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Surveys for **PLANT DISEASES** caused by Viruses & Virus-like pathogens in **TONGA & NEW CALEDONIA**

By

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ABSTRACT

Surveys for plant infecting virus and virus-like diseases were conducted in Tonga, on the islands of Tongatapu, 'Eua, and parts of the Vava'u and Ha'apai groups, and in New Caledonia on the islands of Grande Terre and Lifou. Cucurbit infecting viruses were detected by enzyme linked immunosorbent assay (ELISA) in both countries. In New Caledonia, these were *Zucchini yellow mosaic virus* (ZYMV) in rockmelon (*Cucumis melo*), pumpkin (*Cucurbita maxima*), squash (*C. maxima* x *Cucurbita moschata*) and zucchini (*Cucurbita pepo* var. *melopepo*); *Papaya ringspot virus* in pumpkin, squash and zucchini; and *Watermelon mosaic virus* (WMV) in rockmelon and zucchini. In Tonga, only ZYMV was detected in squash plants at several locations. Other viruses detected by ELISA in Tonga were *Cucumber mosaic virus* in a *Commelina diffusa* sample and *Tomato mosaic virus* (ToMV) in tomato (*Lycopersicon esculentum*). New records were those of ZYMV and WMV in New Caledonia and of ToMV in Tonga.

In Tonga, *Taro bacilliform virus* was detected by polymerase chain reaction (PCR) and *Dasheen mosaic virus* was detected by reverse transcription (RT)–PCR in the aroid crop plants, kape (*Alocasia macrorrhiza*) and taro futuna (*Xanthosoma* sp). In New Caledonia, these viruses plus *Taro vein chlorosis virus* were detected in taro (*Colocasia esculenta*). In Tonga, *Banana streak virus* and *Banana bunchy top virus* were detected in banana (*Musa* sp.) leaf samples by real-time PCR.

Phytoplasmas were detected by nested PCR in *Cyanthilium cinereum* (syn. *Vernonia cinerea*), sweet potato (*Ipomoea batatas*), Indian mulberry or nonu (*Morinda citrifolia*) in Tonga and in tomato, strawberry (*Fragaria* sp.), sweet potato, onion (*Alium cepa*), garlic (*Alium sativum*) and pineapple (*Ananas comosus*) in New Caledonia. Most phytoplasmas belonged either to the Stolbur group (16SrXII) or the '*Candidatus* Phytoplasma aurantifolia' (16SrII) group and one belonged to the Mexican periwinkle virescence group (16SrXIII).

In Tonga, no evidence was found for presence of citrus huanglongbing, previously known as greening disease, in five citrus trees indexed by PCR or for *Tomato leaf curl virus* in eight tomato plants tested using DNA probes.

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INTRODUCTION

Surveys were conducted to assess the general plant virus and virus-like disease status of Tonga and New Caledonia. The last time that such surveys were conducted in Tonga was in the late 1970s (Van Velsen, United Nations Development Program/Food and Agriculture Organization (UNDP/FAO) unpublished report, 1979). These results have been summarised in Mossop and Fry (1984). The viruses present in the samples collected on those surveys were identified by indexing and mechanical inoculation, or by electron microscopy. The records included in the listing of Mossop and Fry (1984) have again been listed, together with records generated after 1984, in the listing of Pearson and Grisoni (2002). The last time that a plant disease survey focusing on diseases caused by plant viruses and similar pathogens was conducted in New Caledonia was in the mid 1980s (Thouvenal 1986, ORSTOM unpublished report). The viruses present in the plant samples collected on that survey were identified by indicator host inoculation studies, serological tests, and electron microscopy. In later years, only a very small number of other plant viruses have been identified in material from New Caledonia. These are included in the listing of Pearson and Grisoni (2002). The known records of diseases caused by virus and virus-like pathogens for which there exists acceptable supportive evidence of the pathogen's identity are summarised in Table 1 (Tonga) and Table 2 (New Caledonia). Records for which only inconclusive supportive evidence of pathogen identity is available are listed in Table 3 (Tonga) and Table 4 (New Caledonia). These include several identifications based on particle morphology as observed by electron microscopy only. This does not provide a specific identification for most viruses and is best used to provide information that complements or helps clarify results of other testing.

