FR024

Control of black sigatoka disease in bananas

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QLD Department of Primary Industries

FR024

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SUMMARY

(A) INDUSTRY SUMMARY

An 11 months delay in appointing the banana inspector delayed the commencement of the surveillance component of this project.

Regular surveys (1-2/year) to most of the islands in the Torres Strait showed that black Sigatoka had not spread to any new locations in the period 1992 - 1995. It was present on the northern islands of Boigu, Duaun and Saibai, the eastern islands of Murray, Darnley and Stephen, and the northern mainland island of Badu. It was not detected on the other mainland islands of Thursday, Horn, Hammond, Prince of Wales, Friday, Moa or Mabuiag, or the central islands of Yam, Sue, Coconut or Yorke. It had been recorded on Thursday and Moa islands, but it had not reappeared after an eradication program in the mid 1980's. Bananas were also eradicated and replanted on Badu Island during this program but black Sigatoka had reappeared on the susceptible cultivar Lady Finger. The Lady Finger plants had been reintroduced but the source of the material or those responsible for the replanting are unknown.

All major areas of inhabitation in the Cape York area were checked each year for banana plants and diseases by the Banana Inspector and or AQIS/NAQS staff. Areas included the aboriginal communities of Lockhart River and Hopevale on the east coast, Kowanyama, Pormpuraaw, Aurukun, Napranum and Mapoon on the west coast, the towns of Weipa, Coen, Laura and Cooktown and the alternate lifestyle communities at Wattle Hills, Portland Roads, Chilli Beach and Bloomfield. Surveys were made mainly during the dry season (ease of travel), but unfortunately conditions during this period are not conducive to lesion development or recognition of the disease.

Black Sigatoka was not found throughout the Cape York area, but it was located in September 1993 at Ayton on a non commercial banana property in the Bloomfield area (70km south of Cooktown and 200km north of Cairns). Bloomfield was outside the area to be covered in the original project outline. The disease was located during a survey to determine the northern limit for yellow Sigatoka a requirement in the development of a Contingency Plan to contain and manage any outbreak of black Sigatoka which may occur on the mainland. In an intensive survey from the Daintree River in the south (75km from Ayton) to Hopevale in the north (40km from Cooktown, 120km from Ayton) most properties were visited and all banana plants checked for disease. Black Sigatoka was found on 10 properties in 3 areas (2 about 2km north of Ayton, 2 about 4km north of Ayton, and 6 at Degarra about 14km south of Ayton). Over 1 180 properties were visited and more than 17 500 banana stems were located and checked for disease on 660 properties.

Black Sigatoka was found on an additional property in November 1994. This property, Auravale, about 15km north of Ayton is relatively large and a number of alternative life style groups are scattered over the property. The diseased plants had not been located or checked in the previous surveys. All diseased plants and all susceptible plants within 50m were

immediately destroyed and all resistant plants (Ducasse, Mysore and Bluggoe) were deleafed. Intensive surveys, by road, on foot and via a helicopter within 40km of Ayton did not locate any additional banana plants with black Sigatoka.

The Banana Replacement Program where all the susceptible plants are removed and replaced with plants resistant to black Sigatoka was implemented in the Bloomfield area following the finding of black Sigatoka. All plants within 40km of Ayton were again inspected for disease, identified and all susceptible types were destroyed (with owners permission) and replaced with a resistant cultivar (TU8, Ducasse or Bluggoe). The majority of the susceptible plants in this area were removed and replaced. Unfortunately a few susceptible plants remained. These were where the owners either wanted to keep their susceptible plants until the resistant plants had produced fruit (maintain supply of fruit, unsure the resistant plants would be acceptable) or refused to participate in the program. The program substantially reduced the amount of susceptible host tissue in the area and the potential threat of back Sigatoka developing and producing sufficient inoculum to spread to other areas including the main production areas.

(B) TECHNICAL SUMMARY

There are two pathways for the black Sigatoka fungus, *Mycosphaerella fijiensis*, to enter and establish in the Australian banana production areas. It could be carried deliberately or inadvertently by man on/in banana material such as leaves, fruit, bells or planting material. Fungal ascospores could also be blown from areas of infestation in the Torres Strait/PNG area onto other banana plants in the Cape York area and move step-by-step southwards until it reached the main production areas south of Cairns.

Strategies developed to substantially reduce the risk of the fungus entering the production areas include:

- the establishment of a biological barrier, an area void of susceptible host tissue between the areas of infestation and the production areas.
- surveillance of the Torres Strait and Cape York areas to monitor for the spread/outbreak of the disease in these areas.
- the eradication of all black Sigatoka infections in the Cape York area.
- an awareness campaign to ensure all residents and other people involved in Cape York are aware of the threat black Sigatoka poses to the local banana industry.
- increase surveillance on movements from the Torres Strait area and international passengers from all black Sigatoka infested areas in particular Papua New Guinea and Irian Jaya.

The Banana Replacement Program, developed in previous projects involves the destruction of all susceptible banana plants and the replacement with cultivars resistant to black Sigatoka. This program was successful at Bamaga (black Sigatoka 1981), the Pascoe River (black Sigatoka 1991), Moa Island and Thursday Island (susceptible cultivars replanted on Thursday Island). Black Sigatoka has not been detected in these areas for at least six years. At Bamaga, black Sigatoka was not present on four stems of Lady Finger plants reintroduced by the locals. The plants were more than 18 months old (one stem had a near mature bunch) and

had grown through at least one wet season, indicating inoculum levels in the area were extremely low or completely absent. The Banana Replacement Program was used on Badu Island but Lady Finger plants continue to be reintroduced to the area and black Sigatoka has reappeared on many of these plants. Fungal inoculum had either survived on banana trash, on the resistant plants or was reintroduced on the Lady Finger planting material.

Black Sigatoka was found in September 1993 in the Bloomfield area, some 200km north of Cairns and 70km south of Cooktown. An extensive survey from the Daintree River to Hopevale north of Cooktown located the disease on 11 properties all in the Bloomfield area within 15km of the small township of Ayton. More than 1 180 properties were visited and over 17 500 banana stems (>1m) were inspected on 660 properties. Cultivars inspected were Williams (including Dwarf Cavendish) (16%), Lady Finger (37%), Ducasse (40%, resistant to black Sigatoka), Red and Green Dacca (5%) and others (3%). All susceptible banana plants on properties where black Sigatoka was located were destroyed (plants dug out, corms and stems cut into small pieces to promote rapid decomposition and necrotic leaves were burnt). The Banana Replacement Program was centred on the Bloomfield area and in 10 months more than 1 300 susceptible plants were destroyed (dug out or injected with glyphosate) and replaced with more than 1 150 resistant plants (TU8, Ducasse and Bluggoe).

The Banana Replacement Program established buffer zones free of susceptible banana tissue around the previous black Sigatoka infested areas at the Pascoe River (80km), Ayton (40km), and Bamaga (100km). These zones need to be extended to cover all of Cape York.

Nine banana cultivars were planted on Murray Island to screen for resistance to strain(s) of *M. fijiensis* most likely to be introduced into Australia. Establishment losses were high and plant numbers were insufficient to draw definite conclusions. Data suggests, however, that Kumakuma, Goldfinger, Kluai Namwa Khom and Da Jaio were highly resistant and SH3436, TU8 were resistant. These results were similar to those from other areas including the South Pacific suggesting that the strains of *M. fijiensis* are similar to those in other areas. In the agronomic evaluation of the black Sigatoka resistant cultivars all lines were inferior to Williams and not suitable for commercial production. The plants were taller (more prone to wind) (except Kluai Namwa Khom), lower yielding, slower to cycle, shorter green life and less acceptable in taste panels. Additional, more acceptable cultivars are required for the Banana Replacement Program.

TECHNICAL REPORT

(A) INTRODUCTION

Sigatoka leaf diseases are the main banana diseases throughout the world. Yellow Sigatoka caused by *Mycosphaerella musicola* Leach ex Mulder occurs/occurred in virtually all banana growing areas in the world. It is widespread in most banana growing areas in Australia (photos 1 & 2). In the last 20 odd years however, yellow Sigatoka has been replaced in most tropical banana growing areas by the more virulent disease black Sigatoka (black leaf streak) caused by *Mycosphaerella fijiensis* Morelet (photos 3 & 4) (20, 22) first recorded in Fiji in 1964 (14). Black Sigatoka is more difficult and more expensive to control (11, 18). It is a more virulent disease with lesions developing 8-10 days faster and ascospore production is about eight times higher than for *M. musicola* (13). In Honduras black Sigatoka replaced yellow Sigatoka within two years (20).

Black Sigatoka is endemic in Papua New Guinea and Irian Jaya to the north of Australia and was recorded in 1981 at Bamaga on the tip of Cape York and on a number of islands throughout the Torres Strait (10). In 1993 it was also recorded in an isolated community on the Pascoe River west of the Lockhart River Aboriginal Community. The initial attempt to eradicate the disease at Bamaga was not successful. All banana plants were dug out and destroyed and after a two year period free of bananas, the area was replanted with the cultivars Williams, Lady Finger and Bluggoe. However within two years black Sigatoka had reappeared and the levels of disease in the area were higher than it had been before the eradication program. A second program however in which all susceptible banana lines were destroyed and replaced with only black Sigatoka resistant lines, has been successful. Black Sigatoka has not been located in the Bamaga area since about 1989 which was 12 months after the second program was completed. This program was also employed at the Pascoe River following the finding of black Sigatoka in 1991. All banana plants in the community were destroyed and the area was replanted with resistant varieties. Again this program appears to have been successful as black Sigatoka has not been detected in the area since the resistant lines were planted in early 1992.

Both Sigatoka diseases are favoured by moist warm conditions. Dry weather and night temperatures below 20 degrees Celsius slow disease development (11, 20). Spread is similar with both diseases and is mainly by movement of leaf material (wrapping), planting material with leaves (sword suckers) and by wind borne ascospores. The success rate of wind dispersed ascospores from small areas of bananas is probably very slight where distances exceed 50 km (20). In central America over land spread into Columbia was prevented by the natural barrier of forested and uninhabited portions of the Darien Peninsula in Panama. However, the movement of small farmers into the area with their inevitable patches of bananas created a chain of host material which has allowed a wind dispersal route and the barrier to be broken (20).

Resistance to the Sigatoka diseases is available and except for a few cultivars, plants resistant to one disease are also resistant to the other (5, 11). Generally all AAA edible clones are susceptible (except for Yangambi km5), whereas AAB plantains have some resistance and with increasing levels of the B genome, resistance levels increase. Many diploids are resistant and most tetraploids from these diploids also have varying levels of resistance (15, 17).

Black Sigatoka resistance screening trials were conducted in the previous projects on Murray Island an eastern island in the Torres Strait. These trials were not completely successful but data collected suggested a number of varieties are resistant. These include the dessert types, TU8, Mysore and Ducasse and the cooking types Bluggoe, Silver Bluggoe, War War, Goly Goly Pot Pot, Silver Kalapua and Simoi are resistant. These cultivars are not immune to the disease, but only a small amount of infection occurs on the older leaves under high disease pressure and when conditions very favourable to disease development. The dessert cultivars are not suitable for large scale commercial production and the demand for cooking types is very limited.

The Australian banana industry is very concerned at the prospect of black Sigatoka moving south from the Torres Strait area to the main commercial production areas. Black Sigatoka would prove very difficult to control in the high rainfall areas of the Tully-Innisfail district which in 1991 produced more than 50% of the Australian banana crop with a wholesale value in excess of $120 million. The Australian banana industry lists the continued exclusion of black Sigatoka from the production areas as a high priority. The presence of the disease would substantially increase production costs (yellow Sigatoka costs $5 million in chemical costs alone) and might also result in marketing problems for the industry through the loss of its "Black Sigatoka free" status and the possible importation of bananas from cheap labour countries.

