Australian banana industry: Status and R&D update

Robert Williams*

General production issues

Banana production in Australia over the past three years has been through a period of very difficult times. In north Queensland, the major production area for Cavendish, recovered from the outbreak of black sigatoka in 2001 through to 2003. Survey results have now indicated the eradication programme that was implemented has been successful, however throughout this period banana price have been very depressed resulting in many medium and small growers exiting the industry. The larger companies have taken up this loss on production by planting more.

In Northern Territory, no further outbreaks of fusarium race 4 have been detected, and the disease has not spread to any other production areas.

Drought conditions, increasing land prices and lack of productivity compared to north Queensland have seen a significant reduction in banana production in these areas. Lady Finger production has now shifted to the cooler areas of north Queensland.

Australian banana production has remained static at just over 22 million cartons (297 000 tonnes) for approximately 14 000 ha. Consumption has continued to increase to just over 15 kg/head/year.

The majority of production is AAA Cavendish types (Williams, Mons Mari and Grande Naine) grown in tropical areas north of the Tropic of Capricorn, whilst AAB Pome – Lady Finger are grown in southern or higher altitude regions in north Queensland. The Eco banana has captured a small but developing market as more growers move into this production and marketing system. Small quantities of ABB Ducasse (Pisang Awak) and AAAB Goldfinger are providing a demand in other niche markets.

The major cultivars are

Cavendish	90%
Lady Finger	8%
Goldfinger	1%
Other	1%

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Restraints on the industry

The Australian banana industry was once a very organized group of producers, having a peak industry body and regional representation, that provided the industry with a solid strategic direction, political representation, funding for R&D and quarantine regulations. However, this has fallen apart in the last two years. Although the peak industry body (Australian Banana Growers Association) still remains, and has primary responsibility for the management of import risk assessments, regional operations are dysfunctional. This has resulted in loss of strategic research priorities and funding and the potential collapse of the internal banana quarantine protocols that have protected the Australian industry from many of the international pests and diseases.

The loss of R&D funding has resulted in no new research projects for the past two years.

While the industry structure is collapsing, additional external factors are imposing significant demands on the production of bananas in Australia such as:

- Labour costs
- Workplace health and safety
- Environmental impact from farming

The lessons learnt from what has happened in Australia provides BAPNET with an opportunity to evaluate how programmes are delivered and adopted by small growers in developing countries. By providing community groups with training in how to assess what the key issues are that impact on their business, and then work with them to address these priorities, greater adoption will result. This is the opposite to what is happening at the moment, where researchers are telling farmers what their problem are and giving them the results of their research.

Research programmes

Outcomes and progress in the research and development projects have been significant. Abstracts of many of the projects are attached in Annex 1.

The R&D programme is focusing along in 4 major themes:

Competitive production systems

- IPM. Developing a systems approach to pest and disease control.
- Decision support. Production and management systems that maximize efficiency.

- Irrigation/nutritional management to maximize inputs but minimize environmental impacts.
- Diagnostic tools for pest and disease detection.
- Mechanization of production and packaging systems.

Environmental sustainability

- Soil health. Developing monitoring tools as indicators of environmental impact.
- Environmental Management Systems (EMS). Combining the various productions and management.

Product innovation

- Varietal evaluation.
- Marker technology.
- Food solutions.

Supply chain solutions

- Postharvest handling.
- QA systems.

Banana research agencies in Australia

- Queensland Horticulture and Forestry Science.
- Queensland Agricultural Biotechnology Centre (QDPI/UQ).
- Queensland University (UQ).
- Queensland University of Technology (QUT).
- Cooperative Research Centre for Tropical Plant Protection (CRCTPP).
- New South Wales Department of Agriculture.
- Western Australia Department of Agriculture.
- Northern Territory Department of Agriculture and Fisheries.

Note: A new CRC for National Plant Biosecurity is being proposed.

Peak industry body

Australian Banana Growers Council. (ABGC).
Australian Banana Congress to be held in Cairns in August 2005

Collaboration prospects

Australia has over many years collaborated extensively with many Asian Pacific countries in a wide range of research projects. This collaboration has resulted in Australia having extensive strong team in:

- fusarium
- virus of banana
- nematodes
- *Erwinia*
- *Mycosphaerella* leaf diseases
- integrated pest management
- banana tissue culture
- banana characterization
- banana genome
- biotechnology
- cropping system management
- information systems

Research agencies within Australia are keen to join in collaboration with neighbouring countries in research projects which align with priority areas for all agencies.

Key issues for INIBAP/BAPNET

- Publication of Brazil Fusarium Symposium.
- Publication of papers from the Malaysian Congress.