Very little is known of the phytoplasma disease status of Tonga and New Caledonia. Phytoplasmas (formerly known as mycoplasmalike organisms) are unculturable bacteria closely related to the genus *Acheloplasma* (Seemüller et al. 1998). They infect plant phloem vessels, are transmitted by phloem feeding insects (mostly leafhoppers) and have been associated with diseases of numerous plant species throughout the world (Seemüller at al. 1998). Presence of phytoplasmas in tomato plants in Tonga showing symptoms of tomato big bud disease has been confirmed by electron microscopy (Van Velsen, UNDP/FAO unpublished report, 1979). Sweet potato little leaf and tomato big bud are distinctive disease symptoms associated with phytoplasmas in some parts of the world (Seemüller et al. 1998). Sweet potato little leaf symptoms have been observed in Tonga (Jackson 1984) and the possible role of phytoplasmas was earlier confirmed when sweet potato plants originating from Tonga were tested by electron microscopy in the USA (Kahn et al. 1972). In New Caledonia, sweet potato little leaf disease symptoms were reported by Jackson (1984) and Thouvenal (1986). Thouvenal (1986) also reported tomato big bud symptoms. However, no attempt was made to confirm presence of phytoplasmas in diseased plant material from New Caledonia. Phytoplasma test results from leaf samples from Tonga and New Caledonia have recently been published in Davis et al. (2006). This information is repeated, together with further details about these samples in this SPC technical paper.

There is some question about the distribution of the citrus disease, huanglongbing (HLB), previously known as greening disease in the Pacific region. HLB is caused, in much of Asia, by another unculturable phloem-limited bacterium, '*Candidatus* Liberibacter asiaticus'. HLB is one of the worst diseases of citrus and has been present for decades in several countries close to the Pacific Islands, including the Philippines and Indonesia. After having been a major quarantine threat to the Pacific region for many years, HLB and its vector, the Asian citrus psyllid (*Diaphorina citri*) were discovered in Papua New Guinea (PNG) in 2002 (Weinert et al. 2004). Both disease and vector are now subjects of a containment campaign in PNG. A report that the disease was found in Tonga in the mid 1990s (Kiritani and Su 1999) is doubted by many HLB researchers, because the detection method used in that study was not reliable. Negative HLB indexing results from citrus leaf samples from Tonga have been summarised in Davis et al. (2005b). Further details on these samples are provided in this SPC technical paper.

Whitefly transmitted geminiviruses have lately become pathogens of escalating importance in tomato crops in many tropical regions of the world (Polston and Anderson 1997). Increased prevalence has been linked to spread of biotype B of *Bemisia tabaci* (silverleaf whitefly). *Tomato leaf curl virus* (TLCV), a monopartite begomovirus in the Geminiviridae, causes one of the worst diseases of tomato. Whilst a strain of TLCV is present in the north of Australia (Stonor et al. 2003), TLCV or similar viruses have never been found in any Pacific Island country or territory served by SPC. Since the silverleaf whitefly became established in Tonga, the possibility of introduction of TLCV or similar viruses has become a cause of concern to the country.

The surveys focused on parts of the country/territory most frequently visited by travellers from other countries, and therefore considered most at risk of new quarantine incursions, plus other islands as requested. The survey in Tonga focused on the islands of Tongatapu, 'Eua, and the Vava'u and Ha'apai groups of islands. In addition, the island of Nomuka in the Ha'apai group was visited because it is believed that banana bunchy top (a disease caused by *Banana bunchy top virus* which is widespread in Tonga) is absent from this island. In New Caledonia, the islands of Grande Terre and Lifou were surveyed. On Lifou, the focus was on vanilla, as the provincial government planned to expand vanilla production on this island.