There are two means by which the black Sigatoka organism could enter the main banana production areas. Airborne spores could be blown from the Papua New Guinea and Torres Strait areas onto susceptible plants in Cape York and move southwards step by step until it reached the Innisfail/Tully areas. It could also be carried by man inadvertently or deliberately, in/on banana material such as leaves, fruit or planting material to the production areas.

Cape York is a large sparsely populated area (1100+ km Cairns to Bamaga). There are aboriginal communities at Lockhart River on the east coast, Aurukun, Kowanyama, Pormpuraaw, Naparum and Mapoon on the west coast, towns of Weipa, Coen, Laura and Cooktown, alternate lifestyle communities (main ones at Wattle Hills, Portland Roads, Chilli Beach, Shellbourne Bay and at Maytown) and grazing property homesteads (map 1). Bananas are widely grown by all inhabitants and effectively form a chain of host material for the possible step by step movement of black Sigatoka from the Torres Strait area to the production areas south of Cairns.

Following the finding of black Sigatoka at the Pascoe River strategies were developed aimed at preventing or at least substantially reducing the risk of black Sigatoka spreading south to the main production areas. These strategies involved :

- The establishment of a biological barrier, void of susceptible host tissue between the Papua New Guinea/Torres Strait areas and the commercial production areas.
- A surveillance program to monitor for the spread of black Sigatoka.
- Screening of cultivars for resistance to black Sigatoka for use in the Banana Replacement Program. Additional resistant cultivars are required to ensure suitable replacements cultivars are available to replace the susceptible Cavendish types, Lady Finger and Red Dacca cultivars.
- An awareness program to inform the residents of Cape York and all visitors to the area of the threat black Sigatoka poses to the Australian banana industry.

The replacement of black Sigatoka susceptible varieties with resistant lines had proven to be successful in containing black Sigatoka at Bamaga, on some Torres Strait islands and at the community on the Pascoe River. This program was used to establish the biological barrier.

Introduction

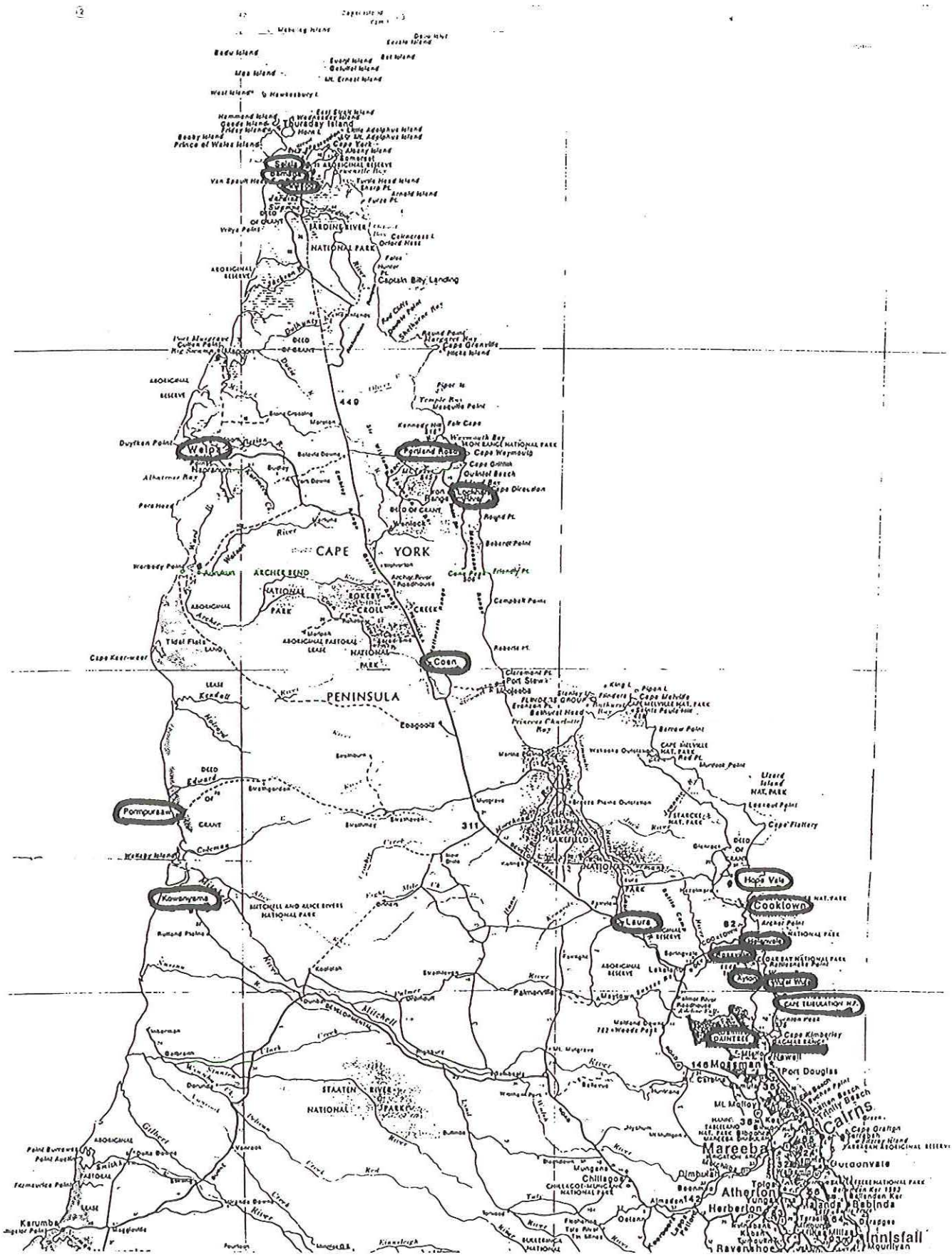
Photo 1. Yellow Sigatoka - Stages 4 and 5.

Photo 2. Yellow Sigatoka - Stage 2

Photo 3. Black Sigatoka - All stages (front cover)

Photo 4. Severe leaf loss due to black Sigatoka

Map 1. Cape York - Torres Strait area Main areas of inhabitation



(B) PROJECT

i. Objectives

- Conduct regular surveys of the Torres Strait area to monitor the distribution/spread of black Sigatoka and of the Cape York area to monitor for the presence of the disease.

- Conduct further trials to screen for resistance to black Sigatoka on Murray Island. Assess the agronomic characters of the lines used in the screening trials.

- Monitor the Banana Replacement Program at Bamaga, Badu Island, Moa Island and Thursday Island. Continue to remove susceptible banana cultivars where detected and replace with resistant cultivars.

- Establish a biological barrier, a buffer zone void of susceptible banana material between the Torres Strait and the main production areas by extending the Banana Replacement Program south from Bamaga to Coen in year 1 and 2 and further south in year 3.

ii Duration of Project

Commencement Date	1 July 1992
Completion Date	30 June 1995

iii Investigation Team

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Principal Plant Pathologist
QDPI Mareeba Q 4880

Project Leader, screening trial, survey coordinator, disease identification, Banana Replacement Program

Roger L. Goebel
District Inspector
QDPI Innisfail Q 4860

Survey of Torres Strait, negotiator in Torres Strait and Cape York, eradication coordinator.

Albert Holder
Banana Inspector
South Johnstone Research Station
QDPI South Johnstone Q 4859

Appointed to the project, surveys of Cape York, Banana Replacement Program, eradication of susceptible cultivars.

Jeff W. Daniells
Principal Horticulturist
South Johnstone Research Station
QDPI South Johnstone Q 4859

Identification of cultivars, agronomic evaluation of cultivars.

Mike K. Smith
Principal Horticulturist
Maroochy Horticultural Research Station
QDPI Nambour Q 4560

Tissue cultured plantlets

Kathy R.E. Grice (1994/95)
Experimentalist
QDPI Mareeba Q 4880

Grow on plantlets, maintain sample records, assist in surveys

iv Location of Project

- Survey work - Torres Strait and Cape York areas.
- Plant Pathology studies - the QDPI Office/Laboratory at Mareeba.
- Black Sigatoka screening trials - Murray Island in the Torres Strait.
- Agronomic Assessment of cultivars - South Johnstone Research Station, Innisfail.
- Tissue cultured plantlets - Maroochy Horticultural Tissue Culture Laboratory, Nambour.
- Resistant plants - tissue cultured plantlets were grown on, initially, at South Johnstone Research Station, then at a private facility near Gordonvale and finally at the Mareeba Office /Laboratory complex.

(C) BANANA REPLACEMENT PROGRAM

In 1982 after black Sigatoka was identified in the Bamaga area on the tip of Cape York an attempt was made to eradicate the disease. All banana plants in the five communities were dug out and destroyed. All areas surrounding these communities were surveyed for old/abandoned camp sites, dumps etc. and all banana plants located were destroyed. A wide range of banana cultivars/lines including Cavendish types, Red Dacca, Lady Finger and a large number of local cooking types were destroyed. The area remained free of banana plants for two years to enable the banana trash to decompose and all the inoculum of *M. fijiensis* to be destroyed. Data available at that time indicated ascospores of *M. musicola* would only survive for 8 - 10 weeks (19). No data was available for *M. fijienses*. The area was replanted with the cultivars Williams, Lady Finger and Bluggoe. Within two wet seasons, however, black Sigatoka was wide spread throughout the communities especially on Williams, and to a slightly lesser degree on Lady Finger. It was not found on Bluggoe. The level of disease (inoculum level) was far higher than before the eradication program. The amount of susceptible host tissue had increased enormously as most of the cooking types destroyed had supported little to no disease and were most likely resistant to black Sigatoka.

All susceptible banana plants were again destroyed in 1986 and after a 12 month period free of bananas the area was replanted with the cultivars TU8, Ducasse and Bluggoe which are highly resistant to black Sigatoka (data from South Pacific and Central America). A few black Sigatoka lesions were found at the end of the wet season in 1989 on old TU8 leaves but the disease was not detected in subsequent years (1990-92).

The eradication program was also employed on the nearby islands of Thursday, Moa and Badu where black Sigatoka was detected. Only resistant banana lines were replanted on Moa and Badu islands while some susceptible plants were replanted on Thursday Island. Black Sigatoka did not reappear on Thursday and Moa Islands but it was detected after 2-3 years on Badu Island on the susceptible cultivar Lady Finger which had been replanted by the local residents.

Resistant cultivars were also distributed widely to all islands in the Thursday Island group. The growing of resistant types was encouraged throughout the Torres Strait to reduce the level of inoculum in the area.

The program of removing the susceptible plants and replanting/replacing with resistant cultivars was highly successful at Bamaga and the surrounding communities. Black Sigatoka has not been detected for more than six years. It also had resulted in a substantial reduction in the level of inoculum on Badu Island. Black Sigatoka was only detected on a few recently planted Lady Finger plants which may indicate the fungus was still present in the trash, present on undetected plants or was re-introduced on the planting material used.

Following the detection of black Sigatoka at the small community on the Pascoe River west of Lockhart River, all susceptible banana plants were again destroyed and the resistant cultivars in the area, Mysore and Bluggoe were heavily deleafed. Additional resistant cultivars mainly TU8 and Ducasse were used to replant the area after about six months. Black Sigatoka has not been detected in this community since the resistant cultivars were planted.

The program, now referred to as the Banana Replacement Program was shown to be very effective in substantially reducing inoculum levels of black Sigatoka and so the risk of the disease spreading to other areas is also greatly reduced. In 1992 the Banana Replacement Program was adopted as a means of establishing a biological barrier, an area void of susceptible host tissue between Torres Strait/PNG area where the disease is endemic and the main banana production areas.

