Management of postharvest diseases of tropical and subtropical fruit using their natural resistance mechanisms in Sri Lanka, the Philippines and Australia (HORT/1997/094)

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Project number	HORT/1997/094
Project name	Management of postharvest diseases of tropical and subtropical fruit using their natural resistance mechanisms in Sri Lanka, the Philippines and Australia
Collaborating institutions	Australia: Department of Employment, Economic Development and Innovation (DEEDI), Queensland—previously the Department of Primary Industries and Fisheries Sri Lanka: Department of Agriculture, University of Peradeniya Philippines: The 2005 extension also included the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development and the University of the Philippines, Los Baños
Project leaders	Australia: Dr Lindy M. Coates and, part-time, Dr Elizabeth Dann Philippines: Dr Chrys Akem
Duration of project	1 July 2002 – 30 June 2007
Funding	Total A$1,875,420 (ACIAR contribution: A$991,909)
Countries	Sri Lanka, Australia (Philippines only after 2005)
Commodities	Mango, banana
Related projects	PHT/1983/056, PHT/1984/044, PHT/1993/093, PHT/1993/877 HORT/2003/071, HORT/2005/154, HORT/2005/153, HORT/2006/111, HORT/2005/157, SMAR/2007/193, HORT/2007/067, HORT/2006/146, HORT/2010/030, HORT/2010/006, HORT/2010/001

Motivation for the project and what it aimed to achieve

In the past three decades, many countries in Asia have promoted horticulture and export market development to increase the income of farmers as they diversify from cereal cropping. Mango and banana are important crops in much of tropical and subtropical Asia, providing income and nutrition through fresh and processed product. However, their intrinsic short shelf life and susceptibility to fruit rots reduce marketability and profits. As a consequence, the development of field and postharvest measures to reduce disease and extend shelf life of mangoes and, at times, bananas, have been a major theme of ACIAR's collaborative research investment in horticulture. Controlling or reducing disease relies on integrated crop and postharvest management, with attention to fungicide application, crop hygiene and nutrition, and the management of ripening, to optimise advantages conferred by the plant's natural resistance factors that prevent and delay disease development until the fruit ripen.

Recognising the need to reduce reliance on fungicides and enhance attention to fruit resistance and other factors, a 1997 ACIAR workshop convened in Thailand reviewed the resistance of subtropical and tropical fruit to disease, and subsequently led to the development of this project. The project capitalised on high-level expertise in mango and banana fruit resistance factors in the Sri Lankan research team, and the Australian scientists' experience with defence activators and knowledge of practical disease control and extension for the mango industry, to strengthen capabilities for managing postharvest diseases of tropical and subtropical crops using their natural resistance mechanisms.

The project evaluated the prospect of utilising inherent plant defence mechanisms in the management of postharvest diseases, focusing on mango (Australia, Sri Lanka) and banana (Sri Lanka). The key diseases were anthracnose in mango and banana, caused by *Colletotrichum gloeosporioides* and *C. musae*, respectively, and stem-end rot in mango, caused by fungi in the family Botryosphaeriaceae (*Neofusicoccum* spp., *Lasiodiplodia theobromae* etc.). A significant component was the identification and evaluation of activators of plant defences under field conditions. The activators were known resistance-inducing agents, including

Sri Lankan project leader, Professor Nimal Adikaram. (Photo: A.W. Cooke, DEEDI)

acibenzolar-S-methyl (Bion®), and elicitors derived from fungal pathogens (in banana). Another component was to characterise some of the key biochemical defences contributing to the resistance, and to identify treatments, varietal properties or other agronomic practices that may influence their relative effectiveness. The final key objective was to enhance the capacity of project teams to conduct plant defence research, and provide information to respective industries via workshops and field days.

Outputs—what the project produced

Technical outputs

1. Increased understanding of the effects of defence activator treatments in mango and banana

In Sri Lanka and Australia, some treatments that activate or enhance the natural defence systems in plants, including acibenzolar-S-methyl (Bion®), salicylic acid and ultraviolet C light (UVC), showed some potential for enhancing and extending disease control for mango and banana when used within an integrated system.

The project concluded that further field trials should focus on the incorporation of Bion® into field disease-management programs, but its registration and adoption remains the decision of Syngenta, the company marketing the product. Other defence activators should be assessed as they become available. Postharvest UVC treatment should be assessed under commercial packing-line conditions.

2. Increased knowledge of how crop nutrition management and rootstock choice in mango influence postharvest disease levels

In Sri Lanka and Australia, excessive application of nitrogen during crop production was shown to result in higher levels of anthracnose in ripening mango fruit, while on low-nutrient-status soils in Sri Lanka, increased potassium nutrition reduced postharvest disease in bananas. The project concluded that the information on the level of nitrogen fertiliser application in banana and mango growing could have immediate impact if made widely available to growers and other agricultural and extension staff. In Australia, rootstock choice was shown to have potential for disease reduction.