METHODS

Survey

The survey of Tonga was undertaken over two weeks in September 2002, and the one of New Caledonia over two weeks in October 2002. In both surveys, as many different areas as possible were visited and crop plants of economic importance and other plants were examined at each survey location. Samples thought to be infected by intracellular pathogens were returned for analyses after rapid desiccation in the field. Samples (about 1 g fresh weight of young leaves or shoot tips) showing disease symptoms were first surface sterilised in 1% available chlorine to eliminate organisms that may be present on external surfaces. The material was then rinsed in water, blotted dry and chopped finely. The sample was desiccated over anhydrous calcium chloride (about 7 g) in sealed plastic vials (25 mL in volume), stored at 4°C until fully desiccated, then stored at –20°C. Samples were returned, under suitable quarantine import permit, to several different laboratories for diagnostic tests.

Enzyme Linked Immunosorbent Assay (ELISA) testing for viruses

Cucurbit samples (plus samples from some non cucurbit weeds growing in/near squash crops) were tested for *Cucumber mosaic virus* (CMV), *Zucchini yellow mosaic virus* (ZYMV), *Watermelon mosaic virus* (WMV), *Papaya ringspot virus* (PRSV) and *Squash mosaic virus* (SqMV) using Agdia Inc. (Elkhart, IN, USA) double antibody sandwich ELISA (DAS–ELISA) reagent sets at the SPC plant virology laboratory, Suva, Fiji. Some tomato samples from Tonga were tested by DAS–ELISA at Rothamsted Research for *Tomato mosaic virus* (ToMV) using a Bioreba kit, for *Tobacco mild green mosaic virus* (TMGMV) and *Cucumber green mottle mosaic virus* (CGMMV) using test kits from the DSMZ Plant Virus Collection and for *Tobacco mosaic virus* (TMV) by indirect ELISA using an antiserum made at Rothamsted. All ELISA test samples were considered positive when absorbance values exceeded three times the mean of appropriate healthy controls that were included on each microtitre test plate.

Polymerase chain reaction (PCR) and reverse transcription PCR (RT–PCR) testing for viruses.

Aroid leaf material (*Colocasia esculenta* from New Caledonia and *Alocasia macrorhiza* and *Xanthosoma* sp. from Tonga) was sent to the laboratory of R. Harding at the Queensland University of Technology, Brisbane, Australia for testing for *Taro bacilliform virus* (TaBV) by PCR and for *Taro vein chlorosis virus* (TaVCV), *Dasheen mosaic virus* (DsMV),*Taro reovirus* (TaRV) and (for *C. esculenta* samples only) *Colocasia* bobone disease virus (CBDV) by RT–PCR using the methods described in Revill et al. (2005).

Real-time PCR testing for viruses

Banana leaf samples from Tonga were subjected to real-time PCR tests for presence of *Banana streak virus* (BSV), *Banana bract mosaic virus* (BBMV), *Banana mild mosaic virus* (BMMV), CMV and *Banana bunchy top virus* (BBTV) at the Central Science Laboratory, York, UK.

PCR testing for HLB

Citrus leaf material was returned from Tonga to the laboratory of M. Garnier, Institut Nationale de la Recherche Agronomique (INRA), Bordeaux, France and the University of the South Pacific Institute of Applied Sciences (USP IAS) molecular biology laboratory, for testing for HLB using PCR as described in Davis et al. (2005b).

Phytoplasma testing

Samples from plants showing phytoplasma-like symptoms from both Tonga and New Caledonia were subjected to nucleic acid extraction, followed by nested PCR at Rothamsted Research as described in Davis et al. (2006).

Other molecular testing

Certain tomato leaf samples from Tonga were sent to the molecular virology laboratory of A. Rezaian, CSIRO Plant Industry, Adelaide, Australia. Here they were tested for TLCV using DNA probes capable of detecting a wide range of variants of this virus.

Electron microscopy for viruses

Some leaf samples from New Caledonia were examined by transmission electron microscopy only, at Rothamsted Research, UK.

RESULTS

The plant virus and phytoplasma records are presented in Table 5 (Tonga) and Table 6 (New Caledonia).

Viruses in New Caledonia

Of the five viruses screened for in cucurbit crops, ZYMV, PRSV and to a lesser extent WMV (but not CMV or SqMV) were all found at several locations on Grande Terre in New Caledonia. ZYMV was detected in *Cucumis melo* (rockmelon), *Cucurbita maxima* (pumpkin), *C. maxima* x *Cucurbita moschata* (squash) and *Cucurbita pepo* var. *melopepo* (zucchini). PRSV was detected in *C. maxima*, *C. maxima* x *C. moschata* and *C. pepo* var. *melopepo*. WMV was found only in *C. melo* and *C. pepo* var. *melopepo.* Mixed infections of two of these viruses were recorded in six samples. Taro (*C. esculenta*) samples were collected from only Poindimie in north-east Grand Terre and these were infected with DsMV, TaBV and TVCV (one record only). Mixed infections of TaBV and the other viruses were found.