In the project proposal, commencing in 1992, all sites of present and previous inhabitation from Bamaga to Coen, were to be surveyed for banana plants. All plants located were to be identified and the owners of the black Sigatoka susceptible banana cultivars were to be encouraged to participate in the Banana Replacement Program and allow these susceptible banana plants to be removed (dug out or injected with glyphosate) and replaced with resistant banana plants. The program however did not commence until mid 1993, due to delays in appointing an inspector (and the purchase of a vehicle) to undertake the program. In July 1993 surveys commenced in the area north of Coen, on grazing properties, and in the alternate life style communities at Wattle Hills, Portland Roads and Chilli Beach. In September 1993, however, black Sigatoka was found in the Bloomfield area, 70km south of Cooktown, the major activities in the project were shifted to the Bloomfield area for 1993/94 (see Black Sigatoka at Bloomfield) with only a minor input into the northern area until late 1994/95 (photo 5).

The Banana Replacement Program was readily accepted by the graziers north of Coen (one exception), the Lockhart River Aboriginal Community and most of the residents at Portland Roads and Chilli Beach. Many of the residents in the Wattle Hills community however were not co-operative and did not agree to the removal of their susceptible plants. Resistant plants were supplied to all residents who requested plants including some of the non co-operative residents who indicated that if it was shown that the resistant cultivars would grow in their area and if fruit production and the taste and texture of the fruit were acceptable they would allow the susceptible plants to be destroyed. This reluctance to co-operate reduced the speed of implementation of the program.

By June 1995 a buffer zone free of susceptible host tissue of about 80km had been established around the Pascoe River area and the amount of susceptible host tissue in the adjacent areas (Wattle Hills, Portland Roads, Chilli Beach and Lockhart Community had been substantially reduced, but some susceptible plants remained especially within the Wattle Hills community. Buffer zones had also been established for about 100km south of Bamaga and for about 40km around the Bloomfield area (map 2).

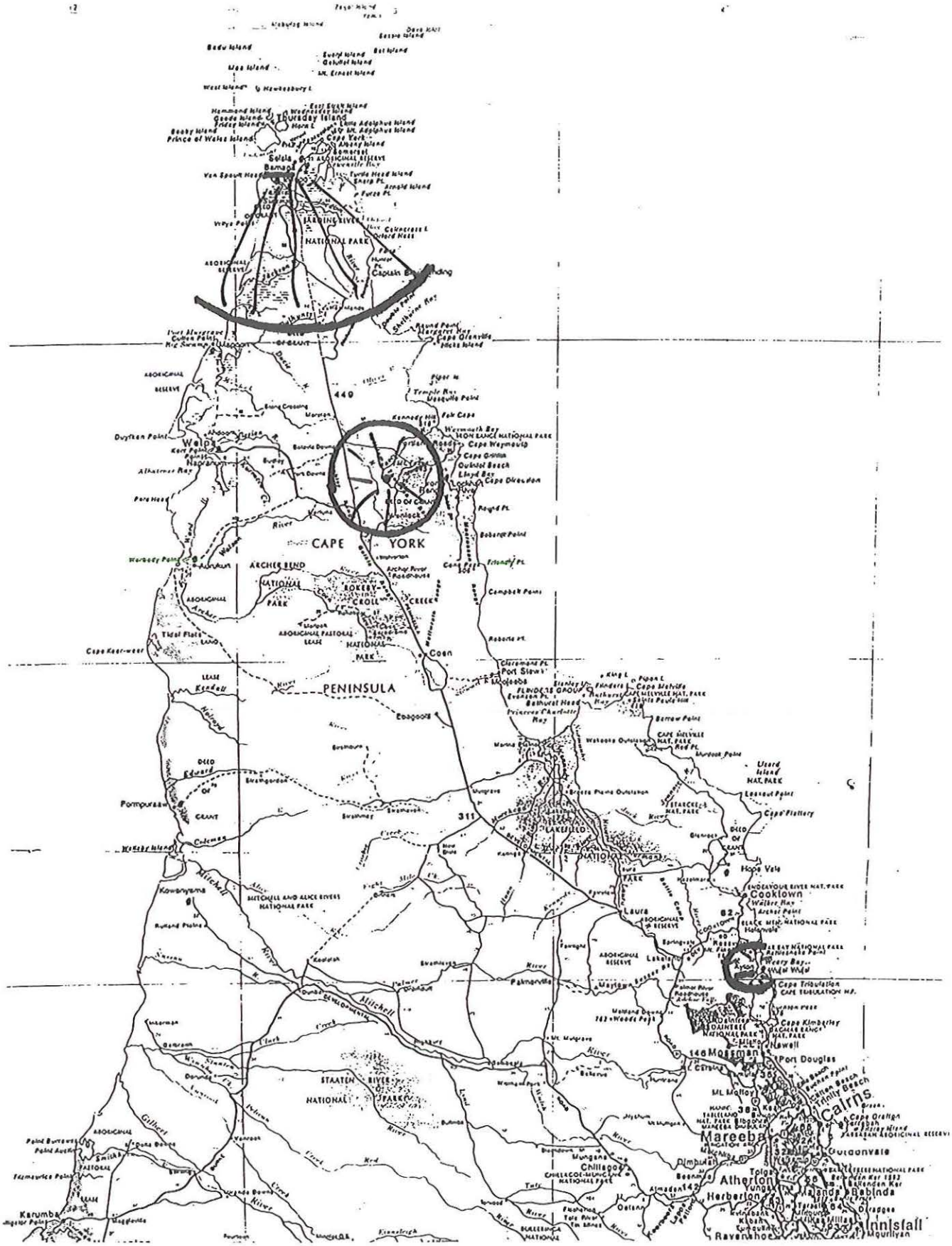
Tissue cultured plantlets, initiated from material selected at the South Johnstone Research Station near Innisfail were produced by the Tissue Culture Laboratory at the QDPI Maroochy Research Station near Nambour. Plantlets were sent to north Queensland in sealed bottles/tubes and deflasked and grown in pots until 30-40cm before distribution to the residents of Cape York. The plants were initially deflasked and grown at the South Johnstone Research Station, but losses occurred due to lack of attention when the inspector was away on surveys in Cape York. Flasks of plantlets were then provided to a commercial tissue culture grow on nursery at Gordonvale south of Cairns, however growth was slow, and the plants were heavily diseased with Deightoniella spot (*Deightoniella torulosa*) and not suitable for use in the program. Facilities (plant house covered with 80% sarlon cloth) were built at Mareeba and plant growth was very successful in this facility (photo 6).

A publicity campaign (examples provided in Appendix 1) throughout the Cape York area, especially following the discovery of black Sigatoka at Bloomfield resulted in considerable interest throughout the area. The Banana Replacement Program was promoted as a source of banana planting material (resistant cultivars) for anyone in the Cape York area wishing to grow bananas and a large number of requests were received from throughout the area including all aboriginal communities. Approximately 300 tissue cultured plants were produced at South Johnstone Research Station, 1000 from the commercial nursery and about 3000 from the nursery facility at the QDPI Laboratory/Office complex at Mareeba. Another 3500 plants were in the Mareeba facility in June 1995.

Photo 5. All banana plants including feral plants were located, checked for disease, identified and if a susceptible cultivar, destroyed (with owner's approval).

Photo 6. Tissue cultured black Sigatoka resistant plants grown in pots at the QDPI Mareeba Office/Laboratory complex.

Map 2. Buffer zones free of susceptible banana tissue established around sites where black Sigatoka had been located.



(D) SURVEYS

i. Torres Strait

In the 10 years from when black Sigatoka had been identified at Bamaga on the mainland, extensive surveys of the Torres Strait located black Sigatoka on the eastern islands of Murray, Darnley and Stephen, the northern islands of Boigu, Saibai and Duaun, and the islands near the mainland of Badu, Moa and Thursday. It was not found on the other islands near Thursday Island or Horn, Prince of Wales, Hammond, Friday or Mabuiag near Badu or any of the central islands (Coconut, Sue, Yorke, Yam) (7).

In the late 1980's under what is now referred to as the Banana Replacement Program, all susceptible banana plants at Bamaga and the nearby islands of Thursday, Moa and Badu were removed and replaced with the resistant cultivars, TU8, Bluggoe and Ducasse. The local cultivars, Goly Goly Pot Pot, Silver Kalapua, War War and Silver Bluggoe which had been identified as resistant to black Sigatoka in the early screening trials on Murray Island were introduced into Badu and Moa Islands in 1991.

Black Sigatoka had not been located at Bamaga, Thursday Island or Moa Island from 1989-1992. It had however reappeared on Badu Island in 1991 on a recently planted susceptible cultivar most likely the cultivar Lady Finger. All susceptible plants were again destroyed in 1991.

1992/93

Two surveys were made of the Torres Strait area and the islands of Murray, Moa, Badu, Thursday and Horn were visited on two occasions while the islands of Darnley, Stephen, Saibai, Boigu, and Yorke were visited on one occasion (photo 7). Black Sigatoka was again located on Murray, Darnley, Stephen, Saibai, Boigu and Badu. It was not found on Yorke, Moa, Thursday (photo 8) or Horn Islands. On Badu Island it was found on a few plants in a group of gardens near the airport. It was not found elsewhere on the island (photo 9). The identity of the infected plants could not be confirmed (no bunches), but it was thought the plants were not any of the plants provided to the island as part of the Banana Replacement Program in 1989 or 1991 (3). All plants with black Sigatoka symptoms were dug out and cut into small pieces.

Black Sigatoka was at relatively low levels throughout all the islands where it was located including Murray Island. The people on Murray Island had recently started a program to grow mainly the local resistant types (mainly cooking types). Black Sigatoka however, was severe on the few susceptible cultivars located, and less than two leaves remained on many bunched Cavendish plants.

1993/94

The finding of black Sigatoka at Bloomfield in September 1993 reduced the level of input into other areas and the Torres Strait was visited on only one occasion and only the islands of Murray (as part of screening trial) Moa, Badu, Thursday and Horn were surveyed.

Black Sigatoka was again severe on the susceptible plants on Murray Island and was also found on Badu Island on Lady Finger bananas. Many of these Lady Finger plants had bunched suggesting the plants may have been present during earlier surveys but were not identified due to lack of a bunch. The local residents claim a preference for this cultivar, but the source of the planting material was not located and those responsible for planting the material were not identified. All diseased plants were removed.

1994/95

Again the Torres Strait area was visited on only one occasion and limited surveys were made on Murray (part of screening trial), Badu, Thursday and Horn Islands. Again black Sigatoka was only found on Murray Island and on a few plants in the gardens near the airport on Badu Island. Despite extensive eradication and education programs on Badu Island, other banana types (photo 10) including the susceptible Lady Finger continue to be planted in the main gardens on the island. The source of planting material is unknown but it is most likely somewhere on the island and some distance from the inhabited areas. The on going eradication program does not appear to concern the residents including the leaders on the island.

ii Cape York Area

Uncertainty with availability of funds from the Queensland Fruit and Vegetable Growers, a QDPI hold on appointment of staff and purchase of additional vehicles caused an 11 month delay in the appointment of the banana inspector. This resulted in most of the surveying and the implementation of the Banana Replacement Program especially in the Cape York area also being delayed. The inspector was appointed in June 1993.

1992/93

All major communities and towns in the Cape York area were surveyed in 1992/93 by AQIS officers, as part of the NAQS survey program involving the coastal areas of Cape York. Black Sigatoka was not detected in the Cape York area.

