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# A survey for plant diseases caused by viruses and virus-like pathogens in the Solomon Islands

*R. I. Davis*[A,C,D] *and H. Tsatsia*[B]

[A]Land Resources Division, Secretariat of the Pacific Community (SPC), PMB, Suva, Fiji Islands.
[B]Agriculture Research Division (Plant Pathology), Department of Agriculture and Livestock, PO Box G13, Honiara, Solomon Islands.
[C]Present address: Northern Australia Quarantine Strategy (NAQS), Australian Quarantine and Inspection Service (AQIS), PO Box 96, Cairns International Airport, Qld 4870, Australia.
[D]Corresponding author. Email: richard.davis@aqis.gov.au

**Abstract.** Surveys for virus and virus-like plant diseases were conducted on the islands of Guadalcanal, Malaita, Ndende and Temon Neo in the Solomon Islands. New plant virus records for the country were those of *Zucchini yellow mosaic virus* (ZYMV) in *Citrulus lanatus* (watermelon), *Cucurbita maxima* (pumpkin), *Cucumis melo* (rockmelon) and *Cucumis sativas* (cucumber); *Turnip mosaic virus* (TuMV) in *Brassica chinensis* (Chinese cabbage); *Tomato mosaic virus* (ToMV) in *Capsicum annuum* var. *annuum* (chilli) and *Solanum lycopersicum* (tomato); and *Tobacco mosaic virus* (TMV) in *S. lycopersicum*, all detected by enzyme-linked immunosorbent assay (ELISA). Phytoplasmas belonging to the '*Candidatus* Phytoplasma aurantifolia' (16SrII) group were detected by nested PCR in *Celosia argentea* and *B. chinensis.* New virus host records, detected by ELISA, were those of the cucurbit-infecting strain of *Papaya ringspot virus* (PRSV-W) in *C. maxima* and *C. sativa*; *Bean common mosaic virus* (BCMV) in *Vigna unguiculata* ssp. *unguiculata* (snakebean) and *Passiflora foetida*; and *Cucumber mosaic virus* (CMV) in *Ruellia prostrata*, *Synedrella nodiflora* and *Nicotiana tabaccum* (tobacco). Other detections using ELISA were those of CMV in *C. annuum* var. *annuum* and *S. lycopersicum*. No evidence was found for presence of citrus huanglongbing, previously known as greening disease. Seven citrus trees indexed negative by PCR for the causal agent, '*Candidatus* Liberibacter asiaticus'.

## Introduction

A survey was conducted in April 2007 to obtain an indication of the general plant virus and virus-like disease status of some of the larger islands of the Solomon Islands. The survey focussed on islands with high populations and, consequently, high food plant production levels. For quarantine reasons, the survey included islands in the south-east of the group close to neighbouring Vanuatu. A plan to also survey islands in the north-west, adjacent to Papau New Guinea (PNG) had to be abandoned because a damaging tsunami affected this region just days before.

It had been over 20 years since any broad plant viral disease survey had been undertaken and that work (Brunt 1987) generated several records. Since that time, only the focussed studies of Brunt and Spence (2000) and of Revill *et al*. (2005) provided more recent published plant virus disease records from the Solomon Islands. The survey of Revill *et al*. (2005) followed up on several years of active research on virus diseases of aroid species. The records of these, which may have been the same viruses identified using less reliable methods, are cited in Pearson and Grisoni (2002). In addition to viruses, phytoplasma infections have been confirmed in several herbaceous hosts in the Solomon Islands (Dabek and Gollifer 1975; Jackson and Zettler 1983), but strain group identifications were not possible at that time. All previously known published records of virus and virus-like diseases of plants in the Solomon Islands are listed in Table 1.

Huanglongbing (HLB, formerly known as greening disease), is one of the worst diseases of citrus trees and is caused by the phloem-limited bacterium, '*Candidatus* Liberibacter asiaticus'. HLB recently reached the Island of New Guinea directly west of the Solomon Islands, where it was first verified in the Indonesian province of Papua in 1999 (Davis *et al*. 2000) then in PNG in 2002 (Weinert *et al*. 2004). HLB was reported to be present in several Pacific island countries in the mid 1990s (Kiritani and Su 1999). However, no ongoing HLB-like disease epidemics have ever been reported in any of the 22 Pacific island countries or territories served by the Secretariat of the Pacific Community (SPC) since that time (SPC, unpubl. data). Moreover, a series of plant disease surveys have recently been undertaken by SPC in collaboration with various plant health organisations in eight Pacific island countries and three territories. These surveys targeted citrus trees for HLB indexing because of their disease-like symptom expression and returned only negative results (Davis *et al*. 2005*b*, 2006*b*, 2006*c*, 2006*d*, 2007*a*, 2007*b*). For these reasons, a similar search for HLB-like symptoms was made in the Solomon Islands wherever citrus trees were found.

