5% increase in the weight of the lint. Sealed polythene bags should be used in future experiments.

Sample description	No.	Moisture content at 8 wks	AFTER 16 WEEKS STORAGE		
			Moisture content (%)	pH	% Fibre damage
mini-bales stored at Namoi Co-op controlled environment	i	8.6	12.0	6.5	8.2
	ii		12.5	6.0	11.5
	iii		11.7	6.0	13.4
	iv	10.0	8.2*	7.5	18.3
	v		8.2*	7.0	13.2
	vi		8.5*	7.0	13.5
	vii	11.9	13.5	8.0	16.4
	viii		13.9	8.0	19.1
	ix		14.1	8.0	19.1
mini-bales stored in a field shed no environ. control	i	8.0	5.9	7.0	5.7
	ii		5.7	7.0	8.5
	iii		5.8	7.0	7.1
	iv	10.5	7.0		
	v		7.5		
	vi		6.3		
	vii	12.1	7.5	7.5	15.2
	viii		7.7	7.5	13.5
	ix		8.6	7.0	8.4

* moisture content determinations delayed - mini-bales stored in laboratory for 1 week.

APPENDIX 1.

SAMPLES DESPATCHED TO DR NIGEL JOHNSON FOR DYE TESTING.

No.	Description	pH	% fibre damage
1.	wet module bottom (0-30cm)- 61% H_2O	5.0	86.9
2.	wet module bottom (30-45cm)- 13% H_2O	7.0	35.7
3.	wet module bottom (45-60cm)- 8% H_2O	7.0	11.6
4.	wet module bottom (60-75cm)- 8% H_2O	6.0	9.5
5.	near module rot ex Midkin	9.5	38.0
6.	away from module rot ex Midkin	7.5	13.4
7.	v. wet module + module rot ex Cudgewa	6.5	55.7
8.	without module rot ex Cudgewa	6.5	8.0
9.	Smith, Post-rain, HP-HG	10.5	34.1
10.	Smith, Post-rain, MP-MG	10.5	51.7
11.	Bullard, Post-rain, MP-MG	6.5	12.9
12.	Auscott Narrabri HP-HG	6.5	7.9
13.	Auscott Narrabri HP-MG	7.0	17.4
14.	Hamparsum, Breeza - August pick	9.0	35.8
15.	Rutter, Caroona - August pick	9.0	29.7

HP-HG = hand picked, hand ginned
MP-MG = machine picked, machine ginned

9. PLANT QUARANTINE AND DISEASES OF COTTON.

(An invited paper prepared for a special edition of 'Australasian Plant Pathology' - to be published in 1992.

Abstract

The Australian cotton industry has developed rapidly since the early 1960's when irrigation became available. Bacterial blight, Verticillium wilt and Phytophthora boll rot have caused significant yield reductions but Australian production areas have been kept free of several potentially important plant pathogens which are present in other countries. The pathogens that cause bacterial blight and Verticillium wilt have been present in Australia for many years. More virulent races and strains of these same pathogens have developed in overseas production areas and the introduction of these new races and strains must be prevented. Standard plant quarantine procedures have achieved the level of protection required by the Australian cotton industry with the possible exception of the introduction of races of the bacterial blight pathogen by symptomless epiphytic transfer. The quarantine dilemma is whether to attempt to provide optimum conditions so that the pathogen, if present, can express symptoms in the host and be detected or to provide conditions that will minimise the growth and development of the pathogen and other epiphytic micro-organisms, if present.

The presence of soil and/or plant material on second-hand machinery imported from overseas constitutes a weak link in the effectiveness of quarantine attempts to prevent the introduction of exotic pathogens into Australia. Those involved in bringing second-hand machinery into Australia should ensure thorough cleaning of such equipment prior to importation. The inspection of this machinery by Quarantine officers also needs to be thorough and the efficacy and feasibility of fumigation could be considered.

Introduction

Cotton (*Gossypium hirsutum* L) was introduced to Australia with the first fleet in 1788 and the first recorded shipment to the United Kingdom was in 1830 (Dowling 1989). Despite several efforts to encourage the development of an Australian cotton industry it was not until the early 1960's and the completion of Keepit dam on the Namoi River that the industry began to flourish. In 1960, cotton production made an insignificant contribution to farm production and exports in Australia. By 1989 cotton had become Australia's sixth biggest agricultural export and the third biggest crop export behind wheat and sugar (Dowling 1990). Approximately 290,000 tonnes of cotton lint were produced on 225,000 hectares in Queensland and New South Wales during the 1989/90 season (Dowling 1990). The majority of the crop (86.5% in 1989/90) is grown under irrigation.