1993/94

Three trips to the northern part of the Cape York area were made in July/August following the appointment of the inspector in June 1993. However, the finding of black Sigatoka in the Bloomfield area in September 1993 resulted in a change of

emphasis for the survey program. Surveys and the bulk of the Banana Replacement Program activities concentrated in the area Cooktown to the Daintree River. All major communities, alternate life style groups including the community on the Pascoe River (photo 11) and a number of abandoned camps (photo 12) were visited on at least one occasion by the inspector or AQIS staff and black Sigatoka was not detected. These surveys were made in the July to November period when travel through the area is feasible. This however is the dry period and conditions were not conducive to symptom development.

1994/95

Again the main emphasis was in the Bloomfield area, but all communities, towns and alternate lifestyle communities were visited on at least one occasion during 1994/95. Black Sigatoka was not detected in the Cape York area. In the Bamaga area, checks were made on all large plantings and a number of residential blocks selected at random. Four stems of the cultivar Lady Finger, one with a bunch, were located at one private residence. Lady Finger was not part of the replacement program in 1989 and had to have been introduced from outside the area. The occupants of the residence did not know the source of the planting material. Black Sigatoka was not detected on the leaves and this may suggest that no inoculum was present or at least the levels were extremely low in the Bamaga area.

Photo 7. Light aircraft used extensively in surveys of the Torres Strait area.

Photo 8. Garden on Thursday Island

Photo 9. Garden on Badu Island

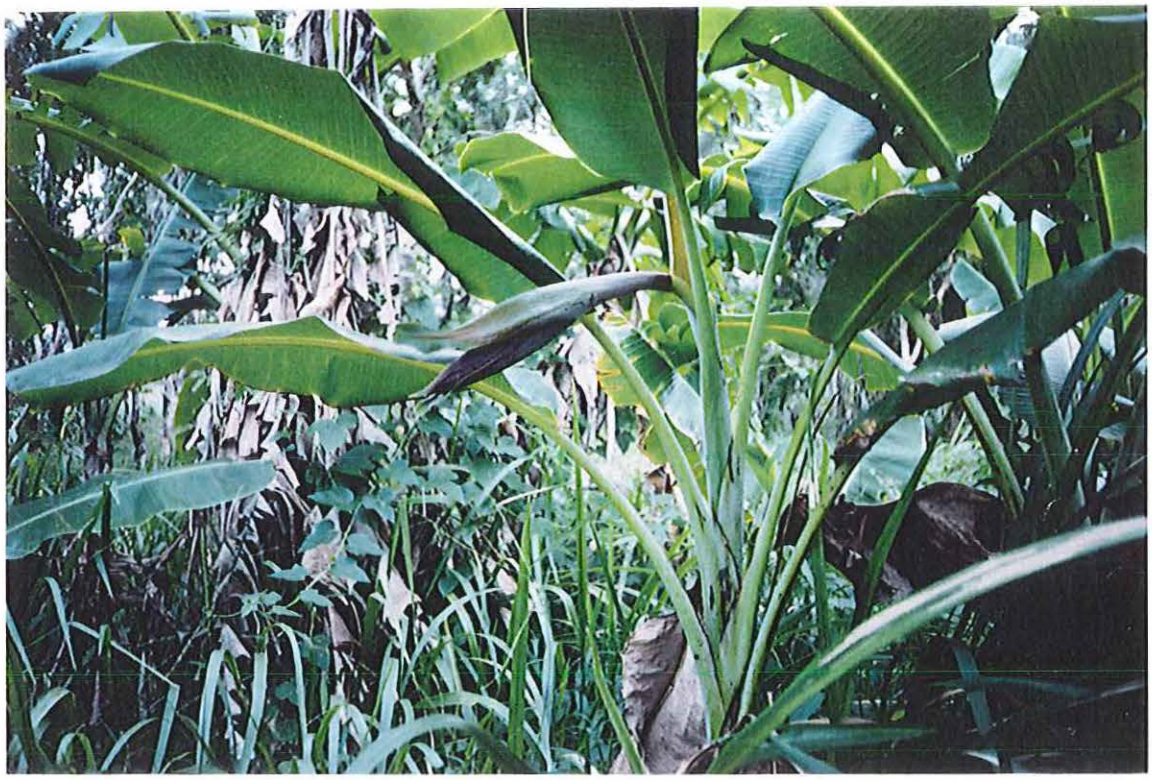


Photo 10. Unidentified cultivars on Badu Island

Photo 11. Resistant replacement plants at the Pascoe River community in 1994

Photo 12. Banana plants at an abandoned camp on Cape York.

(E) BLACK SIGATOKA AT BLOOMFIELD

On Friday, 17 September 1993, black Sigatoka was detected on a banana plant (non commercial bananas) near Ayton in the Bloomfield area. Ayton is about 70 km south of Cooktown and nearly 200 km north of Cairns (map 3). The disease was detected on a return trip from a routine survey of areas north of Coen in Cape York. Yellow Sigatoka (*Mycosphaerella musicola)* is the main leaf disease of bananas in the northern commercial banana production area. Symptoms of yellow Sigatoka are similar to those of the more virulent black Sigatoka (photos 1, 2, 3 &4). It was known to occur in the Daintree area just north of Mossman, but it had not been detected in the Cape York area. As part of the Black Sigatoka Contingency Plan it was necessary to determine the northern limit of yellow Sigatoka. On a return trip from Cape York, banana plants south from the Lakefield National Park on the Cooktown and Bloomfield roads were selected at random and checked for disease. Yellow Sigatoka was detected throughout the Cooktown area and further south. The property just north (about 2 km) of Ayton was selected mainly due to the banana plants being readily visible from the road. Symptoms which resembled black Sigatoka were detected on a plant near a shed (photo 13). *Mycosphaerella fijiensis* was identified on the Ayton sample in the QDPI Plant Pathology laboratory at Mareeba and confirmed by Dr J.A. Alcorn at the QDPI Plant Pathology laboratory at Indooroopilly.

A consultative committee was formed to determine and direct the actions to handle the problem. The committee consisted of the Banana Industry Protection Board, representatives from the Queensland and New South Wales banana industries and QDPI technical, regulatory and managerial staff (figure 1).

All plants infected with black Sigatoka and all susceptible plants within 50 metres of a diseased plant were immediately destroyed. The plants were dug out and the corm and stem material cut into small pieces to enhance decomposition (photos 14 & 15). All resistant plants (Ducasse and Mysore*)* were deleafed to 100% green healthy leaves(photos 16 & 17). All necrotic leaf material was burnt. The extent of the infestation was determined by surveying the area and locating and inspecting all banana plants for disease (photos 18 & 19) including native plants (photo 20) in the Bloomfield area. Black Sigatoka was detected on nine additional properties in three areas, at Ayton (2 properties including original property), 5 km north of Ayton (2 properties) and 14 km south of Ayton (6 properties) (map 4). All diseased plants together with all other susceptible plants within 50 m of any diseased plants were immediately destroyed.

The survey was extended to cover all properties from the Daintree River (80 km south of Ayton) to Hopevale (40 km north of Cooktown) (map 3). Colour prints of a range of symptoms were produced to aid in the survey (figure 2). A total of 1180 properties were visited in the area and over 17 500 banana stems (>1 km in height) were located on 660 properties and checked for disease. The banana varieties located were Ducasse (40%), Cavendish (16%), Lady Finger (37%), Red/Green Dacca (5%) and miscellaneous (3%) (table 1). Black Sigatoka was not detected on any additional properties.

Copies of the minutes of the Banana Industry Protection Board, Black Sigatoka Consultative Committee and reports on the surveys are attached in Appendix 2.

The black Sigatoka outbreak received extensive coverage on the local radio (8 interviews over 6 weeks) and in the local press. Copies of some of the publicity are attached in Appendix 2.

In November 1994, black Sigatoka was located on an additional property (Auravale) in the Bloomfield area (map 4). Auravale is a relatively large property and has a number of alternate life style people living at a number of locations on the property. This property had been surveyed on 2 previous occasions, but the infested plants had not been previously located or inspected. Again all infested plants and all susceptible plants located in an intensive survey of the property were destroyed. Resistant plants, mainly Ducasse were heavily deleafed.

The focus of the Banana Replacement Program was moved from the area north of Coen and concentrated on the Bloomfield area. In the 6 months (November 1993 to April 1994) over 920 plants were destroyed in the area and replaced with more than 850 resistant plants (table 2). Most of the remaining plants (less than 250) were removed over the next 14 months. The removal of the last few plants was slow and a few susceptible plants still remained in June 1995, mainly where residents did not wish to be without banana fruit and wanted to keep their plants until the resistant lines produced acceptable fruit. Overall the local residents were very co-operative, but unfortunately, a few would not participate in the program and have refused to allow their susceptible plants to be removed.

The origin of the black Sigatoka was not definitely confirmed. The disease was first located on a property owned by a retired fisherman who worked near and in Papua New Guinea waters (including the Fly River). He also had close connections to some of the people at Degarra where 6 infested properties were located. The owner of one of the two properties 4km from Ayton sailed ocean going yachts especially in the South Pacific areas. Also the property 15km north of Ayton (Auravale) had close connections to the owners of the Pascoe River property where black Sigatoka was located in 1991. Auravale was the main access route into Cedar Bay National Park and the owners of the Pascoe River property lived in Cedar Bay for many years prior to moving to the Pascoe River.

The disease was estimated to have been in the area for 2-3 years but evidence of aerial spread of spores was limited. The four locations where the disease was found were 2-15km apart and it is very doubtful if airborne dispersal was involved in the establishment of any of these outbreaks. In all cases a number susceptible banana plants free of black Sigatoka were found between the outbreak areas. Close contact between some of the people at each location and/or the exchange of planting material is more likely responsible. Some aerial dispersal appeared to have occurred within each area. At Degarra the six infested properties were all within 500m of the property where symptoms were the most developed. Also of the two properties near Ayton, disease symptoms were fully developed and present on most susceptible plants (not

all) on only one property, whereas on the second property (about 200m away) only a few lesions were found on one plant and no lesions were found on a block of susceptible plants within about 20m.

Figure 1.

Banana Industry Protection Board - Black Sigatoka Consultative Committee

Dr I. Muirhead	Chairman - Banana Industry Protection Board (BIPB)
Mr G Bush	Growers Representative (NQ), BIPB
Mr W Nelson	Growers Representative (SQ) BIPB
Mr K Pegg	Principal Scientist and Government Representative BIPB
Ms D Edward	Secretary BIPB (Secretary to the Consultative Committee)
Mr C Winks	Principal Planning Officer
Mr K Jorgensen	Manager, Plant Health
Mr R Williams	Manager (Horticulture), North Region
Mr R Peterson	Principal Plant Pathologist, Field Co-ordinator
Mr L Collins	Chairman, Banana Sectional Group Committee, QFVG Chairman, Australian Banana Growers Federation
Mr D Hine	Chairman, NSW Banana Industry Committee

Table 1

BANANA SURVEY (NON COMMERCIAL GROWERS)
DAINTREE RIVER TO HOPEVALE

Area	Properties visited	Properties banana	Bananas stem > 1m	Cultivars				
				Ducasse	Cavendish	Lady Finger	Red Dacca	*Miscell
Daintree River to Cape Tribulation	302	203	5800	3190 (55%)	1392 (24%)	522 (9%)	638 (11%)	348 (6%)
Bloomfield	143	99	1449	852 (59%)	159 (11%)	246 (17%)	87 (6%)	101 (7%)
Rossville to the Endeavour River	612	250	4834	1547 (32%)	773 (16%)	2417 (50%)	48 (1%)	48 (1%)
Endeavour River to Hopevale	123	108	5480	1425 (26%)	548 (10%)	3233 (59%)	164 (3%)	109 (2%)
Total	1180	660	17563	7014 40%	2872 16%	6418 37%	937 5%	606 3%

Commercial Banana Plantations

Daintree	2	(5ha and 25ha - Cavendish)
Cape Tribulation	1	(1ha Ducasse)
Cooktown	2	(5ha and 2ha - Cavendish)
Total	5	(25ha Cavendish, 1ha Ducasse)

*Miscellaneous - Green Dacca, Mysore, Gros Michel, Sugar, Bluggoe

Table 2

BANANA REPLACEMENT PROGRAM
BLOOMFIELD AREA
(1/11/93 - 30/4/94)

Area	Plants Destroyed						Plants Remaining						Plants Supplied	
	C	LF	RD	GD	M	O	C	LF	RD	GD	M	O	T8	Bluggoe
N of Ayton	157	16	120	60	19	-	46	-	4	-	24	-	203 +55	34
Auravale	-	-	-	-	-	-	180	-	56	20	72	-	22	-
Bloodwood Road	58	3	3	-	3	1	5	-	-	-	-	-	61	8
Ayton	54	28	51	14	21	-	2	-	-	-	-	-	94	34
S Ayton	6	-	1	-	1	-	20	-	-	-	-	-	48	15
Wujal Wujal	-	28	-	-	-	40	-	-	-	-	-	-	52	13
S Bloomfield River	-	38	4	-	-	-	-	-	-	-	-	-	8	1
Degarra	71	42	86	-	-	2	-	-	-	-	-	-	155 23C	23
Creb track	-	-	-	-	-	-	1	-	15	-	-	12	12	6
Totals	346	155	265	74	44	43	254	-	75	20	96	12	655	134

Black Sigatoka at Bloomfield.