## Methods

### *Surveys*

As many different areas as possible were visited. Crop plants of economic importance, and occasionally also other plants, were

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**Table 1. Previously published plant virus and virus-like disease records from the Solomon Islands**

| Pathogen | Host | Citation[A] | Identification method[B] |
|---|---|---|---|
| *Bean common mosaic virus* (BCMV) (listed as Blackeye cowpea mosaic virus) | *Calopogonium mucunoides* | Brunt (1987) | Serology |
| | *Centrosema pubescens* | Brunt (1987) | Serology |
| | *Clitorea ternatea* | Brunt (1987) | Serology |
| | *Desmodium heterophylum* | Brunt (1987) | Serology |
| | *Macroptilium atropurpureum* | Brunt (1987) | Serology |
| | *Macroptilium lathyroides* | Brunt (1987) | Serology |
| | *Phaseolus vulgaris* | Brunt (1987) | Serology |
| | *Pueraria phaseoloides* | Brunt (1987) | Serology |
| | *Stylosanthes guianensis* | Brunt (1987) | Serology |
| | *Vigna marina* | | |
| *Cassava green mottle virus* (CsGMV) | *Manihot esculenta* | Lennon *et al*. (1987) | Serology, IEM |
| *Colocasia* bobone disease virus (CBDV) | *Colocasia esculenta* | Revill *et al*. (2005) | RT-PCR |
| *Cowpea mild mottle virus* (CPMMV) | *Phaseolus vulgaris* | Brunt (1987) | Unspecified[C] |
| | *Phaseolus aureus* | Brunt (1987) | Unspecified[C] |
| | *Vigna unguiculata* subsp. *sesquipedalis* | Brunt (1987) | Unspecified[C] |
| *Crinum mosaic virus* (CriMV) | *Crinum asiaticum* | Brunt (1987) | Unspecified[C] |
| *Cucumber mosaic virus* (CMV) | *Capsicum annuum* | Brunt (1987) | Unspecified[C] |
| | *Lycopersicon esculentum* | Brunt (1987) | Unspecified[C] |
| *Dasheen mosaic virus* (DsMV) | *Colocasia esculenta* | Revill *et al*. (2005) | RT-PCR |
| *Hibiscus chlorotic ringspot virus* (HCRSV) | *Abelmoschus manihot* | Brunt and Spence (2000) | Serology |
| HCRSV (listed as Hibiscus chlorotic mottle virus) | *Hibiscus rosea-sinensis* | Brunt (1987) | Unspecified[C] |
| *Hippeastrum mosaic virus* (HiMV) | *Hippeastrum hybridum* | Brunt (1987) | Unspecified[C] |
| *Maize mosaic virus* (MMV) | *Zea mays* | Brunt (1987) | Unspecified[C] |
| | *Rottboellia exaltata* | Brunt (1987) | Unspecified[C] |
| *Nerine latent virus* (NeLV) (listed as Hippeastrum latent virus) | *Hippeastrum hybridum* | Brunt (1987) | Unspecified[C] |
| Oil palm orange spotting viroid (OOSVd)[D] | *Elaeis guineensis* | Hanold and Randles (1989) | Molecular probes |
| Phytoplasma | *Ipomoea batatas* | Dabek and Gollifer (1975) | EM |
| | *Ipomoea indica* | Jackson and Zettler (1983) | EM |
| | *Ipomoea triloba* | Jackson and Zettler (1983) | EM |
| | *Merremia pacifica* | Jackson and Zettler (1983) | EM |
| | *Emilia sonchifolia* | Jackson and Zettler (1983) | EM |
| | *Vernonia cineria* | Jackson and Zettler (1983) | EM |
| | *Crotalaria* sp. | Jackson and Zettler (1983) | EM |
| | *Desmodium heterophyllum* | Jackson and Zettler (1983) | EM |
| | *Desmodium triflorum.* | Jackson and Zettler (1983) | EM |
| | *Polygala paniculata* | Jackson and Zettler (1983) | EM |
| | *Vigna sesquipedalis* | Jackson and Zettler (1983) | EM |
| *Sweet potato feathery mottle virus* (SPFMV) | *Ipomoea batatas* | Brunt (1987) | Biological indexing |
| *Taro baciliform virus* (TaBV) | *Colocasia esculenta* | Revill *et al*. (2005) | PCR |
| Taro vein chlorosis virus (TaVCV) | *Colocasia esculenta* | Revill *et al*. (2005) | RT-PCR |
| Taro reovirus (TaRV) | *Colocasia esculenta* | Revill *et al*. (2005) | RT-PCR |
| *Watermelon mosaic virus* (WMV) | *Citrullus lanatus* | Brunt (1987) | Unspecified[C] |
| | *Cucumis melo* | Brunt (1987) | Unspecified[C] |
| | *Cucurbita pepo* | Brunt (1987) | Unspecified[C] |
| | *Momordica charantica* | Brunt (1987) | Unspecified[C] |

[A]The original or earliest available citation of a reliably verified record is provided.