During the past several seasons Australian cotton growers have become very aware of the potential for bacterial blight (*Xanthomonas campestris* pv. *malvacearum* [Smith] Dye), verticillium wilt (*Verticillium* *dahliae* Kleb.) and phytophthora boll rot (*Phytophthora nicotianae* Breda de Haan var. *parasitica* [Dastur] Waterh.) to reduce yields (Allen, 1986; Allen and West, 1987; Allen, 1990). Several other diseases are considered of local or minor importance. However, there are several diseases of major significance to cotton production in other countries which are not present in Australia. Credit for this situation of freedom must go to our isolated geographic position coupled with the comparative youth of the Australian cotton industry and the effectiveness of Australian quarantine procedures to date.

Bacterial Blight

Bacterial Blight caused by *X. campestris* pv. *malvacearum* has, until recently, been regarded as the most important disease of cotton in Australia. Prior to 1974 all isolates of the blight pathogen collected from cotton in Australia were identified as belonging to race 1 (Fahy and Cain, 1987). However in 1974 races 2,3,4,7,10 and18 were detected for the first time in Australia on cotton (Fahy and Cain, 1987). It is highly unlikely that this rapid proliferation of races was spontaneous, particularly since the occurrence of these new races corresponded with large numbers of seed introductions from the United States where these races were already present. A possible explanation is symptomless epiphytic passage through quarantine.

Overseas studies (Brinkerhoff and Hunter, 1963; Schnathorst, 1968; Innes, 1983) and extensive studies at Narrabri Agricultural Research Station have shown that the pathogen survives within the seed, despite acid-delinting in concentrated sulphuric acid or hydrogen chloride gas or chemical seed treatment. Other studies (Moffett and Wood,1984; Brinkerhoff *et al.*, 1984; Wrather *et al.*, 1986) have demonstrated the ability of the pathogen to survive as an epiphyte or saprophyte with no symptom expression on the plant surfaces of both resistant and susceptible cultivars when environmental conditions are not suitable for normal symptom development.

Innes (1983) reported that the optimum temperature for the infection of cotton by *X. c.* pv. *malvacearum* was between 32^o and 36^{o}C. Brinkerhoff and Presley (1967) showed that some cultivars were resistant to blight when grown at 19^{o}C night and 25.5^{o}C day or at 26.5^{o}C night and day but were susceptible when grown at 19^{o}C night and 36.5^{o}C day. Another study (Moffett, 1982) showed that infection could occur at 20^{o}C but that symptom expression was prevented. These studies have also demonstrated the need for leaf wetness and/or high humidity to allow infection and normal symptom development.

Prior to the 1985/86 season nearly all cotton grown in Australia was of the U. S. Deltapine type which is susceptible to the races of the blight pathogen that predominate in Australia. CSIRO plant breeders at Narrabri have since released several cultivars with complete resistance to the blight pathogen and these cultivars have been widely accepted. However, new more virulent races of *X. c.* pv. *malvacearum* have developed in Chad, Upper Volta and the Sudan and a plant breeder in Texas has introduced these new races to the United States for use in breeding programmes (Follin, 1983; Bush, 1984). These new races are virulent on the previously resistant French and U. S. cultivars which contain the B_2-B_3

genes for resistance (Follin, 1983) and it is presumed that the current blight resistant Australian cultivars would also be susceptible.

Verticillium Wilt

The incidence of verticillium wilt in commercial cotton crops has increased significantly in recent years and this has been attributed to the use of susceptible cultivars, increased adoption of minimum tillage practices and repeated cotton cultivation in the same field (Allen, 1990). Verticillium wilt has been regarded as an important disease of cotton in Australia for many years (Evans and Paull, 1967). A comparison of American and Australian isolates of the pathogen showed that all Australian isolates were similar to, but less virulent than, the mild non-defoliating SS-4 strain that occurs in the United States (Schnathorst and Evans, 1971). A severe defoliating T-1 strain was not identified among the Australian isolates and appears to be confined to North, Central and South America (Schnathorst and Evans, 1971).

Exotic Diseases

The Fusarium Wilt - Nematode Complex (*Fusarium oxysporum* Schlect. f.sp. *vasinfectum* [Atk] Snyd. & Hans.). This disease occurs in all cotton growing areas except Australia, Turkey and West Africa (Watkins, 1981). It is particularly severe in China, the Nile Valley of Egypt, the south-eastern United States and part of Tanzania. In the United States losses are greatest on acid sandy soils that also are infested with root knot nematodes. Very high losses occur when susceptible cultivars are grown in wilt infested soil under favourable environmental conditions. Although fusarium wilt can occur in the absence of nematodes, nematode feeding increases the susceptibility of plants (Watkins, 1981).

Phymatotrichum Root Rot (*Phymatotrichum omnivorum* [Shear] Dug.). *P. omnivorum* has a large host range including more than 2000 species of dicotyledonous plants and phymatotrichum root rot has been described as one of the most destructive plant diseases known. The estimated annual loss caused by this disease in Texas is in excess of $25 million. The disease is confined mostly to the calcareous clay soils of the south-western United States and much of Mexico (Watkins, 1981).