Photo 13. The plant on which black Sigatoka was detected in the Bloomfield area.

Photo 14. Banana plants were dug out and moved to a central position.

Photo 15. Banana stems and corms cut into small pieces to ensure rapid decomposition.

Photo 16. Before - clumps of susceptible and resistant plants.

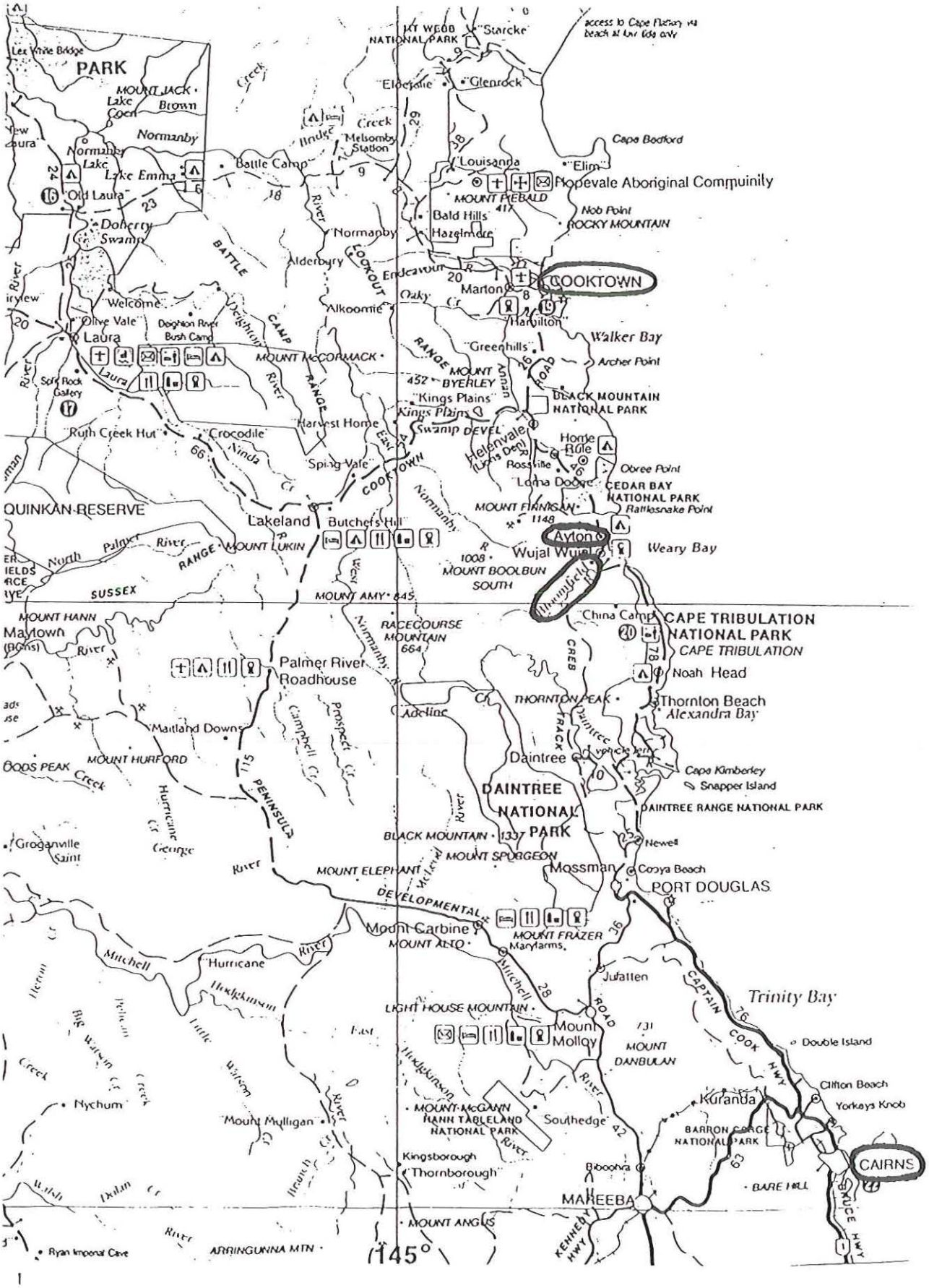
Photo 17. After - all susceptible plants dug out and removed, all resistant plants deleafed.

Photo 18. All banana plants within 75 km of the Bloomfield area were located and checked for disease.

Photo 19. All camp sites, old and new, were located and checked for bananas

Photo 20. Native banana plants (*Musa banksii)* were also included in the survey.

Map 3. Ayton and the Bloomfield area in relation to Cairns and Cooktown.



Map 4. Location of black Sigatoka infested properties in the Bloomfield area

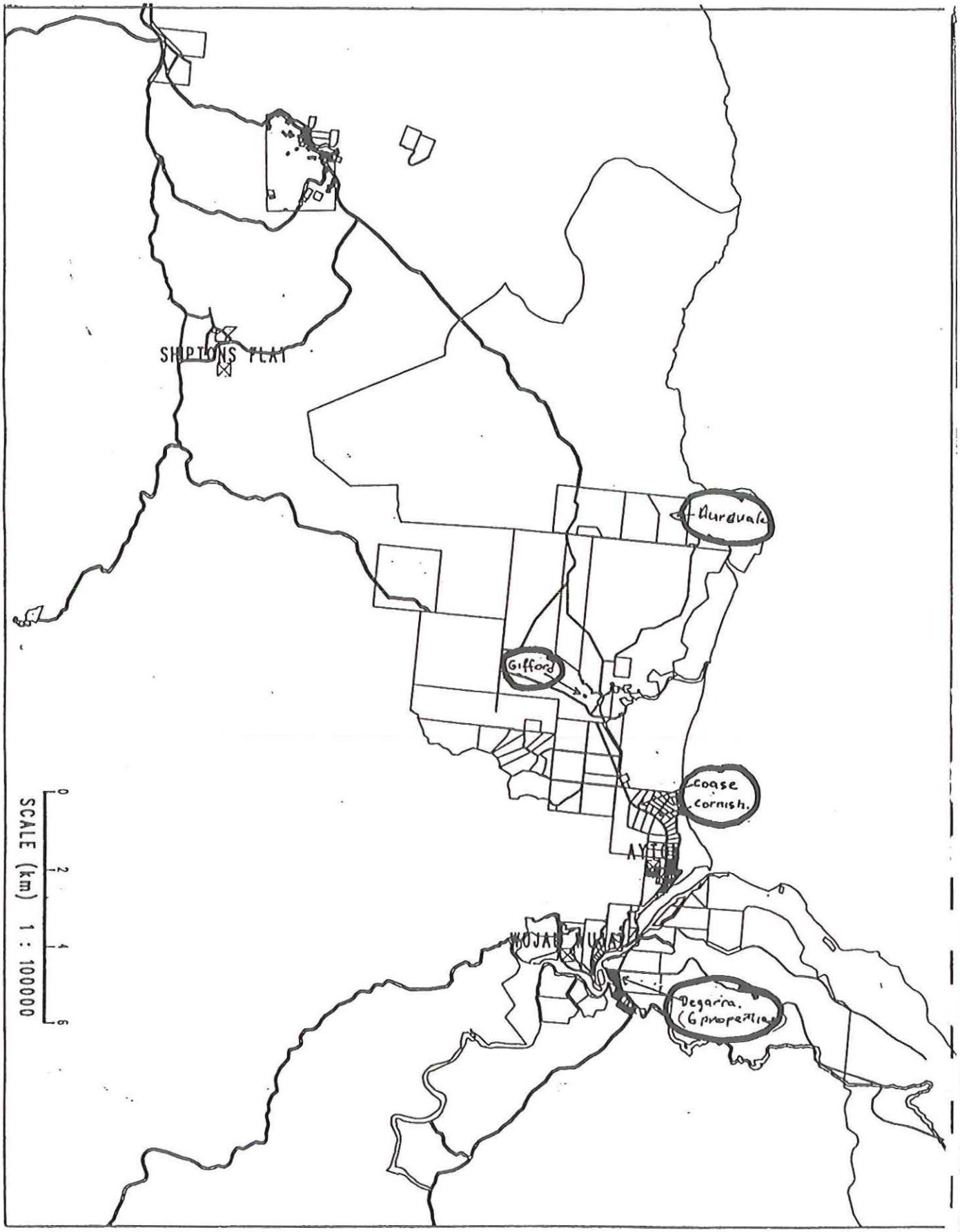
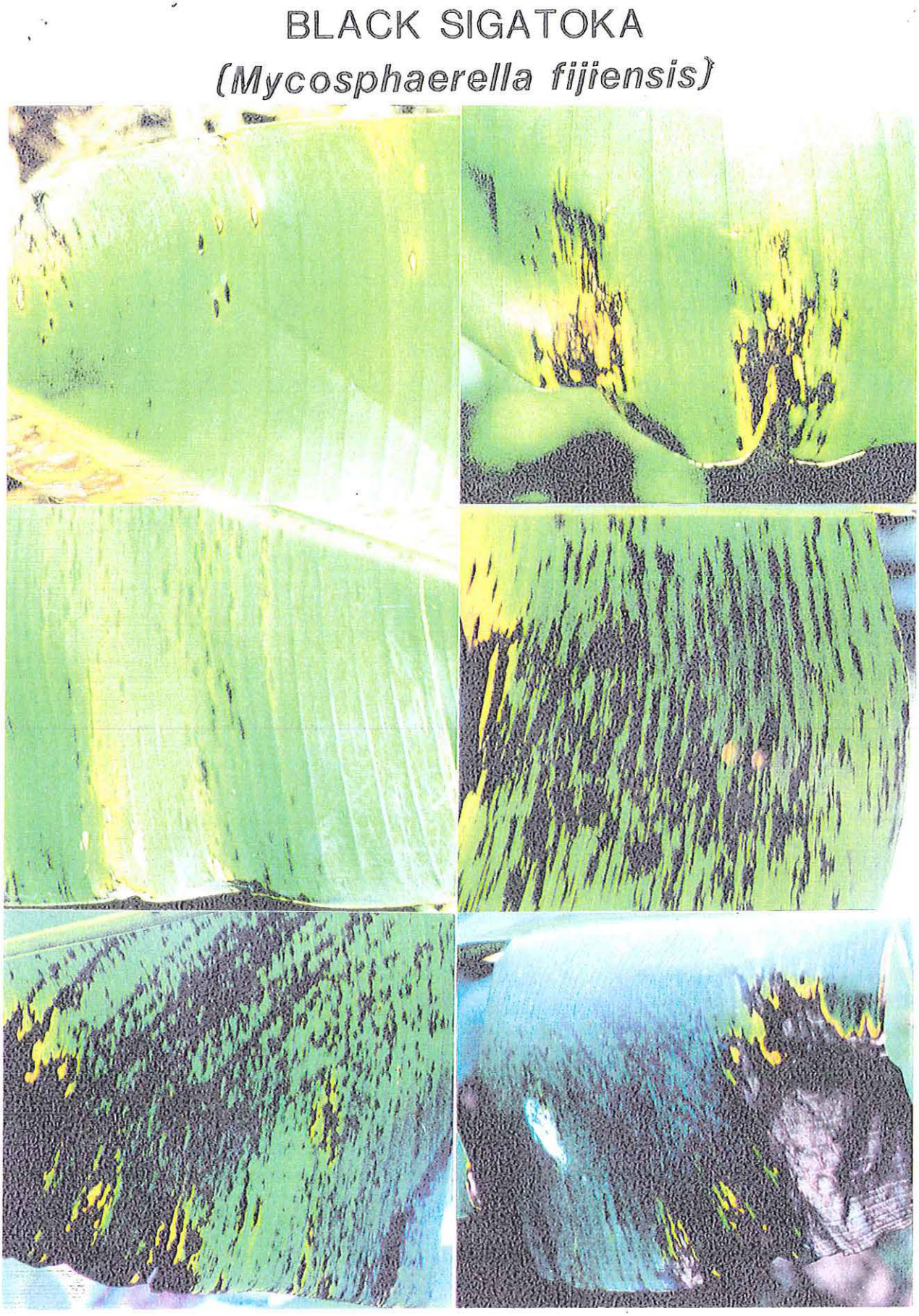