Annex 1

PROJECT TITLE: Chemical and non-chemical control of banana corm rot

PROJECT NUMBER: FR03025

PROJECT START: January 2004

PROJECT COMPLETION: January 2007

PROJECT/PROGRAM LEADER: Steve Akiew
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PROJECT TEAM: Steve Akiew (Bacteriologist), Lynton Vawdrey (Plant Pathologist), Stewart Lindsay (Extension Officer), Kim Badcock (Experimentalist), Victoria Jones (Molecular Biologist)

SYNOPSIS OF PROJECT: A new type of banana corm rot, not previously recorded in Australia, was identified in 1997 on several plantations in Tully-Innisfail, with infections ranging from 2% to 12%, and appears to be increasing in incidence. Corm rot severely affects mature plants, particularly the first ratoons during the summer season. It is soil-borne, and enters the plant through wounds caused by insects, machinery, tools and chemical injury. Plants may tip over quite easily, being broken across the rotted rhizome. The disease also occurs in the Northern Territory and Western Australia. Banana corm rot in Australia is caused by the bacterium *Pectobacterium* (*Erwinia) chrysanthemi.*

These research project commenced in January 2004 to further study *P. chrysanthemi* in-depth, develop a molecular diagnostic tool (polymerase chain reaction, PCR) to identify the bacterium, and devise control methods that could be used in conjunction with the agronomic practices recommended for commercial banana production in Queensland.

PROGRESS TO DATE: A polymerase chain reaction (PCR) protocol for the identification *of E. chrysanthemi* in bananas has been developed and has been successfully used to identify the pathogen. Genetic variations have been observed amongst *P.chrysanthemi* strains isolated from bananas in Queensland and in Western Australia. Pathogenicity of the bacterium has been successfully established, and field trials have commenced to confirm the effectiveness and applicability of chemical and non-chemical options to reduce the impact of the disease on yield of Cavendish. Bacteria that are highly antagonistic to the corm rot bacterium and chemicals registered for agricultural use are being tested in for field application. A corm rot management protocol will be made available to banana growers and researchers by 2007.

CRITICAL ISSUES IMPACTING ON THE PROJECT: The most critical issue impacting on the project is the seasonal variations from year to year that appear influence the occurrence and severity of the disease. This directly affects experimental results obtained within a limited (1-2 years) period. Sufficient funding to support a five-year project would have a positive impact on this type of project**.**

LINKAGES TO OTHER PROJECTS: Soil Health Project (Tony Pattison), Biofumigation Project (ACIAR).

PROJECT TITLE: Management options for banana bunch pests

PROJECT NUMBER: FR00013

PROJECT START: Dec 2000

PROJECT COMPLETION: March 2004

PROJECT LEADER: David Astridge

PROGRAM LEADER: Bob Williams

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PROJECT TEAM: David Astridge, Jeff Lambert, Tanya Martin and Stewart Lindsay

SYNOPSIS OF PROJECT: The major bunch pests in Australia include the banana scab moth (*Nacoleia octasema* (Meyrick) (Lepidoptera: Pyralidae) and banana rust thrips (*Chaetanaphothrips signipennis* (Bagnell) (Thysanoptera: Thripidae) which are responsible for up to 90% of all bunch damage. Banana flower thrips (*Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae) and sugarcane bud moth (*Opogona glycyphaga* Meyrick) (Lepidoptera: Tineidae) are also becoming increasingly important pests to control. Banana bunch pests can cause serious fruit damage resulting in market rejection and the loss of grower income. The current commercial control of banana bunch pests is primarily based on the strategic use of organophosphate insecticides, which can be harmful to the environment and human health. Investigations are currently under way by the Australian Pesticides & Veterinary Medicines Authority (APVMA) to identify, restrict or eliminate the use of environmentally toxic pesticides. The APVMA is currently reviewing chlorpyrifos, one of the most heavily relied upon insecticides. This has increased the priority of the Australian banana industry to find alternative insecticides for bunch pest management. Reduced dependence on organophosphate insecticides is essential to promote sustainable pest management practices and further develop integrated pest management (IPM) in the Australian banana industry. This project investigated the efficacy and potential for using environmentally soft insecticides. Biopesticides, and other insecticides with new modes of action were tested as alternatives to organophosphates for the control of banana bunch pests.

PROGRESS TO DATE: Bioassays and field trials have been completed (2000-2003) to examine treatment efficacy against banana bunch pests in Queensland. The most effective new insecticide treatments for banana scab moth control included emamectin benzoate (Proclaim®), tebufenozide (Mimic®), and indoxacarb (Avatar®). All treatments were equally as effective as the chlorpyrifos (Lorsban 750 WG®) standard and gave less then 5% bunch damage in field trials. Thiamethoxam was the only new insecticide treatment that was equally as effective as chlorpyrifos for controlling the pest spectrum.