[B]EM, electron microscopy; IEM, immunosorbent electron microscopy; PCR, polymerase chain reaction; RT-PCR, reverse transcription polymerase chain reaction.

[C]Viruses were identified following this survey by reliable individual methods or combinations of less specific techniques that were available at that time: host inoculation tests, and/or electron microscopy and/or serology. In some cases, details of which identifications were achieved with which methods were not provided.

[D]Tentative name cited in Hanold and Randles (2003).

examined at each location. Samples of leaf or shoot material showing symptoms thought to be caused by intracellular pathogens were returned for analyses after rapid desiccation in the field. Samples, consisting of ~1 g fresh weight of young leaves or shoot tips were surface sterilised in 1% available chlorine, chopped finely and desiccated over anhydrous calcium chloride. Samples were stored at 4°C until fully desiccated, and at −20°C thereafter. Most samples were returned under quarantine material import permit to the SPC plant virology laboratory or the University of the South Pacific (USP) Institute of Applied

Sciences (IAS) molecular biology laboratory, both in Suva, Fiji. Samples for phytoplasma testing and electron microscopy examination were sent to the Central Science Laboratory (CSL) Diagnostics Laboratory, York, UK. Four days were spent on survey on or near the island of Ndende in Tumotu Province, 3 days on the island of Malaita and 6 days on the Island of Guadalcanal. In total, 11 individual sites each on Ndende and Malaita islands, 14 on Guadalcanal and one on the island of Temon Neo were surveyed.

### *Enzyme-linked immunosorbent assay (ELISA) testing for viruses*

Cucurbit samples from all surveys were tested for *Cucumber mosaic virus* (CMV), *Papaya ringspot virus* (PRSV), *Squash mosaic virus* (SqMV), *Watermelon mosaic virus* (WMV), and *Zucchini yellow mosaic virus* (ZYMV) using double antibody sandwich ELISA (DAS-ELISA). Solanaceous leaf samples were tested by DAS-ELISA for CMV, *Impatiens necrotic spot virus* (INSV), *Potato virus Y* (PVY), *Tobacco mosaic virus* (TMV), *Tomato mosaic virus* (ToMV) and *Tomato spotted wilt virus* (TSWV). One plant each of tobacco (*Nicotiana tabaccum*) and the roadside weeds *Ruellia prostrata* and *Synedrella nodiflora* were tested by DAS-ELISA only for CMV. One Chinese cabbage (*Brassica chinensis*) was tested for *Turnip mosaic virus* (TuMV), and two banana leaf samples were tested for *Banana bunchy top virus* (BBTV), also by DAS-ELISA. Several snakebean (*Vigna unguiculata* ssp. *unguiculata*) and one *Passiflora foetida* leaf sample were tested by indirect ELISA for the potyvirus group and, specifically, for the potyvirus, *Bean common mosaic virus* (BCMV). Citrus leaf samples were tested for *Citrus tristeza virus* (CTV) by compound direct ELISA. All these tests were conducted at the SPC plant virology laboratory using ELISA reagent sets and positive controls (Agdia Inc., Elkhart, IN), according to the manufacturers recommendations. In addition to the Agdia positive controls, the CTV and BBTV ELISA test plates also included several fresh positive controls from Suva, Fiji. All ELISA test samples were considered positive when absorbance values exceeded three times the mean of appropriate non-infected controls that were included on each microtitre test plate.

### *PCR testing for HLB*

Citrus leaf material was tested for HLB at the USP IAS molecular biology laboratory, using the PCR techniques described in Davis *et al*. (2005*a*). Positive controls were similar desiccated citrus leaf samples from an HLB quarantine zone in PNG that were processed (DNA extraction and PCR) together with the Solomon Island samples. The PCR integrity of DNA extracts that tested negative for HLB was verified by amplifying 16SrDNA of other bacteria present in the preparations using the PCR primers rP1/fD1 (Weisburg *et al*. 1991).

### *Phytoplasma testing*

Samples from one *B. chinensis* and the ornamental plant *Celosia argentea*, showing phytoplasma -like symptoms were subjected to nucleic acid extraction, followed by nested PCR and DNA sequence analysis at CSL Diagnostics Laboratory, UK, as described in Davis *et al*. (2006*a*).

### *Electron microscopy testing for viruses*

At CSL, UK, two sugarcane (*Saccharum officinarum*) samples showing Fiji leaf gall disease-like symptoms were examined using transmission electron microscopy only.