Viruses in Tonga

ZYMV was detected in a number of *C. maxima* x *moschata* leaf samples from Tongatapu. Marginal positive results for this virus were also obtained from watermelon samples from Vava'u and Ha'apai and from legume weeds on Tongatapu (*Desmodium* sp.), 'Eua and Ha'apai (both were *Macroptilium atropurpureum*). CMV was detected in a *Commelina diffusa* sample from 'Eua. ToMV was detected in tomato leaf samples from Tongatapu and Ha'apai. DsMV and TaBV were both detected as mixed infections of *Alocasia macrorhiza* and *Xanthosoma* sp. on 'Eua, whilst DsMV alone was found infecting *Xanthosoma* sp. on Ha'apai. Amongst the banana leaf samples from Tonga subjected to real-time PCR testing, a strong positive result (in which a mean *Ct* value of two replicate wells <30 in a 40 cycle reaction was obtained) was recorded for BSV and BBTV, but not the other banana infecting viruses, in banana leaf samples from both Ha'apai and Vava'u and for BBTV only in a leaf sample from 'Eua. No BBTV-like symptoms were seen anywhere on Nomuka, suggesting the island may be free of this disease.

A number of cucurbit samples showing convincing virus-like symptoms on young leaves did not test positive for any of the five viruses indexed for. These were one *C. maxima* x *moschata* leaf sample from 'Eua in Tonga and two *C. pepo* var. *melopepo,* two *Cucumis sativas* and one *Momordica charantia* on Grande Terre in New Caledonia.

Phytoplasmas in Tonga

Phytoplasmas were detected in the roadside weed *Cyanthilium cinereum* (syn. *Vernonia cinerea*) showing little leaf, witches' broom (proliferation of axillary buds) and phyllody (replacement of petals with leaf-like structures) on Tongatapu; *Ipomoea batatas* (sweet potato) showing little leaf, chlorosis and witches' broom on Ha'apai; and *Morinda citrifolia* (Indian mulberry or nonu) showing yellowing of leaves on Ha'apai. The phytoplasma associated with yellowing of Indian mulberry was most closely related to '*Candidatus* Phytoplasma solani' belonging to the Stolbur group (16SrXII), according to the IRPCM Phytoplasma/Spiroplasma Working Team (2004). The other phytoplamas found belonged to the '*Candidatus* Phytoplasma aurantifolia' (16SrII) group.

Phytoplasmas in New Caledonia

On Grande Terre Island, phytoplasmas were detected in *Lycopersicon esculentum* showing swollen floral organs (big bud symptoms); *Fragaria* sp. (strawberry) showing virescence (greening of leaf petals), abnormal development of fruits and seed abortion; *Alium cepa* (onion) and *Alium sativum* (garlic) plants showing grassy shoot (an unusual grass-like growth habit); and *Ananas comosus* (pineapple) showing excessive secondary bud growth or leaf proliferation. On Lifou Island, phytoplasmas were detected in *I. batatas* (sweet potato) showing little leaf, chlorosis and witches' broom. Phytoplasmas belonging to the Stolbur group (16SrXII) were those associated with onion and garlic grassy shoot, pineapple proliferation and strawberry virescence. Two phytoplasmas associated with sweet potato little leaf and tomato big bud were most closely related to '*Ca.* P. aurantifolia' (16SrII group). A phytoplasma belonging to the Mexican periwinkle virescence group (16SrXIII) was associated with a moderately severe sweet potato little leaf syndrome on Lifou Island.