The pseudo biopesticide spinosad (Success®) was the most effective treatment against all bunch pests and is now registered as a bunch treatment for the control of banana rust thrips and sugarcane bud moth. The fungal biopesticides *Beauveria bassiana* and *Metarhizium anisopliae* although producing slower mortality times in the lab bioassays then the new insecticide treatments and spinosad were not significantly different ($P<0.05$) in the level of fruit damage compared to the other treatments. Although reasonable control was achieved against all bunch pests the high levels of phytotoxicity present in the field trials make these treatments unacceptable at this time. Future research will concentrate on changing the oil formulations to reduce the phytotoxic effects in the developing bunches and testing different dose rates.

The potassium based fatty acids treatment (Natrasoap®) had reduced efficacy against banana rust thrips making this treatment unacceptable at the reduced rate tested (5ml/L). *Bacillus thuriengiensis var. kurstaki* gave very good control of banana scab moth and sugarcane bud moth in field trials and were equally as effective as the chlorpyrifos standard.

In the insecticide impregnated plastics trial the diazinon and suSCon® strips as well as the chlorpyrifos impregnated bunch covers were equally as effective as dusting and spraying with chlorpyrifos and achieved less than 5% bunch damage against all pests. The low toxicology profiles, unique modes of action and good efficacy of all treatments make them suitable for use in developing insecticide resistance management strategies, further developing IPM in Australian bananas.

FUTURE WORK AND RECOMMENDATIONS: It is recommended that, (1) insecticide efficacy; dose rate and residue data is generated to proceed with product registration of all treatments equally as effective as the chlorpyrifos standard. (2) Additional insecticides with new modes of action and low mammalian toxicity are registered so an effective insecticide resistance management strategy can be developed. (3) The potential for using biological insecticides should be further investigated by testing new pathogens against the pest complex in bananas. (5) Field trials are repeated for southeast Queensland to examine environmental effects on treatment biodegradation.

CRITICAL ISSUES IMPACTING ON THE PROJECT: None

LINKAGES TO OTHER PROJECTS: Management of Banana Rust Thrips (HAL Project No FR96023)

POSSIBLE FUTURE INIBAP (ACIAR) PROJECT: "Taxonomy and Potential Biological Control of Banana Scab Moth (*Nacoleia octasema* (Meyrick) (Lepidoptera: *Pyralidae*) in Australasia"

AIM: To further develop IPM systems in bananas by identifying and introducing potential biological control agents for the control banana scab moth.

WORK REQUIRED: Detailed taxonomy of the banana scab moth throughout its geographic regions (eg. Malaysia, Indonesia, Fiji, Vanuatu, New Guinea) as well as all species of its food plants is required to further enhance the potential for using biological control. Parallel studies are also required on the taxonomy and host preference of the natural enemies to help identify the most suitable biological control agent of this pest. Host preference studies are also required for the introduction of biological control agents. Once identified predator complexes can be built using ecological engineering methods to establish insectaries suitable for the maintenance and establishment of the biological control agents.

POTENTIAL OUTCOME: There is a very good chance that if this work is completed effective biological control agents can be identified and used to help control banana scab moth across the geographic regions for these banana industries. This should result in reducing insecticide applications and enhancing IPM systems for controlling this pest.

PROJECT TITLE: Plant tissue culture: providing strategic support for the banana industry

PROJECT NUMBER BA04007

PROJECT START: November 2004

PROJECT COMPLETION: November 2007

PROJECT/PROGRAM LEADER: Sharon Hamill - Senior Research Scientist
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PROJECT TEAM: Jeff Daniells - Principal Horticulturist, John Thomas - Principal Plant Virologist, Mike Smith - Principal Research Scientist, Ralf Dietzgen - Principal Biotechnologist,

SYNOPSIS OF PROJECT: The Australian banana industry has relied on plant tissue culture in a strategic way for many years and has identified a suite of key activities that can only be achieved by utilising banana tissue culture.

This project provides Australia with a tissue culture quarantine importation laboratory to facilitate safe access to valuable new varieties that are used in research (eg. disease resistance, reduced environmental impacts, improved farm practice and market expansion/diversification). This significant Australian banana germplasm collection of approximately 500 accessions will be maintained in vitro and supported by a field collection that also allows collection of agronomic data on new varieties. Australian researchers need to have access to the Australian collection to look for valuable traits such as pest and disease resistance, improved productivity, including more efficient nutrient use for lower environment impacts for less cost.