## Results

The viruses and phytoplasmas detected in samples collected on the survey are listed in Table 2. Cucurbit virus testing by DAS-ELISA gave records only from Guadalcanal and Ndende Island. ZYMV was detected in *Citrullus lanatus* (watermelon) at two locations on Gaudalcanal, in *Cucurbita maxima* (pumpkin) at five locations on Guadalcanal and two on Ndende Island, in *Cucumis melo* (rockmelon) at two locations on Guadalcanal, and in *Cucumis sativas* (cucumber) at one location on Guadalcanal. PRSV-W was detected in *C. lanatus* at one location on Gaudalcanal, in *C. maxima* at three locations on Gaudalcanal, in *C. melo* at two locations on Guadalcanal, in *Cucumis sativas* (cucumber) at one location on Guadalcanal, in *Momordica charantia* (bitter gourd) at one location on Guadalcanal, and in the cucurbit weed, *Coccinia grandis* at one location on Guadalcanal. CMV was detected in *C. lanatus* at one location on Gaudalcanal, in *C. maxima* at one location on Ndende, in *C. melo* at one location on Guadalcanal, in *Trichosanthes anguina* (snake gourd) at one location on Ndende. CMV was also detected in one *Ruellia prostrata* on Guadalcanal, one *Synedrella nodiflora* on Ndende, one *Nicotiana tabaccum* (tobacco) on Malaita, one *C. annuum* var. *annuum* (chilli) on Ndende as well as in *C. annuum* var. *annuum* and *S. lycopersicum* (tomato) on Guadalcanal at three and two locations, respectively. Other viruses detected in leaf samples of solanaceous species were ToMV in *C. annuum* var. *annuum* at one location on Ndende and in *S. lycopersicum* at one location on Guadalcanal, and TMV in *S. lycopersicum* on Guadalcanal. *V. unguiculata* ssp. *unguiculata* (snakebean) leaf samples from five locations on Guadalcanal plus one *Passfilora foetida* leaf sample from Guadalcanal tested positive to BCMV and also the potyvirus group, by ELISA. TuMV was detected by ELISA in one *B. chinensis* (Chinese cabbage) plant on Guadalcanal.

Phytoplasmas belonging to the '*Candidatus* Phytoplasma aurantifolia' (16SrII) group were found on Guadalcanal. They were associated with little leaf and witches' broom disease symptoms in *Celosia argentea* at one location and with phyllody in *B. chinensis* at another. A sample from *Saccharum edule* (a food plant closely related to sugarcane) showing grassy shoot-like symptoms on Guadalcanal also tested positive by nested PCR for phytoplasma. However, the PCR amplification was weak, resulting in insufficient DNA to perform sequence analysis to determine strain group.

Spherical particles of 57–65 nm and 72–76 nm diameter were seen using transmission electron microscopy in samples of gall tissue excised from sugarcane leaves showing Fiji leaf gall disease-like symptoms at two locations on Guadalcanal.

Important negative results are presented in Table 3. HLB indexing returned negative PCR test results from three citrus trees on Guadalcanal and four on Ndende. No trees on Malaita could be

**Table 2. Plant virus and phytoplasma records from a survey of the Solomon Islands, April 2007**

Cucurbit leaf samples were screened by ELISA for the five most common cucurbit infecting viruses (PRSV, ZYMV, WMV, CMV and *Squash mosaic virus* (SqMV)). Leaf samples screened for BCMV (genus *Potyvirus*) were also screened for the potyvirus group by ELISA and were positive for both antisera. Solanaceous leaf samples were screened by ELISA for CMV, *Impatiens necrotic spot virus* (INSV), *Potato virus Y* (PVY), *Tomato spotted wilt virus* (TSWV), TMV and ToMV. ELISA test results were considered positive when absorbance readings (405 nm) exceeded 3 × mean of healthy controls. Marginally positive test results (+m) were those that exceeded twice the mean of the healthy controls, but were less than 3 × the mean. Phytoplasmas were detected by nested PCR, then identified by sequence analysis