South-Western Cotton Rust (*Puccinia cacabata* Arth.& Holw.) This disease is regularly observed in cotton growing areas of northern Mexico and the south-western United States. Yield reductions of up to 75% were reported from Arizona in 1930 and 1959. In recent years the disease has occurred more frequently and with greater severity in Mexico than in the United States (Watkins, 1981).

Diseases Caused by Viruses and Mycoplasma-like Organisms (MLO). The Compendium of Cotton Diseases (Watkins, 1981) lists 17 naturally occurring virus and MLO diseases of cotton and several have been of economic importance, principally outside of the United States. These include leaf curl, mosaic and blue disease (Watkins, 1981). None of these have been observed in Australia.

Discussion

The pathogens that cause bacterial blight and verticillium wilt of cotton have been present in Australia for many years. However, the introduction of those races or strains that are now present in overseas production areas poses a threat to the Australian cotton industry and must be avoided. Similarly, the introduction of other exotic plant pathogens needs to be prevented. Standard plant quarantine procedures have achieved the level of protection required with the possible exception of the introduction of races of the bacterial blight pathogen by symptomless epiphytic transfer.

Symptoms of bacterial blight of cotton will not develop unless the required temperature and humidity are provided. Normal glasshouse conditions allow survival of the blight pathogen as an epiphyte but are not suitable for symptom development. The provision of high temperatures and misting allows symptom development and detection of the pathogen on susceptible cultivars but also promotes symptomless epiphytic development on resistant cultivars. For these reasons the plant quarantine protocol for cotton has been modified to include the pre- and post quarantine acid-delinting of seed, intermittent misting and warm temperatures during early growth to allow detection of the pathogen on susceptible cultivars and applications of a copper bactericide to eliminate epiphytic populations on resistant cultivars.

There is some criticism of this protocol because of the danger of promoting the survival and development of epiphytic micro-organisms and increasing the chance of contaminating other plant material. The growth, survival and dispersal of epiphytic populations is minimised when foliage is kept dry and the relative humidity is maintained as low as possible (Leben, 1981). The quarantine dilemma is whether to attempt to provide optimum conditions so that the pathogen, if present, can express symptoms in the host and be detected or to provide conditions that will minimise the growth and development of the pathogen if present. An alternative strategy would be to assume the pathogen to be always present and to apply eradicative treatments such as foliar bactericides or hot water treatments. However, the use of foliar bactericides would not be expected to control populations protected within the buds and the efficacy of hot water seed treatments for the control of *X. c.* pv. *malvacearum* within cotton seed has been questioned (Navaratnam *et al.*, 1980).

Second-hand Machinery from Overseas

There are considerable economic advantages in purchasing second-hand machinery overseas. Consequently there is a significant flow of such equipment into Australia. Second-hand agricultural machinery is subject to quarantine inspection on arrival in Australia. This inspection is for the detection of soil and plant materials. There are no mandatory treatments required.

Specialised second-hand machinery for the cotton industry in Australia usually originates from the United States and may be delivered on farm in Australia within four to six weeks of purchase. The complexity of this equipment makes thorough inspection difficult and undetected soil and cotton debris has been observed on inspected machinery.

The presence of soil and/or plant material on second-hand machinery constitutes a weak link in the effectiveness of quarantine attempts to prevent the introduction of exotic pathogens into Australia. Those involved in bringing second-hand machinery into Australia should ensure thorough cleaning of such equipment prior to importation. The inspection of this machinery by Quarantine officers also needs to be thorough and the efficacy and feasibility of fumigation could be considered.

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APPENDIX I : Current Co-operative Cotton Pathology Research- Myall Vale

Programme	NSW Agric. Myall Vale	Queensland DPI, Toowoomba	CSIRO Myall Vale	CSIRO Canberra	UNE Armidale	Sydney University	UNSW, Sydney	Queensland University	Incitec Brisbane	CSD Wee Waa
1. DISEASE SURVEYS	Annual Nov. & March surveys Curr. CRDC	Annual Surveys Curr. CRDC								
2(a) CONTROL OF VERT. & SEEDLING DISEASES	Field evaluation of fungicides and cultural practices Curr. CRDC	Field evaluation of cultural practices for vert control	Cultivar trials Verticillium resistance, Verticillium nursery			Dr B. Lyons + two Hons. students Vert Wilt Curr. CRDC				Annual CSD seed treatment Trial
2(b) BIOCONTR-OL OF VERT. & SEEDLING DISEASES	Curr. CRDC			Field evaluation of engineered cvs when available Curr. CRDC				Dr Peter Dart Dr Helen Ogle + a PhD student	Paul Hart Field evaluation of potential biocontrol agents	
3. VAMS	MeBr and Rotation crop expts Curr. CRDC		Dr Greg Constable Galathera expts		Dr J.F.Brown David Nehl Curr. CRDC	Dr P McGee + Student Curr. CRDC				
4. BARRE FIBRE DAMAGE	Field expts Curr. CRDC						Dr Mike Palethorpe & Curr. CRDC			
5. TRAINING				PhD	PhD Hons	3 Hons		PhD		