Figure 2. Leaflet showing symptoms of black Sigatoka provided to the inspectors for the survey.



(F) SCREENING FOR BLACK SIGATOKA RESISTANCE

Banana cultivars resistant to black Sigatoka are an essential component of the strategy to reduce the risk of *M. fijiensis* entering the Australian banana industry. The Banana Replacement Program replaces susceptible cultivars with resistant plants and it is essential for the success of the program that the residents of Cape York receive "like for like". Resistant cultivars need to be acceptable as replacements for the Cavendish types, or the cultivars Lady Finger, and Red and Green Dacca, the main cultivars grown in the area.

i Other Programs

There are a number of programs throughout the banana world looking for (by breeding, selection) and screening for resistance to black Sigatoka (5,12,15,17) The aim of the ACIAR Project 9033 "Banana Improvement in the South Pacific" 1987-1993 was to collect *Musa* germplasm from around the world and to evaluate a range of this material at three locations in the South Pacific, Tonga, Western Samoa and Cook Islands (Rarotonga and Aitutaki). Black Sigatoka had devastated commercial banana industries in those three nations over the previous 20 years. A large range of *Musa* germplasm, many with resistance to black Sigatoka was collected from many cultivar collections in many countries and deposited in the QDPI Maroochy Tissue Culture Laboratory at Nambour. Selected lines were screened for resistance to black Sigatoka and evaluated for commercial production in three series of trials over about a six year period in each of the three countries (8,16).

The International Network for the Improvement of Banana and Plantain (INIBAP) commenced the International Musa Testing Program (IMTP) in about 1991 to screen new breeding material, cultivars, selections for resistance to black Sigatoka and Panama Race 4 (*Fusarium oxysporum* f. Sp. *cubense*). In phase 1 of the black Sigatoka program, 7 lines from the FHIA program in Honduras, were compared with 9 standard lines with known reactions to black Sigatoka at six sites throughout the main banana growing areas (table 3). The multisite program was selected to ensure the cultivars were subjected to the disease under a range of climatic conditions (disease severity), any pathogenic variability or strains of *M. fijiensis* would be identified (6) and as a safety mechanism should some trials be lost (cyclones, neglect, etc.).

FHIA-01 (Goldfinger), and FHIA-03 (Plantain type) were highly resistant while FHIA-02 (Cavendish type) was resistant to black Sigatoka at the six sites (table 3) (9). These three lines should be considered for the Banana Replacement Program. Each represents a type of banana frequently requested by residents in the Cape York area.

Phase 2 of the program commenced in 1994/95 with 8 sites for black Sigatoka and 6 for yellow Sigatoka. Germplasm to be screened included material from Honduras, Brazil, Cuba, plus the reference/standard lines (table 4) (1).

ii *Murray Island*

A range of cultivars were known to be resistant to black Sigatoka from the other programs. However, the reaction of these potential cultivars to strains of *M. fijiensis* which occur in Papua New Guinea the most likely source for an introduction was unknown. A strain of *M. fijiensis* was detected in 1989 which could invade and establish severe symptoms in the field on the previously resistant cultivars TU8 and Paka . This strain was widespread on Rarotonga in the Cook Islands, but was not present on the other islands. A similar strain was detected in Tonga using invitro tests (6), but severe field symptoms have not been observed in Tonga (8,16).

A trial was conducted on Murray Island, an eastern island in the Torres Strait to screen banana cultivars to the strain(s) of *M. fijiensis* most likely to enter the Australian mainland. Climatic conditions, in particular temperature and rainfall are conducive to the development of black Sigatoka for at least 6 months each year on Murray Island.

Trial Details

Nine banana cultivars with reported resistance to black Sigatoka and/or yellow Sigatoka and a range of agronomic attributes were selected for inclusion in the trial. Cultivars were:-

TU8	AAAA
Buccaneer (T12)	AAAA
Kumakuma	AA
Da Jaio	ABB
SH3436	AAAA
SH3481 (Gold Finger)	AAAA
Kluai Namwa Khom (dwarf Ducasse)	ABB
Kofi	AAB
Williams (susceptible check)	AAA

Tissue cultured plantlets were produced at the QDPI Tissue Culture Laboratory at the Maroochy Research Station. The plantlets were deflasked and grown to at least 30 cm at the QDPI Mareeba Office/Laboratory complex. The trial was planted in March 1994 with two replications of five plants/plot (land availability prevented the use of more plants/plot or more replications) (photo 21).

Disease Assessment Methods

Disease levels were assessed using the parameter, Youngest Leaf Spotted (YLS)(21). This is a relatively simple, rapid method of assessment which can be applied at anytime in the growth cycle provided unbunched plants/suckers are available and climatic conditions have been conducive to disease development for the previous 2-4

months. The younger the leaf with fully developed lesions, the faster the disease has developed and the more susceptible is the cultivar.

Results

Plant growth

Although conditions were moist at planting, conditions over the following few weeks were unseasonally dry and many plants failed to establish. A tank and hoses had been supplied but water was not applied immediately after planting. The number of plants which established varied with the cultivar and this may be indicative of the ability of the cultivars to survive under adverse conditions. A plant which survives under less than ideal conditions would be an advantage in the Banana Replacement Program. Plant numbers suitable for disease assessments in 1995 varied from one for TU8 and Kofi to nine for Kluai Namwa Khom and Goldfinger.

The late spring and summer period in 1994 was also very dry and irrigation was applied in December. Unfortunately, the quality (salinity) of the water applied was very poor and caused extensive necrosis of most leaves. The wet season commenced in early January 1995 and continued until June. Plant recovery was fairly rapidly and plant growth was good (photo 22). The first bunches (Williams) were harvested in June 1995 (16 months after planting). The normal cycle period (planting to harvest) for Williams is less than 12 months in the Innisfail area.

Disease Assessments

Disease levels were assessed in July 1995 (photo 23). YLS assessments are normally made on unbunched plants, but due to limited plant numbers, bunched plants were also assessed. Disease levels were relatively high (photo 24) with the YLS values of 5.7 for the susceptible cultivar Williams (table 5). YLS values for the other cultivars ranged from 5.3 for Buccaneer to 11.1 for Kluai Namwa Khom.

Plant numbers were insufficient for definite conclusions to be drawn, but the data recorded did provide an indication of the reaction of the cultivars. The data suggested Kumakuma, Goldfinger, Kluai Namwa Khom and Da Jaio were highly resistant, SH3436, Kofi and TU8 resistant while Williams and Buccaneer were susceptible. These results are similar to those recorded elsewhere, in particular in the ACIAR Project 9033 " Banana Improvement in the South Pacific" trials in Tonga, Western Samoa and the Cook Island.

Conclusions

- The data suggests the strains of *M. fijiensis* in the Torres Strait are similar to those in the South Pacific.

- The TU8 strain of *M. Fijiensis*, identified in Rarotonga was not detected on Murray Island.

- Data supports the results from other screening trials that Goldfinger, Kluai Namwa Khom, Kumakuma, Da Jaio, Kofi, SH3436 and TU8 are all suitable for inclusion in the Banana Replacement Program.

- Murray Island or any other island in the Torres Strait area are not recommended for further screening trials. Previous trials in earlier projects were also not entirely successful for a range of reasons. Availability of land and water in the Torres Strait are very limited and insufficient for screening type trials. Expertise in field trials is not available and additional supervision is not practical as access to these islands is costly and difficult (3 days travel for 1-2 hours on Murray Island).

- Other areas such as Papua New Guinea should be explored for sites for future screening trials.

The trial report prepared for the Queensland Banana Industry Protection Board is attached in Appendix 3.

Table 3.

Germplasm evaluated for reaction to Black Sigatoka in IMTP Phase 1

FHIA Hybrid	Genome	Related Type	Parentage	Reaction [1] across 6 sites
FHIA-01 (SH 3481)	AAAB	Pome	Prata Anã (dwarf Prata) x SH 3142	HR
FHIA-02 (SH 3486)	AAAA	Cavendish	Williams (Cavendish) x SH 3393	HR
FHIA-03 (SH 3565)	AABB	ABB group	SH 3386 x SH 3320	R
FHIA-04 (SH 3653)	AAAB	Plantain	AVP 67 (French plantain) x SH 3437	R
FHIA-05 (SH 3706)	AAAB	Plantain	AVP 67 (French plantain) x SH 3437	HS
FHIA-06 (SH 3583)	AAAB	Maia Maoli	Maqueño x SH 3437	S
FHIA-07 (SH 3584)	AAAB	Maia Maoli	Maqueño x SH 3437	HS

Reference Clones	Genome	Type	Perceived reaction [1]	Reaction [1] across 6 sites
Tuu Gia	AA	edible cultivar	HR	ER
Musa acuminata ssp. *burmannicoides* (Calcutta IR 124)	AA	wild species	HR	ER
Musa acuminata ssp. *malaccensis* (Pahang IR 296)	AA	wild species	HR	ER
Pisang Lilin	AA	edible cultivar	HR	HR
Pisang Berlin	AA	edible cultivar	R	R
Pisang Mas	AA	edible cultivar	R	S
Musa balbisiana (Tani)	BB	wild species	R	R
SF 215/NBA 14	AA	edible cultivar	S	S
Niyarma Yik	AA	edible cultivar	HS	HS

[1] ER: Extremely Resistant (hypersensitive-like response), HR: Highly Resistant, R: Resistant, S: Susceptible. HS: Highly Susceptible

Table 4.