| Host plant | Field collection number | Approximate location | Symptoms[A] | Pathogen[B] |
|---|---|---|---|---|
| Acanthaceae | | | | |
| *Ruellia prostrata* | 4647 | Tanaghai, Guadalcanal | YOGM | CMV |
| Amaranthaceae | | | | |
| *Celosia argentea* | 4645 | Tanaghai, Guadalcanal | Little leaf and witches' broom | Phytoplasma in '*Ca*. P. aurantifolia' (16SrII) group |
| | 4646 | Tanaghai, Guadalcanal | Little leaf and witches' broom | Phytoplasma in '*Ca*. P. aurantifolia' (16SrII) group |
| Asteraceae | | | | |
| *Synedrella nodiflora* | 4594 | Airstrip, Ndende Is., Tumotu | Mild YOGM | CMV |
| Brassicaceae | | | | |
| *Brassica chinensis* | 4640 | Tanaghai, Guadalcanal | GOYVB | TuMV |
| (Chinese cabbage) | 4694 | Divit, West Guadalcanal | Phyllody | Phytoplasma in '*Ca*. P. aurantifolia' (16SrII) group |
| Cucurbitaceae | | | | |
| *Citrulus lanatus* | 4704 | Ati Ati, East Guadalcanal | YOGM | ZYMV |
| (watermelon) | 4707 | Ruavatu, East Guadalcanal | Mild YOGM | ZYMV, PRSV-W |
| | 4708 | Ruavatu, East Guadalcanal | Mild YOGM | ZYMV, PRSV-W, CMV |
| *Coccinia grandis* | 4684 | ROC farm, Guadalcanal | None | PRSV-W |
| | 4685 | ROC farm, Guadalcanal | None | PRSV-W |
| *Cucurbita maxima* (pumpkin) | 4590 | Airstrip, Ndende, Tumotu | Mild YOGM | ZYMV, CMV |
| | 4591 | Airstrip, Ndende, Tumotu | Mild YOGM | ZYMV, CMV +m |
| | 4592 | Airstrip, Ndende, Tumotu | Mild YOGM | ZYMV, CMV |
| | 4614 | Kala Bay, Ndende, Tumotu | Mild YOGM | ZYMV |
| | 4615 | Kala Bay, Ndende, Tumotu | Mild YOGM | ZYMV |
| | 4623 | Tetere, Guadlcanal | Strong YOGM | ZYMV |
| | 4624 | Tetere, Guadlcanal | Strong YOGM | ZYMV, PRSV-W, CMV +m |
| | 4625 | Tetere, Guadlcanal | Strong YOGM | ZYMV, PRSV-W +m |
| | 4638 | Tetere Prison, Guadlcanal | YOGM | ZYMV |
| | 4689 | Divit, West Guadalcanal | Slight YOGM | ZYMV |
| | 4693 | Divit, West Guadalcanal | YOGM | ZYMV |
| | 4706 | Ati Ati, East Guadalcanal | YOGM | ZYMV, PRSV-W |
| | 4723 | Papangu, East Guadalcanal | YOGM | ZYMV, PRSV-W |
| *Cucumis melo* (rockmelon) | 4675 | ROC farm, Guadalcanal | YOGM | ZYMV, PRSV-W |
| | 4676 | ROC farm, Guadalcanal | YOGM | ZYMV +m, PRSV-W |
| | 4677 | ROC farm, Guadalcanal | YOGM | ZYMV, PRSV-W |
| | 4621 | Tetere, Guadalcanal | YOGM | ZYMV, PRSV-W, CMV |
| | 4622 | Tetere, Guadalcanal | YOGM | ZYMV, CMV |
| *Cucumis sativas* (cucumber) | 4626 | Tetere, Guadalcanal | Strong YOGM | ZYMV |
| | 4627 | Tetere, Guadalcanal | Strong YOGM | ZYMV, PRSV-W |
| *Momordica charantica* (bitter gourd) | 4678 | ROC farm, Guadalcanal | YOGM | PRSV-W |
| | 4679 | ROC farm, Guadalcanal | YOGM | PRSV-W |
| *Trichosanthes anguina* (snakegourd) | 4589 | Neele, Ndende Is., Tumotu | YOGM | CMV |
| Fabaceae | | | | |
| *Vigna unguiculata* ssp. | 4628 | Tetere, Guadalcanal | YOGM | BCMV |
| *sesquipedalis* (snake bean) | 4629 | Tetere, Guadalcanal | Very strong YOGM | BCMV |
| | 4642 | Tanaghai, Guadalcanal | Golden YOGM | BCMV |
| | 4643 | Tanaghai, Guadalcanal | YOGM | BCMV |
| | 4671 | ROC farm, Guadalcanal | Very strong YOGM | BCMV |

**Table 2.** (*continued*)

| Host plant | Field collection number | Approximate location | Symptoms[A] | Pathogen[B] |
|---|---|---|---|---|
| | 4672 | ROC farm, Guadalcanal | Very strong YOGM | BCMV |
| | 4673 | ROC farm, Guadalcanal | Very strong YOGM | BCMV |
| | 4674 | ROC farm, Guadalcanal | Very strong YOGM | BCMV |
| | 4710 | Dova, East Guadalcanal | YOGM | BCMV |
| | 4711 | Dova, East Guadalcanal | YOGM | BCMV |
| | 4725 | Papangu, East Guadalcanal | YOGM | BCMV |
| Passifloraceae | | | | |
| *Passiflora foetida* | 4702 | Ruavatu, East Guadalcanal | YOGM | BCMV |
| Poaceae | | | | |
| *Saccharum edule* | 4701 | West, Guadalcanal | Grassy shoot | Phytoplasma[C] |
| Solanaceae | | | | |
| *Capsicum annuum* var. | 4603 | Netiboi, Ndende Is., Tumotu | General chlorosis | ToMV |
| *annuum* (chilli) | 4604 | Netiboi, Ndende Is., Tumotu | General chlorosis | CMV |
| | 4681 | ROC farm, Guadalcanal | YOGM | CMV |
| | 4683 | ROC farm, Guadalcanal | Very strong YOGM | CMV |
| | 4688 | ROC farm, Guadalcanal | YOGM, crinkle and curl | CMV |
| | 4721 | Papangu, East Guadalcanal | Very strong YOGM and crinkle | CMV |
| | 4722 | Papangu, East Guadalcanal | Very strong YOGM and crinkle | CMV |
| | 4657 | Dala, North Malaita | General chlorosis | ToMV +m |
| *Solanum lycopersicum* (tomato) | 4636 | Tetere, Guadalcanal | Mild YOGM | CMV |
| | 4637 | Tetere, Guadalcanal | Mild YOGM | CMV |
| | 4712 | Huhula, East Guadalcanal | Mild YOGM | CMV, TMV, ToMV |
| | 4713 | Huhula, East Guadalcanal | Mild YOGM | TMV, ToMV |
| | 4715 | Huhula, East Guadalcanal | Strong YOGM | CMV, TMV, ToMV |
| | 4716 | Huhula, East Guadalcanal | Strong YOGM | TMV, ToMV |
| *Nicotiana tabaccum* (tobacco) | 4670 | West Coast, Malaita | Faint YOGM | CMV |