Important negative results

Important negative detection test results from Tonga are presented in Table 7. A number of tomato plants growing near Lapaha on Tongatapu were showing symptoms very similar to those caused by TLCV infection. These are a general stunt and yellowing, plus a characteristic set of distinctive leaf symptoms: leaves bent down, leaflets rolled upwards and inwards, a purple colour to the lower side of leaf veins. TLCV was not detected using DNA probes in eight of these plants. No signs of an ongoing HLB epidemic (spreading decline or aggregated groups of trees showing HLB-like symptoms) were found anywhere in Tonga where citrus was grown. Moreover, no such reports have ever been made to MAF staff. Huanglongbing indexing returned negative results from two citrus samples from Ha'apai and three from Vava'u.

Important negative electron microscopy examination results from New Caledonia are presented in Table 8. These are all from vanilla leaf samples from Lifou Island.

Figures 1–22 show the symptoms caused by some of the viruses/phytoplasmas found in a number of hosts.

DISCUSSION

These surveys provide the first records of WMV and ZYMV in New Caledonia, and of ToMV in Tonga, plus several new host records. Following the study of Van Velsen (UNDP/FAO unpublished report, 1979), in which virus particles of the correct description were seen under the electron microscope, this survey provides full confirmation of DsMV and TaBV in *Xanthosoma* sp. and *A. macrorhiza* in Tonga. Revill et al. (2005) previously confirmed presence of these viruses in *C. esculenta* in Tonga and of these plus TaVCV in *C. esculenta* samples from New Caledonia. TaBV appears to be a virus of only minor importance, except when taro plants are infected with both it and CBDV. Co-infection with both viruses is believed to often (but not always) result in the lethal disease alomae (Revill et al. 2005). DsMV is also thought to cause yield losses in taro (Jackson et al. 2001) and ornamental aroids (Chase and Zettler 1982).

This survey, and the paper of Davis et al. (2006), record the first six phytoplasma host records for New Caledonia (*A. comosus, A. cepa, A. sativum*, *Fragaria* sp., *I. Batatas, and L. esculentum)* and two new records for Tonga (*C. cinereum* and *M. citrifolia*). The *A. sativum* phytoplasma infection is a new host species record worldwide.

ZYMV was the only cucurbit infecting virus identified in Tongan squash crops. ZYMV has been recorded before in cucurbit crops in Tonga, together with WMV (Pearson and Grisoni 2002). In addition to the ZYMV and WMV records in New Caledonia, this survey confirms the presence of PRSV in the territory, which had been listed before in the unpublished report of Thouvenal (1986). This is the cucurbit infecting strain of this virus (PRSV-W) which is closely related to the papaya infecting strain, and causes important disease in cucurbit crops through much of the world (Purcifull et al. 1984). These viruses causing mosaic diseases of cucurbits are members of the genus *Potyvirus*, and share some common characteristics of great relevance to control. These viruses cannot survive in the soil or in decayed plant material. Whilst PRSV-W is not thought to be seed transmitted, there are reliable reports of low rates of cucurbit seed transmission of ZYMV in Australia (see http://www.dpi.qld.gov.au/horticulture/9575.html) and of both WMV and ZYMV in New Zealand (Fletcher et al. 2000; Burgmans and Fletcher 2000). All three cause systemic infections, meaning that infected plants cannot be cured with any spray treatment or by removing parts of the plant showing symptoms. They are spread from plant to plant by many different species of aphid vectors. They are non persistently transmitted by these aphids, meaning they are picked up from an infected plant in a few seconds, then held on the insect's mouth parts for several hours and can be transmitted to another plant during brief feeding probes. This is most damaging if the aphids move from crop host to crop host (spreading the virus within the crop) or from weed host to crop (introducing more new infections to the crop). Because of this non persistence, spraying crops with insecticides is not a useful control measure. In fact, such sprays can increase spread because they often do not immediately kill the aphids. Instead, they are disturbed, fly to other nearby plants and feed and transmit virus before they die.