One of the aims of this project is to undertake research that will lead to improved quality of tissue cultured plants in reduced susceptibility to pests and diseases and lower incidence of somaclonal variation. Banana tissue culture research in this project will also investigate obstacles to the quality of plants produced including role ofendophytic bacteria

The activities in this project will:
- allow industry to safely import valuable banana varieties.
- maintain Australia's banana biodiversity as a disease-free collection of plants.
- improve the level of international biosecurity – in combination with virology research.
- supply disease-resistant varieties as part of the disease exclusion or

eradication strategy.

- provide disease-free banana varieties for research and industry evaluation.
- improve Australian domestic quarantine. Australia has the best disease-free planting material scheme in the world based on accredited commercial tissue culture laboratories and nurseries (QBAN) using tissue culture to produce virus-free plants.
- undertake research to understand obstacles to tissue culture quality that will eventually assist commercial and research laboratories and subsequently encourage uptake of banana tissue culture.

PROGRESS TO DATE: The establishment of one of the world's major *in- vitro* collections of *Musa* germplasm and, concomitantly, the introduction, multiplication and distribution of new banana varieties for Australian researchers and producers.

- Registration as the Australian Quarantine Inspection Service tissue culture laboratory to facilitate safe importation of banana into Australia
- The establishment of a Quality Banana Approved Nursery (QBAN) Scheme, via a network of commercial tissue culture laboratories and nurseries, whereby growers can have access to clean, uniform planting material with improved productivity.
- The development of ways to eliminate or manage two major problems in commercial banana tissue culture. Due to research on virus transmission growers can be assured the material they purchase is free from disease. While we do not understand the causes of off-types during tissue culture production our research has provided selection criteria that allows dwarf offtypes to be identified and "rogued" out at the nursery stage. This quality selection protocol has reduced the number of off-types reaching the grower.
- Field evaluation of tissue-cultured plants that have identified susceptibility to fusarium wilt
- The use of embryo culture and meristem culture.
- The development of autotetraploid varieties using colchicine applied to *in-vitro* cultures.
- Isolation and identification of endogenous bacteria residing in banana corm tissue.

CRITICAL ISSUES IMPACTING ON THE PROJECT: The key aim is utilizing plant tissue culture biotechnology to facilitate biosecurity, promote biodiversity and create market development opportunities with new varieties.

Increasing pressure from outside the industry, such as threat of imports, disease incursions, and unreliable markets, plus internal pressures resulting in lack of industry unity may either encourage growers to take up the challenge of best practice or cause them to delay. However, there is unanimous agreement that industry in the meantime will need to maintain its arsenal of strategic research activities to provide the national industry with the means to move forward.

Likewise, grower uncertainty due to black sigatoka and fusarium incursions combined with threat of imports have impacted negatively on QBAN where growers have been delaying plantings until they are more aware of the outcomes of these threats. The developing QBAN tissue culture sector is still struggling with delayed orders and payments resulting in reduced cash flow. Ongoing support will need to be provided.

LINKAGES TO OTHER PROJECTS: This project supports all Australian banana research projects that require banana germplasm, both providing material and facilitating importation of new varieties.
With its bacteria research component it links to projects looking at biological control agents to improve both plant and soil health.

Eradication of black sigatoka from Australian banana areas

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ABSTRACT: Black Sigatoka caused by *Mycosphaerella fijiensis* Morelet, was detected in the major banana production area of North Queensland, Australia in 2001. An intense inoculum annihilation program and an intense spray program were conducted over a 6-month period from September 2001 to February 2002, to eradicate the disease. Prevalence of yellow Sigatoka (*M. musicola* Leach), a related disease was reduced from a 96% incidence in the banana areas to extremely low/undetectable levels in more than 96% of the commercial banana areas. All unmanaged banana plants were located and destroyed. In a verification program from May 2002 to May 2003 when the control program was less intense, yellow Sigatoka re-developed in 72% of the area. Yellow Sigatoka also developed on 51% of the unsprayed sentinel plant blocks established throughout the area. Black Sigatoka was not detected during the verification program or during the following 16 months under a less intense surveillance program. To date (November 2004) black Sigatoka has not been detected for 36 months indicating that black Sigatoka was successfully eradicated from the banana production region of north Queensland.

Key words: banana; *Mycosphaerella fijiensis,* black leaf streak; black Sigatoka; eradication.