Germplasm to be evaluated for reaction to Black Sigatoka in IMTP Phase 2

FHIA (Honduras)				
1.	SH 3444 (AAAA)	FHIA-23	Highgate x SH 3362	ITC 1265
CNPMF/EMBRAPA (Brazil)				
2.	PV 03-44 (AAAB)	EMB 402	Pacovan x Calcutta 4	ITC 1262
3.	PV 03-22 (AAAB)	EMP 404	Prata Anã x Calcutta 4	ITC 1261
INIVIT/INIFAT (Cuba)				
4.	SH 3436-9 (AAAA)		Somaclonal variant of SH 3436 (Highgate x SH 3142)	ITC 1283
Reference/Standard Clones or natural Germplasm				
5.	Yangambi km5 (AAA)		Ibota	ITC 1123
6.	Saba (ABB/BBB)		Saba	ITC 1138
7.	Pisang Ceylan (AAB)		Mysore	ITC 0650
8.	Calcutta 4 (AAw)	Highly resistant/hypersensitive response		ITC 0249
9.	Pisang Lilin (AA)	Highly resistant		ITC 0001
10.	Pisang Berlin (AA)	Susceptible		ITC 0611
11.	Niyarma Yik (AA)	Highly susceptible		ITC 0269
12.	Local cultivar	To be selected by officer-in-charge of each test site as an appropriate local standard to compare reactions		

Table 5.

Reaction of cultivars to Black Sigatoka on Murray Island 1994/95

Cultivar	*Plants Assessed	Disease Assessment (YLS)	Total leaves	Disease Reaction **
Williams	3	5.7	7.0	S
Buccaneer	2	5.3	6.0	S
TU8	1	7	8	R
Kofi	1	7.0	9.0	R
SH3436	4	7.2	7.5	R
Kumakuma	5	*** 10.8	9.8	HR
Da Jaio	3	8.7	7.7	HR
Goldfinger	4	10.0	9.0	HR
Kluai Namwa Khom	6	11.1	11.3	HR

* Ten plants / cultivar planted except for Williams (12) and Buccaneer (8)

** Disease Reaction: - S - susceptible, R - resistant, HR - highly resistant

*** Where fully developed lesions not present on plant, it is assumed for calculation purposes, that the disease would have occurred on the next leaf.

Murray Island screening trial.

Photo 21. Trial area after planting in March 1994.

Photo 22. Trial area July 1995.

Photo 23. All plants were assessed for disease in July 1995.

Photo 24. Black Sigatoka symptoms on Williams in July 1995.

(G) AGRONOMIC EVALUATION OF BLACK SIGATOKA RESISTANT CULTIVARS

The Banana Replacement Program depends not only on the availability and use of banana cultivars resistant to black Sigatoka but also on cultivars suitable for growing in the Cape York/Torres Strait areas, often under less than ideal conditions as well as being acceptable (yield, taste, texture) to the local residents.

Cultivars used in the initial Banana Replacement Program at Bamaga and the islands of Thursday, Moa and Badu were TU8, Ducasse and Bluggoe. TU8 is a Cavendish type, tetraploid (AAAA) hybrid of Highgate from the Jamaican breeding program. It was highly resistant to black Sigatoka in Jamaica and Central America and resistant in the South Pacific trials. Ducasse (AAB) is a vigorous plant with small to medium sized sweet fruit and was highly resistant to black Sigatoka in many early screening trials. Bluggoe (ABB) is a vigorous cooking type grown widely in the Torres Strait area and resistant in early trials in the South Pacific (5,8,16). It was also free of disease throughout the Torres Strait area.

Additional cultivars with a wider range of cultural attributes and more acceptable tastes and textures were needed for the Banana Replacement Program to be extended throughout the Cape York area and be widely accepted by the local residents.

Agronomic evaluation of cultivars which had been shown to be resistant to black Sigatoka in other areas (including the ACIAR Project 9033, "Banana Improvement in the South Pacific" with sites in Tonga, Western Samoa and the Cook Islands) (8,16) was part of a larger cultivar assessment program at the QDPI, South Johnstone Research Station near Innisfail (2).

The aims of the program in relation to the black Sigatoka resistant cultivars were to;

- Evaluate the agronomic characteristics of known black Sigatoka resistant cultivars.
- Assess the suitability of the cultivars for use in the Cape York/Torres Strait areas.
- Provide data for the release of the suitable cultivars for use in the black Sigatoka Banana Replacement Program and where possible for commercial production (4).

Methods

Cultivars were grown in replicated trials over a number of cycles on the South Johnstone Research Station. A range of agronomic attributes throughout each cycle were measured, recorded and compared to the standard north Queensland cultivar, Williams which was included in all trials.

Results

Some of the main agronomic features of the cultivars evaluated are shown in table 6. The following points can be made:

- All black Sigatoka resistant cultivars evaluated except for Kluai Namwa Khom were taller than Williams. This increased height makes most aspects of crop management more difficult especially if commercial production is being considered. The hybrids of Highgate (TU8, T6, T12 and SH-3436) were also more prone to wind damage than Williams.

- Williams was higher yielding than the other varieties especially when yield/unit time is considered. All of the hybrids were slower in their cycling.

- The major drawback over the years for commercial suitability of the hybrids has been fruit quality including greenlife and taste. Shorter fruit greenlife was indicated for some of the hybrids in these trials. None of the evaluated varieties rated as highly as Williams in taste panels conducted.

Outcomes

- Goldfinger (photo 25)(4), Yangambi km5 (photo 26), Kluai Namwa Khom (photo 27) and SH-3436 (photo 28), were released and recommended for inclusion in the Banana Replacement Program.

- Goldfinger was launched as a commercial variety primarily for subtropical conditions in 1995.

- Kluai Namwa Khom (dwarf Ducasse) has potential as a commercial cultivar and is being large scale multiplied by a number of Ducasse growers attracted by the crop management advantages due to its shorter stature.

Table 6

Plant and bunch characteristics of some black Sigatoka resistant varieties.

Variety	Planting to Harvest (days)	Bunch Weight (kg)	% Extra Large Fruit	Fruit Greenlife (days)	Pseudostem Height (m)
*Trial 1**					
Williams**	251	35.4	86.5	46.8	2.59
SH-3436	321	35.2	68.6	19.6	3.30
TU8	324	25.5	39.3	21.4	3.30
Trial 2					
Williams	317	45.0	93.7	n.a.	2.59
Goldfinger	359	41.5	96.4	n.a.	3.31
Trial 3					
Williams	296	34.9	88.2	33.5	2.74
TU8	349	33.4	72.1	41.1	3.62
T6	310	32.1	59.0	29.7	3.10
T12	362	36.1	88.3	40.1	3.64
Yangambi km5	318	30.1	-	n.a.	4.05
Trial 4					
Williams	309	36.8	n.a.	n.a.	2.76
Kluai Namwa Khom	302	27.8	n.a.	n.a.	2.62
Ducasse	305	28.2	n.a.	n.a.	4.19

* Results presented for trials 1 and 2 are the average for a plant crop and one ratoon, for trials 3 and 4 the results are the average of a plant crop and 2 ratoons.

** Williams is the industry standard and is susceptible to black Sigatoka.

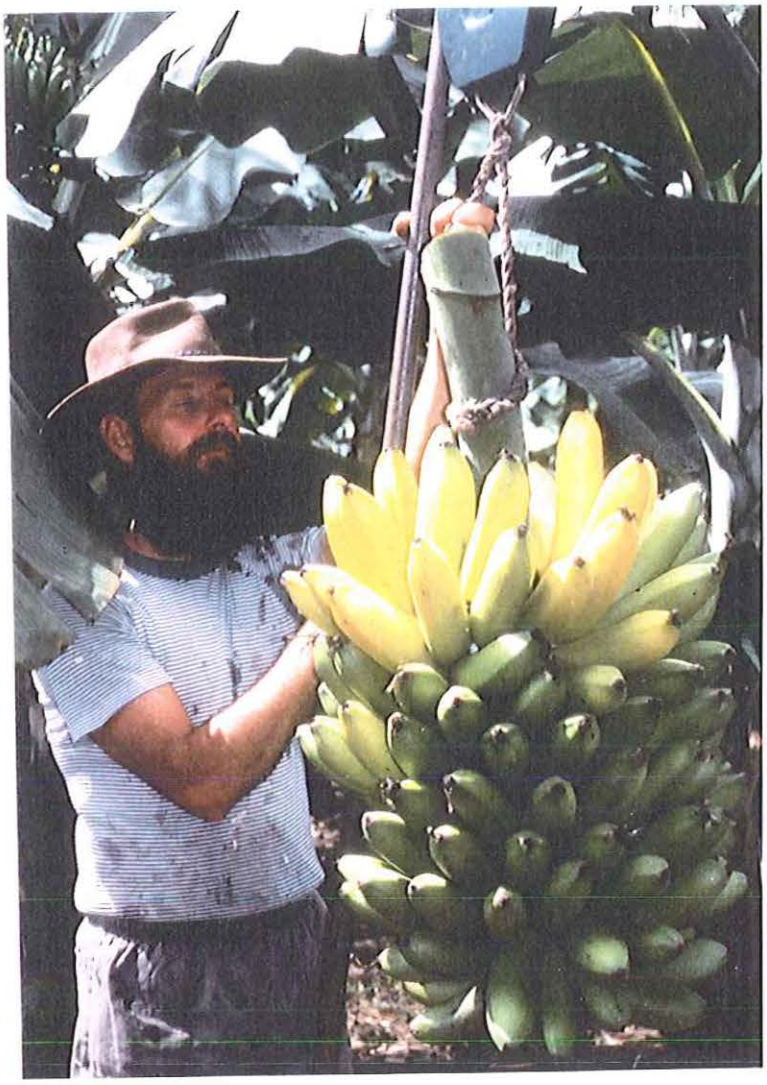


Photo 25. Goldfinger
(FHIA -01, SH3481)

Photo 26. Yangambi km5

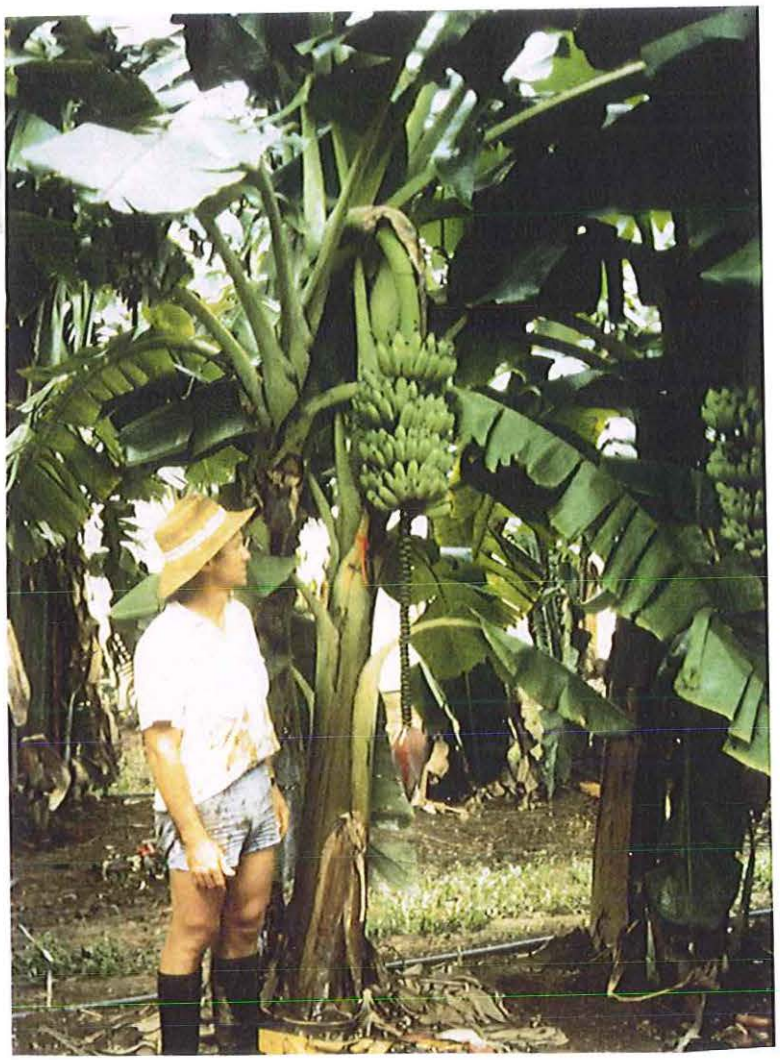


Photo 27. Kluai Namwa Khom (dwarf Ducasse)

Photo 28. SH3436.