[A]GOYVB: green on yellow vein banding, YOGM: yellow on green mosaic.
[B]Viruses detected were: BCMV, Bean common mosaic virus; CMV, *Cucumber mosaic virus*; CTV, Citrus tristeza virus; PRSV-W, cucurbit infecting strain of *Papaya ringspot virus*; TMV, *Tobacco mosaic virus*; ToMV, *Tomato mosaic virus*; TuMV, *Turnip mosaic virus*; WMV, *Watermelon mosaic virus*; ZYMV, *Zuchinni yellow mosaic virus*.
[C]This phytoplasma could not be identified to strain group because sequence analysis was not possible.

found showing any symptoms even slightly similar to those of HLB. Two *Musa* sp. leaf samples from Malaita were showing an unusual upright growth habit and leaf samples from both tested negative by ELISA for BBTV. Eight *C. annuum* var. *annuum* and six *S. lycopersicum* plant leaf samples tested negative for the tospoviruses TSWV and INSV.

## Discussion

These surveys provide the first records of ZYMV, TuMV, ToMV and TMV in the Solomon Islands. This is also the first time that phytoplasmas associated with plant disease symptoms in the Solomon Islands have been identified to strain group. Additionally, the survey adds the new national host records of BCMV in snakebean and the common roadside weed closely related to passionfruit, *P. foetida*; CMV in tobacco, and the roadside weeds *R. prostrata* and *S. nodiflora*. The survey also lists more records of CMV in chilli and tomato. Although the presence of PRSV-W (the cucurbit infecting strain of PRSV) was not previously recorded, the virus is probably not new to the country. It is likely that the records of WMV listed by Brunt (1987) were in fact detections of PRSV-W, which was known as WMV-1 at that time (A. Brunt, pers. comm.). Of the cucurbit infecting viruses, ZYMV was found to be the most prevalent on the survey reported here and this has been the case on surveys of several other Pacific islands (Davis *et al*. 2006*d*, 2007*a*, 2007*b*). Low rates of seed transmission of ZYMV in cucurbits in Australia (Horlock and Persley 2004) and New Zealand (Burgmans and Fletcher 2000; Fletcher *et al*. 2000) have been reported and it has been suggested that long distance spread of ZYMV throughout the world may have been via infected seeds (Desbiez and Lecoq 1997). Relatively recent multiple introductions via seed may well provide an explanation for why the survey of Brunt (1987) did not find ZYMV in the Solomon Islands but, 20 years later, the virus has become widespread.

The record of CMV in *S. nodiflora* adds to recent records of CMV in this host from Vanuatu (Davis *et al*. 2006*b*) and Nauru (Davis *et al*. 2007*b*). These records are a notable species addition to the previous known CMV host listings of Douine *et al*. (1979) and Anon. (2002). This survey also adds *R. prostrata* to these CMV host lists, though the related *Ruellia tuberosa* is listed by Douine *et al*. (1979).

Snakebean leaf samples from several mosaic disease-affected crops examined on this survey all reacted to BCMV (and potyvirus group) antisera. This suggests that the same virus may be responsible for the disease in all locations. However, according