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PROJECT TITLE: Soil and root health for eco-banana production

PROJECT NUMBER: FR02025

PROJECT START: 1 July 2002

PROJECT COMPLETION: 30 June 2005

FUNDING SOURCE: QFVG/HAL/QHI

PROJECT/PROGRAM LEADER: Mr Tony Pattison, QDPI
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SUMMARY: This project aims to develop tools for banana growers to determine the health of their soil, by providing practical and usable key soil indicators. The indicators will be developed from a range of soil biological, physical and chemical characteristics. These key soil indicators will be used to validate the improvement in soil health by the use of pre-plant organic amendments and the use of interrow crops. They will also be used to benchmark the current status of soil health on banana farms and also to form a soil health scorecard for use by banana growers that can be incorporated into a management system that allows for continuous improvement in soil health.

A detailed survey will be used to develop the key soil health indicators. Only the most practical and meaningful indicators will be used by banana growers, but will be correlated to measurements of soil processes such as the recycling of nutrients and disease suppression. The survey to develop the key soil indicators will be conducted on similar soil types from the main banana production areas. In each production area, triplicate soil samples will be taken down the soil profile to determine the effects farm management has on soil biological, physical and chemical properties. The samples will be taken from a conventional banana growing soil, a low input or organic banana production system and an undisturbed system, either rainforest or pasture. This will measure the effects of farm management on soil properties and determine which soil characteristics are most susceptible to change due to farm management. The soil characteristics, which are most sensitive to change due to farmer's management and the most practical for the banana industry to use, will be adopted as key soil indicators throughout the project.

The key soil indicators developed from the initial survey will be used to develop a soil health scorecard for use by banana growers. The soil health scorecard will be tested for practicality and reliability to indicate soil health by a second survey over three years. The survey will take place yearly on banana farms on a range of soil types and management practices. This will indicate the current soil health status of banana soils and what soil characteristics need to be improved. It will also allow banana growers to incorporate a soil health recording system into an environmental management system to validate their method of farming to environmental agencies and allow continuous improvement in soil health.

To help banana growers determine what is the best method to improve the health of their soil, trials are planned to test pre-plant organic amendments and the use of interrow crops. The pre-plant amendments applied to bananas are intended to provide growers with workable solutions to improve the soil health indicators and allow a more sustainable method of soil management. Pre-plant amendments and the soil health indicators will be linked to the sustainability of banana production by measuring plant growth and yields over a three year period. The amendments will also be tested for their addition of nutrients and ability to suppress soil borne diseases. The use of pre-plant amendments builds on

information gathered from previous projects on the use of compost and mill ash to develop disease suppressive soils.

The use of crops in the interrow of bananas is intended to improve the plant, soil and water relationships within the banana paddock and to reduce the movement of sediment from the banana paddock. A number of shade tolerant species will be tested for their ability to persist within the banana interrow, withstand traffic, their resistance to soil borne diseases and their agronomic suitability for a banana production system. The effects of interrow species will also be tested for their effects on the key soil health indicators to determine if this allows growers to improve their soil health and the sustainability of banana growing. The use of interrow crops builds on information gathered on the resistance of banana fallow crops to soil borne diseases.

The project to develop soil indicators to determine the health of banana growing soil has evolved due to the observations made of poor plant growth, restricted root growth and plant toppling observed on banana farms when there is no plant pathogen involved. Often the only apparent cause of poor plant growth is poor soil structure. The poor soil structure has been difficult to describe to banana growers. The effect soil structural degradation has on banana growth has no quantifiable or descriptive measures to indicate to banana growers how poor soil health is impacting on plant growth. To increase the awareness to banana growers of the effects of poor soil structure and soil degradation have on production and sustainability of banana cultivation, pot trials have been included in the project. The pot trials will also investigate the interaction of a pathogen, such as nematodes and Fusarium wilt, on bananas in poorly structured soil. This trial will demonstrate if soil conditions can increase the susceptibility soil borne disease has on banana growth.

The project aims to develop practical science for banana growers to develop useful and practical indicators of soil health. To help with the adoption and uptake of the use of soil indicators, an extension component of the project comprising a biannual newsletter, annual farmer field schools and the development of a banana root and soil health manual and testing kit will be developed. The soil health manual and testing kit will complement one another and allow growers to use a soil health scorecard to assess and validate their management practices in relation to soil health. This information can then be incorporated into an environmental management system for growers to continually improve the health of soils under banana cultivation.

For banana growers to improve their knowledge of soil health practices, they need indicators that can quantify and describe their current soil health status as well as management options that growers can implement to improve soil health. This project will improve the knowledge of soil health, allow growers to monitor and validate soil health and give options to improve soil health management. As a result of improved soil health from this project banana growers will be able to reduce losses due to poor soil structure, validate their farming practices and continuously improve soil health management to sustainably produce bananas in Queensland.