3. In Sri Lanka and Australia, knowledge of the constitutive defences against fruit diseases and varietal differences in mango and banana was enhanced, and some insights into practical application of this knowledge were obtained.

Mango. Until this project was undertaken, mango fruit resistance to disease had been associated with the levels of resorcinols in fruit peel. The project has expanded knowledge of the role and interactions of resorcinols and cultivar differences in mango fruit resistance to anthracnose and stem-end rot, and implicated other mechanisms as preformed (galloyltannins) and induced (superoxides, H_2O_2, hypersensitive response, chitinases, peroxidase) defence mechanisms.

A significant 'world first' demonstration from Sri Lanka was to show that the galloyltannin class of compounds was a major component contributing to antifungal activity in mango peel extracts. The Sri Lankan team had first detected these compounds in 1986, but they needed the support (and equipment)

from ACIAR to progress the research. The role of galloyltannins in disease resistance has not previously been reported in plants. However, they have been reported by others in studies on mango chemistry. As well, mango latex was shown to possess chitinase activity and the ability to decompose fungal spores.

Building on previous work in ACIAR projects, retention of long stems in fruit was shown to reduce disease levels in fruit by ensuring retention of antifungal resorcinols for a longer time after harvest.

Banana. In Sri Lanka, leading-edge research focused on the induced defences in banana. The occurrence of several phenylphenalone-type phytoalexins, accumulating in response to infection of banana fruit by *Phyllosticta musarum*, the pathogen causing the mild symptoms of freckle disease, confirmed earlier work by the Sri Lankan group. In subsequent research, the compounds were partially characterised, and freckle infection was also shown to induce other biochemical defences, such as pathogenesis-related proteins, phenolics and other structural defences. Most significantly, freckle infection, and the consequent induction of defences, reduced anthracnose development during ripening.

The project concluded that:

- global knowledge of natural plant defence systems and their regulation in mango and banana had been significantly enhanced by the project, and the capacity of all project teams to conduct such research had been elevated
- the cultivar × disease-resistance work could have a short-term impact if growers/industry used project information to choose or develop varieties with higher disease resistance
- assessment of fruit defence chemicals should be a routine component of disease resistance screening and postharvest storage research

Mango nursery-stock production in Sri Lanka using modern grafting techniques. (Photo: G.I. Johnson, H4D)

- in the longer term, the selection and adoption of more resistant rootstocks (mango) will be beneficial, and the understanding of biochemical defences could lead to the development of assays for screening germplasm for resistance as part of a breeding program.

Capacity outputs

Capacity building and training featured strongly in the project: PhD studies by seven students, four in Sri Lanka, and three in Australia, and an MSc in Sri Lanka, contributed significantly to project outputs. The benefits of their study and on-the-job training have also extended beyond the project, as demonstrated by their subsequent publications and research, and/or successful employment at universities. Field days (two in Sri Lanka, annually in Australia) and training activities (three workshops in Sri Lanka, two in Australia) extended outputs to the broader industry in Sri Lanka and Australia. Benefits also accrued for Indonesia and Bangladesh, the home countries of two of the students who studied in Australia.

Adoption—how the project outputs are being used

Based on project outputs and the registration of the defence-boosting treatment acibenzolar-S-methyl (Bion®) for use in Australia as a seed dressing in cotton, research to assess the application potential of defence activators has continued on mango, avocado and lychee in Australia, and on mango in the Philippines. Bion® is regarded as having potential in Australia as a combination treatment in situations of high disease pressure (e.g. during nursery propagation; after heavy rainfall; before a long storage period). However, in the Philippines, the results were variable and it was concluded that the treatment may not be cost-effective in the short term.

Following on from the project, Australian assessment of the utility of ultraviolet light treatment for control of postharvest diseases on mango or avocado has not been promising but did have some value on citrus.

While assessing defence-boosting treatments, two new diseases (mango malformation and *Cladosporium* inflorescence blight[1]) were recorded in Sri Lanka, with the latter a first record on mango in Sri Lanka.

In Sri Lankan research, some additional insights have been gained into how defence-activator treatment of bananas enhanced disease resistance.

Based on project outputs and other related Australian research, crop-management strategies and improvement in postharvest disease control through nutrition management and rootstock choice continue to be developed for commercial application in tropical and subtropical horticulture. Nutrition management and rootstock selection for disease resistance are also being assessed or promoted in ACIAR project activities in partnership with Pakistan and the Philippines.

1 Also reported by: Guillen-Sanchez D. de J., Yanez-Morales M., Teliz-Ortiz D., Siebe-Grabach C. and Bautista-Banos S. 2007. Morphological and molecular characterization of *Cladosporium tenuissimum* Cooke (Deuteromycotina: Hyphomycetes) on mango tree panicles: symptoms, pathogenicity and severity of the fungus. Fruits (Paris) 62, 361–368.