**Table 3. Notable samples from the Solomon Islands in which no pathogen was detected in specific tests**

| Host plant | Field collection number | Approximate Location | Symptoms[A] | Virus tested |
|---|---|---|---|---|
| Musaceae | | | | |
| *Musa* sp. (banana) | 4655 | Dala, North Malaita | Upright habit | BBTV |
| | 4656 | Dala, North Malaita | Upright habit | BBTV |
| Rutaceae | | | | |
| *Citrus japonica* (kumquat) | 4588 | Neele, Ndende Is., Tumotu | Chlorosis and GOYVB | HLB, CTV |
| *Citrus* × *aurantifolia* (lime) | 4611 | Minevi, Temon Neo, Tumotu | Chlorosis | HLB, CTV |
| *Citrus* × *limon* (lemon) | 4582 | Waters, Ndende Is., Tumotu | GOYVB | HLB, CTV |
| | 4585 | Pala, Ndende Is., Tumotu | Chlorosis and GOYVB | HLB, CTV |
| | 4698 | Divit, West Guadalcanal | Chlorosis | HLB, CTV |
| *Citrus maxima* (pomello) | 4699 | Manakiki, West Guadalcanal | Chlorotic blotch and corky veins | HLB, CTV |
| | 4719 | Nr Huhala, East Guadalcanal | Chlorotic blotch and corky veins | HLB, CTV |
| Solanaceae | | | | |
| *Capsicum annuum* var. *annuum* (chilli) | 4603 | Netiboi, Ndende Is., Tumotu | General chlorosis | TSWV, INSV |
| | 4604 | Netiboi, Ndende Is., Tumotu | General chlorosis | TSWV, INSV |
| | 4681 | RoC Farm, Honiara, Guadalcanal | YOGM | TSWV, INSV |
| | 4683 | RoC Farm, Honiara, Guadalcanal | Very strong YOGM | TSWV, INSV |
| | 4688 | RoC Farm, Honiara, Guadalcanal | YOGM, crinkle and curl | TSWV, INSV |
| | 4721 | Papangu, East Guadalcanal | Very strong YOGM and crinkle | TSWV, INSV |
| | 4722 | Papangu, East Guadalcanal | Very strong YOGM and crinkle | TSWV, INSV |
| | 4657 | Dala, North Malaita | General chlorosis | TSWV, INSV |
| *Solanum lycopersicum* (tomato) | 4636 | Tetere, Guadalcanal | Mild YOGM | TSWV, INSV |
| | 4637 | Tetere, Guadalcanal | Mild YOGM | TSWV, INSV |
| | 4712 | Huhula, East Guadalcanal | Mild YOGM | TSWV, INSV |
| | 4713 | Huhula, East Guadalcanal | Mild YOGM | TSWV, INSV |
| | 4715 | Huhula, East Guadalcanal | Strong YOGM | TSWV, INSV |
| | 4716 | Huhula, East Guadalcanal | Strong YOGM | TSWV, INSV |

[A]GOYVB, green on yellow vein banding; YOGM, yellow on green mosaic.

[B]HLB, tested negative by PCR for presence of '*Candidatus* Liberibacter asiaticus'; BBTV, tested negative by ELISA for *Banana bunchy top virus*; CTV, tested negative by ELISA for *Citrus tristeza virus*; TSWV, tested negative by ELISA for *Tomato spotted wilt virus*; INSV, tested negative by ELISA for *Impatiens necrotic ringspot virus.*

to the manufacturers of the BCMV antisera, positive reactions to other potyviruses are possible, indicating that a range of slightly different viral pathogens, may be responsible (Anon. 2008). Mosaic diseases of legumes apparently caused by BCMV have been recorded in the Solomon Islands before (Brunt 1987). BCMV is transmitted at high rates in legume seeds and is spread from plant to plant non-persistently by several aphid species (Brunt *et al*. 1996). A similar snakebean mosaic disease situation prevailed on Guam in the 1990s (Wall and Kimmons 1996), when BCMV was known as Blackeye cowpea mosaic potyvirus (BlCMV). Currently on Guam, however, a successful cultural control program is coordinated by extension staff of the University of Guam (G. Wall, University of Guam, pers. comm.). The principles of this are removal of sources of inoculum within plots and use of non-infected seed. These principles could be applicable in the Solomon Islands. One *P. foetida* sample also tested positive to potyvirus group and BCMV antisera. Similar results were obtained from *P. foetida* leaf samples taken from Nauru (Davis *et al*. 2007*b*). Important diseases in commercial passionfruit in Australia are caused by the potyviruses *Passionfruit woodiness virus* (PWV) (Persley 1993) and the tentatively named Passiflora virus Y (PaVY) (Parry *et al*. 2004). The symptoms shown by the potyvirus-positive *P. foetida* leaves on Guadalcanal are identical to those of PaVY in *P. foetida* found in northern Australia (R. Davis, unpubl. data). Further work is needed to determine the exact identity of the potyviruses found on this survey in legumes and *P. foetida*.

The phytoplasmas implicated in the plant diseases on this survey which could be identified are members of the '*Ca.* Phytoplasma aurantifolia' (16SrII) group. Members of this same group are the most frequently found phytoplasmas in Australia (Gibb *et al*. 1995; Davis *et al*. 1997; Schneider *et al*. 1999; Davis *et al*. 2003), on the island of New Guinea (Davis *et al*. 2003) and on several other Pacific islands (Davis *et al*. 2006*a*, 2007*a*). In contrast to earlier years, the body of knowledge on the phytoplasma disease status of the Pacific islands is now developing into a valuable resource for quarantine use. It is important to note that these phytoplasmas, like those found on other Pacific islands, are quite different from those implicated elsewhere in the world in severe diseases of plant commodities that are also valued in the Pacific. Possibly the most damaging of these would be the phytoplasmas associated with lethal diseases of coconuts belonging to the *Coconut lethal yellowing* (16SrIV) group. This group includes phytoplasmas in Central America and the Caribbean tentatively named '*Candidatus* Phytoplasma palmae' and phytoplasmas on the African continent, tentatively named '*Candidatus* Phytoplasma cocostanzaniae' and '*Candidatus* Phytoplasma