SUMMARY OF PROGRESS:

SURVEY: 34 fields in north Queensland were sampled to validate 4 key soil health indicators: pH, electrical conductivity (EC), NO_3-N and labile C. Samples taken from the fields were processed using soil health kit methods at laboratories in South Johnstone and sub-samples from each field sent to NRM&E accredited laboratories at Indooroopilly for duplicate analysis. The four key soil indicators were significantly related validating the methods used in the soil health kit were able to provide reliable measures of soil properties (Table 1).

Table 1. Correlation of four key soil health indicators between soil health kit measurements and accredited laboratory techniques.

Key soil indicator	Equation	Variance accounted for (%)	
pH	$pH_{sj} = (1.1 \times pH_i) - 0.7$	98	(*P*<0.001)
Electrical conductivity	$EC_{sj} = 0.01 + (0.39 \times EC_i)$	64	(*P*<0.001)
NO_3-N	$NO_3\text{-}N_{sj} = 25.8 + (2.69 \times NO_3\text{-}N_i)$	71	(*P*<0.001)
Labile C	Labile $C_{sj} = 203 + (155 \times$ Labile $C_i)$	37	(*P*<0.001)

$_{sj}$ = measured at South Johnstone using the soil health kit. $_i$ = measured at Indooroopilly at accredited laboratories.

Labile C measurements had the largest variation between measurements conducted in South Johnstone and Indooroopilly. This may be due to the heterogeneity of carbon in the soil as well as differences in techniques. However, the soil health kit technique of measuring labile C is the only method that can currently be conducted without sophisticated equipment and provides a good indication of the carbon status of the soil.

INTERROW CROPS:Interrow crops, pinto peanut, butterfly pea, carpet grass and bahia grass were planted in January, 2004. Dry matter samples were measured in April, 2004 and revealed pinto peanut and pinto peanut and carpet grass mix had significantly higher dry matter production than other treatments. There were significant differences in soil physical, chemical and biological properties between the interrow and the row area of bananas. Physically, the interrow area had significantly higher bulk density, slower water infiltration and less stable aggregates relative to row area. Chemically, the pH, EC and NO_3-N were significantly lower in the interrow relative to the row. Biologically, the interrow area was a more fungal dominated system, whereas the row area around bananas was bacterially dominated with more plant parasitic nematodes. No nematode suppression has been detected.

PRE-PLANT AMENDMENTS: The pre-plant amendment field trial investigating mill ash, mill mud, compost and grass hay was established on August 28, 2003. Following the application of amendments there was an increase in the soil NO_3-N and soil respiration measurements in compost treated plots resulting in an increase in the bacterial feeding nematodes and increased the bacterial dominance of the soil microbial community. However, at the second assessment in March 2004, there were no differences in soil NO_3-N levels. There was a significant increase in the labile C under the grass hay treatment relative to the untreated plots. This resulted in a reduction in the bacterial to fungal ratio relative to the untreated plots, which suggested that nutrients were being decomposed by a

more fungal dominated pathway. There has been no change in measurable physical properties, plant growth parameters or nematode suppression under the amendments so far in the trial.
The use of silicon amendments has been able to give a significant reduction in fusarium wilt symptoms in glasshouse trials. It is thought that the soluble silicon is able to improve the disease resistance in banana plants. However, the exact method, quantity and best method of application are still being determined.

BENEFICIAL MICROORGANISMS: Beneficial microbe field trial to establish antagonistic organisms to burrowing nematodes has been completed and the results are still being analysed. Initial results suggested there is no nematode suppression or growth promotion in the field from inoculation of plants with beneficial microorganisms. Conversely, an isolate of *Cytophaga* sp. has given significant suppression of fusarium wilt in pot trials. This is thought to be due to up regulation of endochitinase and osmotin plant defence genes in presence of bacteria and fusarium and direct antagonism of the bacteria against fusarium.

PROJECT TITLE: PCR primer verification and analysis of the black sigatoka outbreak in Tully

PROJECT NUMBER: FR99009

FUNDING SOURCE: BIPB/HAL/CRC Tropical Plant Protection

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TECHNICAL SUMMARY: Black sigatoka, caused by the fungal pathogen *Mycosphaerella fijiensis*, is a major quarantine threat to the Australian banana industry. The disease is endemic in most banana growing regions in the world, including the Torres Strait Islands. Consequently, vigilance is required to prevent introductions to the Australian mainland and for this regular surveillance for leaf spot symptoms is carried out in Queensland banana plantations and diagnosis of suspect lesions is confirmed at the Centre for Tropical Agriculture in Mareeba. Differential diagnosis of black sigatoka is complicated by the occurrence of yellow sigatoka, caused by the closely related species *Mycosphaerella musicola*, which is endemic in Australian banana crops. However, these two pathogens can be reliably distinguished based on morphology of conidial structures if present.