(H) BLACK SIGATOKA CONTINGENCY PLAN

The Banana Industry Protection Board identified a need in 1988 for a plan should black Sigatoka occur outside the Bamaga area. A "dummy run" exercise was held in June 1989 at the Kamerunga Horticultural Research Station near Cairns with a range of people that would be involved if black Sigatoka was found on the mainland outside Bamaga.

Preliminary contributions for a plan were prepared before the exercise by Roger Goebel (Inspector, Innisfail) and the Plant Pathologists, David Jones, Mark Ramsay and Ken Pegg (Indooroopilly). These preliminary plans were expanded at the end of the exercise and the first draft of the Black Sigatoka Contingency Plan was prepared and released for comment in September 1990.

There was little further activity in the development of the plan until after black Sigatoka was found in an isolated community on the Pascoe River in 1991. A second draft was produced in 1992. These plans were further upgraded following the black Sigatoka finding at Bloomfield and the third draft was released in 1995. These plans were widely distributed to industry representatives and to all sections of the QDPI who had been involved in the earlier black Sigatoka eradication programs. The third draft "Contingency Plans for Containment and Management of Black Sigatoka outbreaks in Queensland" is attached in Appendix 4.

[The final draft edition was printed in June 1996].

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GENERAL DISCUSSION

Black Sigatoka is endemic in Papua New Guinea, Irian Jaya and parts of the Torres Strait. It is more virulent and more difficult and costly to control than yellow Sigatoka which is throughout most banana growing areas in Australia. The presence of black Sigatoka in the Torres Strait and Papua New Guinea, is a major threat to the entire Australian banana industry, as illustrated by the introductions detected, at Bamaga, Pascoe River and in particular Bloomfield. Black Sigatoka would substantially increase the cost of production (up to 40 sprays applied for black Sigatoka in Central America compared with 20-25 in the local industry), the loss of yield and fruit quality and may also result in marketing problems as the loss of the "Black Sigatoka free" status may lead to importation of bananas and the loss of the entire banana industry.

The source of the inoculum for the disease outbreaks at Pascoe River and at Bloomfield is unknown. The two areas, however, are connected through the close association of the owners of the Pascoe River property and the Auravale property in the Bloomfield area. There are also two connections between the owners of two of the infested properties at Bloomfield and Papua New Guinea and other South Pacific areas. Surveillance/awareness programs are necessary to prevent the unintentional introduction of banana material infected with black Sigatoka.

The black Sigatoka outbreaks at both the Pascoe River and Bloomfield were detected in surveys of the area. An AQIS survey of the Cape York area detected the outbreak near the Pascoe River, while the disease was detected at Bloomfield in a survey to determine the distribution of yellow Sigatoka in the Cape York which was required as part of the Black Sigatoka Contingency Plan. A thorough survey of the entire Cape York area is required to determine if any other diseased plants are present. Areas of diseased plants in the Cape York area would be a major threat to the industry. Regular complete surveys (1-2/year) are necessary to ensure early detection of any outbreaks which would increase the success of any eradication program, prevent the secondary spread of the organism and maybe enable the source of the inoculum to be identified.

Surveys for black Sigatoka should be extended to include all banana production areas in Australia. All areas with air and sea ports with connections to the northern neighbours should be regarded as a high risk area and banana plants in these areas need to be inspected on a regular basis. Early detection may enable eradication programs to be used as was employed in the Bloomfield area. Eradication of a widespread outbreak of black Sigatoka in the main production areas would be very difficult if at all possible. A national survey would confirm the black Sigatoka free status required by AQIS to maintain quarantine on importation of bananas from black Sigatoka infested areas.

Black Sigatoka in the Torres Strait is a continuing threat to the industry especially with the increasing traffic (air, sea and road) to the area. Widespread planting of black Sigatoka resistant cultivars would substantially reduce inoculum levels and the risk of spread. A large

range of better quality resistant cultivars is required for this to be attractive to the local residents.

Disease levels and damage caused in the Bloomfield area were not high at any of the 11 sites where black Sigatoka was found. Climatic conditions prior to September 1993 were not conducive to black Sigatoka development (dry for previous 6-8 weeks) and plant growth was poor in all areas (lack of water and/or nutrients). Inoculum levels would not have been high (low level of disease and little host tissue) and may account for the low level of secondary spread over very short distances (<500m).

The black Sigatoka fungus, *M. fijiensis*, could enter the Australian mainland as airborne ascospores on/in banana material such as leaves (dry or green), fruit, or planting material. The strategies developed to prevent the introduction or at least substantially reduce the risk of the fungus entering the mainland, in particular the main banana production areas, should be successful. The Banana Replacement Program was successful in eradicating black Sigatoka or at least substantially reducing inoculum levels at Bamaga, Pascoe River and recently at Bloomfield. Black Sigatoka has not been detected at Bamaga since 1989 (one year after resistant lines planted) and the Lady Finger plants located near Bamaga in 1994 remained free of disease for more than 12 months or at least one wet season. The disease has not been detected at the Pascoe River since all susceptible plants were removed in 1993. It was also successful on Thursday and Moa Islands but not on Badu Island. Susceptible cultivars continue to be reintroduced to Badu Island and black Sigatoka maybe carried on these plants.

The Banana Replacement Program is an effective means of establishing a biological barrier between the infested areas to the north of the Australian mainland and the commercial production areas. The initial proposal of establishing a barrier from north of Coen to Bamaga had to be changed with the finding of black Sigatoka at Bloomfield. In the limited time available (project duration in relation to Banana Replacement Program was only two years due to delays in appointing the inspector), buffer areas were established around the areas where black Sigatoka had previously been located, rather than an actual barrier across the Cape York area. Buffer zones free of the majority of susceptible host tissue have been established around Bamaga (100km), Pascoe River (80km) and Bloomfield (40km) to ensure any inoculum remaining in these areas is isolated from suitable host tissue and unable to produce additional inoculum for further spread. These zones need to be increased in size until the biological barrier is over 1 000km in size and include the entire Cape York area from Bamaga in the north to the Dagmar Range just north of Mossman in the south.

Black Sigatoka resistant cultivars are essential for the Banana Replacement Program and the wider range of cultivars/types the easier it is to persuade the residents of Cape York to participate in the program. The present selection of only three cultivars, TU8 (Cavendish type), Ducasse (a sweet Lady Finger type) and Bluggoe (a cooking type) is very restrictive. Also, TU8 has not been very successful in many areas. It does not grow under any conditions less than ideal and the flavour, taste and texture are not widely accepted. Other cultivars are essential.

Murray Island is not a suitable site for successful cultivar screening trials. Land and water is limited and it is difficult to access (three days travel to visit the site for 1-2 hours). Another site is required for future screening trials and Papua New Guinea should be considered. A

Government Research Station is located within about 30 minutes drive out of Port Moresby. Access is relatively easy with regular flights between Cairns and Port Moresby. If, however, this is not feasible, results from other programs could be used to select cultivars for the Banana Replacement Program. The reaction of the cultivars included in the Murray Island trial and the ACIAR or IMTP programs was very similar indicating that strain(s) of *M. fijiensis* in the Pacific area are very similar and little pathogenic specialization was detected. Papua New Guinea, however, is part of the area where *M. fijiensis* evolved and if pathogenic specialisation does occur it is very likely it will originate from this area.

Data from the Murray Island trial, the ACIAR and IMTP programs and the cultivar evaluation trials at South Johnstone Research Stations suggests the following cultivars should be released and included in the Banana Replacement Program, Kluai Namwa Khom (dwarf Ducasse), Goldfinger, Yangambi km5, FHIA-02, Pisang Ceylan (very similar to Mysore but free of Banana Streak Virus) and the cooking type Blue Java.

The success of the Banana Replacement Program depends on the co-operation of the residents in Cape York and this has been received from the majority of the residents in the area. Effective communication through direct contact and awareness programs has been an essential part of gaining this co-operation from the residents.

RECOMMENDATIONS

(A) EXTENSION/ADOPTION BY INDUSTRY

Progress achieved in the project, including unexpected findings and changes in directions were communicated to banana growers and other industry members via field days, growers meetings, radio, rural press (see publicity for the black Sigatoka finding at Bloomfield, Appendix 2), Banana Topics and the industry publication F&V News.

An update on black Sigatoka including the progress of the project was presented at the Scientific Workshop Session of the Banana Industry Congress (Surfers Paradise 3-7 May 1995). The Congress was attended by more than 500 delegates including all sections of the industry and a large number of growers and overseas visitors.

There was no Adoption by Industry requirements in this project.

See Appendix 1, 2 and 3 for press releases, articles in rural press and industry publications and Appendix 5 for publications arising from this project.

(B) FUTURE DIRECTIONS

There is a need to hasten the implementation of the strategies developed to reduce the risk/prevent the introduction of black Sigatoka into the main banana production areas especially in north Queensland. The finding of black Sigatoka at Bloomfield demonstrates the risk facing the industry is real and the disease could enter and establish anywhere in Queensland. The future requirements include the following:

- A need to increase the surveillance of all areas of Cape York and all other banana growing areas to ensure black Sigatoka is not present and ensure early detection of any introductions. All bananas in Cape York, north of Mossman need to be regularly inspected for disease.

- The biological barrier between the Torres Strait area and the production areas should be extended from Bamaga in the north to the Dagmar range (Dayman Point) near Mossman in the south (1000 + km). This would prevent the step by step southerly movement of the fungus, increase awareness of the problem throughout the Cape York area and prevent the establishment of the disease from any unintentional introduction of the fungus on banana leaves, fruit etc.

- An increase in an awareness/education program targeted at all groups who travel through Cape York, including visitors, tourist operators, fishermen, miners and Government personnel.

- Surveillance should be increased on all aeroplanes and boats originating from the Torres Strait/Papua New Guinea areas and all other international ports.

- Additional resistant cultivars are required which are more suitable for growing in the Cape York area, frequently under less than ideal conditions and have more acceptable taste and texture. Cultivars which are similar to Williams, Lady Finger and Red Dacca are required.

(C) FINANCIAL/COMMERCIAL BENEFITS

The Queensland Banana Industry, valued at over $175 million per annum in 1991 is mainly situated on the west tropical coast of north Queensland. Climatic conditions are favourable for foliage disease development and yellow Sigatoka costs the industry in chemical control alone, more than $5 million each year. Black Sigatoka is a more virulent disease which develops more rapidly and is more difficult to control. In Costa Rica, where the sensitivity of the fungus to the very effective DMI fungicide group has declined, 40-45 applications of fungicides are required each year to control black Sigatoka. If black Sigatoka is introduced to the wet tropical coastal areas of north Queensland, it would most likely replace *M. musicola* within 2-4 years and the present cost for the control of leaf diseases ($5 million) would be expected to increase 2-4 fold. Many growers would not be able to survive such an increase in costs and would be lost to the industry. Also the presence of black Sigatoka would result in the loss of the present "Area Freedom" status for the Australian Banana Industry which may result in importation of bananas from countries with very low production costs (labour costs $4-8/day). For each year black Sigatoka is kept out of the Australian Banana Industry, in particular the north Queensland area, there is a financial benefit of $10-20 million to the industry and an orderly marketing system with financial returns for the grower.