cocosnigeriae' (IRPCM Phytoplasma/Spiroplasma Working Team – Phytoplasma Taxonomy Group 2004). Closer to the Solomon Islands, in Indonesia, Kalimantan wilt is a disease of suspected phytoplasma aetiology on the island of Kalimantan (Harrison and Jones 2003). After coconut 'infecting'-phytoplasmas, perhaps the next most significant regional phytoplasma quarantine threat may be those associated with serious diseases of sugarcane, such as sugarcane white leaf disease, known in south-east Asia (Rishi and Chen 1989) but not in the Pacific islands. The phytoplasma associated with grassy shoot-like symptoms in *S. edule* on Guadalcanal could not be identified. In parts of Asia, sugarcane grassy shoot is a disease problem associated with a phytoplasma (Marcone *et al*. 2001) that is not assigned to a strain group in the IRPCM Phytoplasma/Spiroplasma Working Team – Phytoplasma Taxonomy Group (2004) listing. It is, however, related to the phytoplasma associated with sugarcane white leaf disease (Sdoodee *et al*. 1999; Marcone *et al*. 2001).

Stands of sugarcane apparently affected by Fiji leaf gall disease were found at two locations on Guadalcanal. Symptoms of this disease are stunting, presence of leaf galls and a general 'chewed off' appearance. These are extremely distinctive and it is unlikely that a pathogen other than the causal agent of Fiji leaf gall disease, *Fiji disease virus* (FDV), could be the cause. Although it was impossible to confirm these visual observations with virus-specific laboratory testing following the survey, some of the spherical virus-like particles seen by electron microscopy were around 70 nm in diameter, which is correct for FDV. In commercial sugarcane production, timely removal of infected plants (rogueing) can be an effective Fiji leaf gall disease control strategy (Egan *et al*. 1989). Similarly, this disease can be readily controlled in village gardens by removing affected plants and carefully selecting symptomless planting material for propagation.

This survey provides more negative qualitative (widespread visual observations of disease absence) and quantitative (laboratory test results, Table 3) data, indicating that HLB is not present in the Pacific islands east of New Guinea. The negative citrus HLB screening results reported here adds to similar results published for 12 other countries/territories served by SPC (Davis *et al*. 2005*a*, 2005*b*, 2006*b*, 2006*c*, 2006*d*, 2007*a*, 2007*b*), to bring the total number of Pacific island citrus trees indexed HLB negative by PCR to 80.

It was surprising that every citrus leaf sample tested for HLB also tested negative for CTV by ELISA (Table 3), because citrus tristeza disease is widespread around the world (Brunt *et al*. 1996). A wider CTV-focussed survey is needed to determine if these islands really are free of tristeza disease.

Banana bunchy top disease is a very high priority quarantine target in the Pacific because, although BBTV's distribution is widespread, many islands still remain free of the virus. By early 2008, laboratory test records confirming presence of BBTV in Fiji, Tonga, Samoa (Karan *et al*. 1994), New Caledonia (Kagy *et al*. 2001), Wallis island in the French Territory of Wallis and Futuna (Davis *et al*. 2006*c*), Guam and the Commonwealth of the Northern Mariana Islands (Davis *et al*. 2007*b*) had been published. In addition, there are also reliable reports dating back many years of distinctive bunchy top disease symptoms in Tuvalu and American Samoa. Whether a diagnostic test to confirm these records has been performed is not known. Many banana plants were examined during this survey and no bunchy-top-like symptoms were seen. The nearest observations were two banana plants, found on Malaita, showing an unusual slightly upright growth habit. Both were sampled and indexed negative for BBTV by ELISA.

Diseases caused by tospoviruses are an important emerging problem in nearby Australia (Persley *et al*. 2006). Fourteen solanaceous plants were sampled because they were showing various symptoms, including some that resemble those of tospovirus infection. Negative results were obtained from all 14 leaf samples tested for two important tospoviruses, INSV and TSWV. It is not known, however, if other tospoviruses were present.

In summary, the findings reported here provide a useful assessment of some of the virus and phytoplasma diseases present on the islands surveyed and also suggest the absence of certain key quarantine threats from the island group. It is important to note, however, that it did not include a comprehensive screen of all samples collected for all possible virus and virus-like diseases. This could be achieved only with long-term access to a suite of diagnostic resources, including extensive use of electron microscopy and herbaceous indicator hosts. One valuable conclusion within the survey was the comparatively disease-free status of Malaita compared with the other islands visited. Only two virus records, one of ToMV and one of CMV, came from this island. Overall, these results, like those made on other Pacific islands in recent years, reinforce the critical importance of maintaining effective plant quarantine on all islands of the Pacific.

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