In April 2001, an outbreak of black sigatoka occurred in the Tully Valley. Previous

outbreaks of the disease had occurred on non-commercial properties in North Queensland and each of these had been successfully eradicated. However, the Tully incursion was located in Australia's largest commercial growing region as well as being in Australia's highest rainfall zone. In addition, traditional diagnostic methods could not be used as high rainfall had washed away fungal structures necessary for a definitive diagnosis. The Centre for Tropical Plant Protection developed a gel-based PCR assay capable of differentiating black and yellow sigatoka in leaf samples which was used to help diagnose samples during the eradication, surveillance and area freedom programs in the Tully Valley.

Through the combined efforts of scientists, extension officers and banana growers, black sigatoka was declared eradicated from the Tully Valley in May 2003, with no disease detected since November 2001. Following this success, two important questions were highlighted: (1) What was the likely source of the Tully outbreak and (2) would the gel-based assay be capable of detecting future incursions of the disease in Australia?

To address the issue of the likely source of the outbreak, a comprehensive sequence study was undertaken. The internal transcribed spacer (ITS) and intergenic spacer (IGS) and D1/D2 regions of the ribosomal gene complex of *M. fijiensis* were sequenced from banana samples collected during the Tully eradication campaign and compared to an extensive catalogue of isolates of *M. fijiensis* and *M. musicola* as well to *M. eumusae*, a third closely related pathogen which causes a similar disease on banana, Eumusae leaf spot (ELS). Isolates for comparison were sourced from local and international collections and included sequences from Africa, India, Central and South America, the Caribbean, Asia and the Pacific Islands as well as sequences from previous Australian incursions. The results of the phylogenetic analysis revealed a number of important findings: (1) confirmation of *M. fijiensis, M. musicola* and *M. eumusae* as three distinct species; (2) identification of two new species of *M. musicola* occurring in Malaysia and Indonesia and (3) that the source of the Tully 2001 incursion was very unlikely to have been sourced from previous incursions in Cape York but was more likely a new introduction.

To ensure the ability to detect future incursions of black sigatoka and related species into Australia, the ITS sequence data was assessed for integrity of the diagnostic primer sites. In addition, the gel-based PCR assay was screened against the DNA catalogue of local and international isolates of banana and non-banana *Mycosphaerella* spp. as well as other banana phytopathogens. Detection of very low level (0.04%) cross-specificity was found during testing necessitating a more specific assay format to be sought. Consequently, TaqMan® MGB probe assays have been developed for black and yellow sigatoka and these assays are ready for technology transfer.

The conclusion that the source of the Tully 2001 outbreak was most likely from a new introduction and not from a previous outbreak in Cape York, indicates that the earlier eradication programs have been successful. This finding should serve to strengthen confidence in the Tully eradication program and also provide support that eradication should be pursued in the event of any future incursions. The finding that *M. musicola* appears to be comprised of at least three species has important implications in quarantine. The two possible new species from Indonesia and Malaysia have not been identified in Australia and the pathogenicity of them is unknown. There is a very real possibility that these species could enter Australia undetected and for this reason, it is recommended that an extensive study of *M. musicola* is undertaken to determine if there are differences in pathogenicity in genotypes from different geographical regions.

As a result of this study, improved diagnostic assays for black and yellow sigatoka have been developed. Incorporation of quality assurance controls into this test is desirable and multiplexing the two tests into a single tube assay would have benefits in quality control and cost. The development of a TaqMan® MGB probe assay for *M. eumusae* has begun, however, thorough validation of this assay is necessary. Further work addressing these issues is recommended towards the goal of providing the Australian banana industry with the very best diagnostic tools for surveillance of these exotic pathogens.

PROJECT TITLE: Using nutrient-rich bananas to improve health and livelihoods in the Pacific

ACIAR RESEARCH PROGRAM AREA: Crop Protection

PARTNER COUNTRY/IES: Solomon Islands, Kiribati, Papua New Guinea

PROPOSED COMMISSIONED IARC: International Plant Genetic Resources Institute (IPGRI): International Network for the Improvement of Banana and Plantain (INIBAP) programme; Proposed Australian Collaborating Organisations: Queensland Department of Primary Industries and Fisheries (QDPIF); University of Queensland (UQ)

PROPOSED PARTNER COUNTRY COLLABORATING ORGANISATION/S: The Secretariat of the Pacific Community (SPC), Fiji; Planting Materials Network, Solomon Islands; National Agricultural Research Institute, Papua New Guinea