Rice planting in Sri Lanka. Mango production can provide additional income for rice farmers. (Photo: G.I. Johnson, H4D)

The importance of avoiding excessive nitrogen application during crop production to help optimise postharvest ripening and disease management has been extended to the Australian mango industry through the 'Better mangoes' program funded by Horticulture Australia.

In Sri Lanka, further work on banana has shown that the uptake of potassium in banana, and its effect on disease resistance, differed according to initial soil potassium status. Enhanced levels of potassium also resulted in flowering 5 weeks earlier than usual.

Knowledge of the constitutive defences against fruit diseases in mango and banana has been further extended, and peer-reviewed publications are making the information widely available. The findings and approaches to resorcinol assessment have also been adopted in the Australian mango-breeding program.

In Australia, as a spillover under ACIAR project HORT/2007/067[2] in the Philippines, further work to assess the retention of long stems as a means of reducing disease by retaining antifungal resorcinols in the fruit has given variable results. In Sri Lanka, retention of latex by harvesting fruit with long stalks reduced anthracnose development.

2 'Improved domestic profitability and export competitiveness of selected fruit value chains in the southern Philippines and Australia'

Since the completion of the project, further research by the Sri Lankan team has detected six phytoalexins in the peel of banana cultivar 'Embul', of which four compounds had not been reported previously. As well, the antifungal activity in eight local banana varieties following freckle infection has been assessed. However, not all observed affects correlated with cultivar resistance/susceptibility.

The global knowledge of natural plant-defence mechanisms and what affects them has been significantly enhanced by this project, and the skills and capacity of all project teams to conduct such research have been elevated.

Impact—the difference the project has made or is expected to make

This project has not yet had any substantial impact on the local farming community in Sri Lanka. The most significant impact of the project has been enhancement of research capacity, and of basic knowledge for international research on mango and banana disease-resistance mechanisms. As well, the project has yielded new insights into the changes in constitutive and induced defence mechanisms as fruit ripen and develop disease, with effects influenced by cultivar, field nutrition and rootstocks, and into the use of defence-boosting treatments.

This knowledge has already been incorporated into the teaching of plant pathology in Sri Lanka, and made accessible to a wider audience through scientific publications, review papers and international conference and workshop presentations. As a consequence of their achievements in the project, the PhD graduates in Sri Lanka have moved into teaching and research positions within Sri Lanka, while those from Australia are now continuing research and/or teaching in Queensland, Indonesia and Bangladesh. All of the graduates are using the knowledge and skills gained in the project in their new roles.

Bagging of individual mango fruit to prevent attack by fruit fly and control damage by physiological and pathological disorders. (Photo: G.I. Johnson, H4D)

Key outputs of the research on mango and banana defence systems were presented in two papers by Professor Nimal Adikaram and Dr Elizabeth Dann at the International Congress of Plant Pathology in 2008. Outputs of the work were also incorporated into a review of postharvest handling and quarantine treatments for mango by Drs Greg Johnson and Peter Hofman in the 2009 revision of the CABI monograph *The Mango*.

Knowledge from the project is also influencing the direction of mango breeding and storage research in Australia and globally, with renewed interest in incorporating aspects of the work into future ACIAR project planning. Recent interest in the measurement of the resorcinols and other defence mechanisms in mango as part of ACIAR project research was stimulated when Professor Adikaram from Sri Lanka and (former PhD student of the project) Dr Zainuri from Indonesia participated in an ACIAR-organised mango disease workshop in Darwin in May 2011. Professor Adikaram presented two review papers on mango defence systems at the workshop.

Crop-management impacts

The banana and mango nutrition findings have been incorporated into recommendations for farmers in Sri Lanka, and there has been a minor level of adoption by farmers who are producing mango for the export market, with prospects for wider adoption as Sri Lankan horticulture begins to modernise. In Australia, the nutrition recommendations have been widely adopted by mango farmers, and the information on the relative susceptibility of mango cultivars and the differences in resorcinol levels has influenced approaches to the breeding program.

Defence-boosting impacts

Information about the potential of defence-boosting treatments, particularly use of acibenzolar-S-methyl (Bion®), has supported continuing evaluation of their use in Australia. Selected defence-boosting treatments have also been tested in the Philippines (where Bion® is registered for use on mango), with mixed results.

Mango defence systems

The global research interest in resorcinols is primarily due to their presence in grains, poison ivy, cashew shell and other plant products, and their allergenic effects on humans. Thus, potential spillover of the mango defence-system research includes enhanced understanding of a group of compounds that are human allergens. However, for horticulture, the most significant opportunity is the considerable potential for enhancing mango disease control through greater understanding and management of resorcinol levels in fruit.