PROJECT SUMMARY: Vitamin A deficiency is a major cause of debilitating health problems in developing countries and contributes significantly to infant and maternal mortality. Recent studies have shown that some traditional varieties of banana grown in the Pacific islands contain enough provitamin A carotenoids to readily satisfy needs for Vitamin A when consumed in amounts that are realistic in areas (especially Oceania and East/Central Africa) where people (some 400 million, worldwide) eat bananas as a staple food. In particular, Englberger et al. working in the Federated States of Micronesia (FMS) have laid the foundation of this project by demonstrating the basic feasibility of this concept. This project will lead the way for the development of an international effort to encourage wider consumption of carotenoid-rich bananas, based on an assessment of their nutrient content, bioavailabilty, consumer-acceptability and agronomic-adaptability. Drawing on the expertise of the project collaborators in nutrient analysis (UQ, QDPIF), consumer acceptance (UQ, INIBAP and local partners) and the evaluation and dissemination of banana varieties (QDPIF, SPC, INIBAP and local partners), the results of the project will indicate whether a wider effort based on consumer education and dissemination of existing high-carotenoid varieties is likely to achieve the desired health impacts or whether it is necessary to invest in breeding efforts to transfer the desired traits to new varieties with wider acceptability and adaptability.

OBJECTIVES WILL BE TO:

- evaluate the carotenoid levels in existing varieties (based on collections of Pacific varieties at QDPIF and elsewhere) and the likely bioavailability of Vitamin A based on the ways in which these bananas are grown, processed and consumed
- identify ethnobotanical uses of banana and gain an understanding of the acceptability of various high-carotenoid banana varieties to consumers, both at first encounter and after nutrition education
- evaluate the agronomic adaptability of promising high-carotenoid banana varieties, considering growth cycle, yield, disease-resistance and adaptation to different agro-ecologies

THE EXPECTED OUTPUTS WILL INCLUDE:

- an understanding of the technical and social factors influencing and limiting the availability of Vitamin A resulting from consumption of high-carotenoid bananas
- initiation of positive health outcomes in the study areas, resulting from increased awareness of the value of consuming high-carotenoid bananas
- the foundation for a realistic inter-regional strategy for using bananas to alleviate Vitamin A deficiency problems in developing countries (which is expected, when implemented through other projects, to have an immediate impact in those Pacific nations where Vitamin A deficiency has been identified, such as the Solomon Islands and Kiribati, and eventually in other regions, especially sub-Saharan Africa).

HOW THE PROJECT WILL BE UNDERTAKEN: The project focuses on novel research on the bioavailability of Vitamin A based on consumption of *Musa* and will examine pre- and post-harvest factors influencing its availability in both *in-vitro* and *in-vivo* studies. Equally important are the social actions and interactions within target countries with technical back-up provided by Australian partners, SPC and INIBAP. Promising banana/plantain cultivars will be identified in existing collections (QDPIF, SPC, NARI, INIBAP Transit Centre) and fruit assessed for carotenoid content and bioavailability. Agronomic assessment of a subset of varieties will begin immediately in Australia and target countries, in order to complete a full production cycle at contrasting sites (rainfall, altitude, soil fertility, disease pressure) within the project period. Participatory methods will be used to evaluate likely acceptability and consumption patterns, with and without complementary nutrition education. For each of the countries, the aim will be to identify the most favorable combination of Vitamin A/bioavailabilty and social acceptability. Analysis of data within a sociological and biophysical framework (using GIS) will provide a basis for assessing the likely cost and impact of a larger-scale strategy based on disseminating existing high-carotenoid varieties, accompanied by participatory training in food processing, health and nutrition.

Uptake pathways would include future projects of INIBAP regional networks (in both Asia/Pacific and Africa) and SPC.

Australian and International Project partners (other than Pacific NARS):

- Dr Mike Smith, Sharon Hamill, Greg Mitchell, Dr Craig Davis, Jeff Daniells, QDPIF. Germplasm acquisition and characterisation and supply of fruit for analysis; Initiation, virus indexing and provision of banana germplasm; Nutrient analysis, food processing
- Prof Mike Gidley, A/Prof Geoff Marks, Dr Terry Coyne, Dr Faroukh Ahmed, UQ. *In vitro* bioavailability studies, clinical nutrition and *in vivo* bioavailability.
- Dr Gus Molina, Dr Richard Markham. IPGRI-INIBAP. Networking for dissemination of materials, information and assessment of cost-benefits for a global program
- Dr Lois Englberger, SPH UQ and Micronesia (contracted through INIBAP). Engagement with local communities to identify promising germplasm, and approaches to assess and enhance the cultural acceptability of nutrient-dense cultivars.
- Dr Mary Taylor, SPC. Sourcing and maintaining banana germplasm, distribution of promising lines and facilitation of evaluation in member countries.