The best method to combat these viruses is to use resistant or tolerant cultivars. These are available for several cucurbit crops, but there was no known resistant or tolerant hybrid export quality squash seed available in 2006. Losses can be reduced if cropping systems are carefully designed. In large scale commercial cropping situations, such as those found on Grande Terre Island in New Caledonia and on Tongatapu, Tonga, adjacent older cucurbit crops and wild cucurbit crop plants or weeds can be significant reservoirs of mosaic virus inoculum. Specifically, continuous presence of susceptible crops in adjacent plantings or within an area should be avoided. Certain cultural control strategies can reduce incidence of non persistent viruses in crops. Removal of alternative hosts in and around the crop is a key step to reduce initial inoculum levels, before the virus spreads through the crop. Natural hosts of PRSV-W and ZYMV are mostly in the Cucurbitaceae (see: http://image.fs.uidaho.edu/vide/sppindex.htm#S). Certain members of other families are known to be hosts, but their importance in the field is not clear. This means that cucurbit volunteers and weeds should be key targets for control. Importantly, this study identified two possible weed hosts for this virus in Tonga, which returned marginal positive ELISA test results (*Desmodium* sp. and *Macroptilium atropurpureum*). WMV is known to have a wider natural host range (see http://image.fs.uidaho.edu/vide/descr878.htm). A number of symptomless weed samples taken from in and around mosaic affected squash plots in Tonga tested negative by ELISA for the five cucurbit infecting viruses (R. Davis, unpublished data, 2003). These were one *Amaranthus* sp., three *C. diffusa,* one *M. atropurpureum,* two *Solanum* spp. (local name was polopa), and five unidentified weeds (collection numbers were 3004, local name longolongouha, plus 3005, 3006, 3014, 3017, specimens were photographed and pressed).

Intercropping with non host plants can be a valuable control technique for non persistent plant viruses. They are a barrier to host-plant-to-host-plant virus movement because the virus is lost from aphid mouth parts when they probe on non-hosts. This practice is of limited value in intensive production systems such as those currently employed in the Tongan squash industry. However, certain observations made during this survey suggest that, in a similar way, non-host buffer zones between crops could be important. One clear conclusion made during the Tonga survey was that incidence of mosaic symptoms on squash leaves appeared to be considerably higher on the Island of Tongatapu than on the islands of 'Eua and Vava'u. The production regime on Tongatapu is much more intensive than on other islands and this may be the reason why virus diseases have built up to noticeably higher levels. The greatest contrast was between central Tongatapu and 'Eua. Although plantings were very large in both cases, the squash on Tongatapu was a monoculture over a large area, while plantings on 'Eua were often surrounded by much larger regions of natural vegetation.

This meant that, on Tongatapu, inoculum sources and vectors were close to most plantings. On ‘Eua in contrast, similar plantings were more isolated from each other and separated by buffer zones of natural vegetation that would mostly not be hosts to viruses that infect squash.

This study found phytoplasmas in ‘*Ca.* P. aurantifolia’ (16SrII group) associated with sweet potato little leaf symptoms in both Tonga and New Caledonia, with *C. cinereum* in Tonga and with tomato big bud disease in New Caledonia, as is the case in Australia (Gibb et al. 1995; Davis et al. 1997; Schneider et al. 1999; Davis et al. 2003). 16SrXII group phytoplasmas were associated with four crop species in New Caledonia (*A. cepa, A. sativum, A. comosus* and *Fragaria* sp.) and one on Tonga (*M. citrifolia*). ‘*Candidatus* Phytoplasma australiense’ within the 16SrXII group is believed to cause important crop diseases in Australia and New Zealand. These are Australian grapevine yellows (Padovan et al. 1995), papaya dieback disease (Gibb et al. 1996; Liu et al. 1996) and strawberry lethal yellows and green petal diseases (Padovan et al. 2000) in Australia; and *Phormium* yellow leaf disease (Liefting et al. 1998), strawberry lethal yellowing (Andersen et al. 1998), and cabbage tree decline (Andersen et al. 2001) in New Zealand. The only previous records of phytoplasmas in *M. citrifolia* and *A. comosus* are phytoplasmas in the ‘*Candidatus* Phytoplasma asteris’ (16SrI) group associated with similar symptoms on Futuna Island (Davis et al. 2005a). The phytoplasma associated with mild little leaf symptoms in sweet potato on Lifou island, New Caledonia, was particularly unusual. It belonged to the Mexican periwinkle virescence group (16SrXIII). This group is poorly characterised so far, and contains the Chinaberry yellows phytoplasma.

The records of CMV in *C. diffusa* is a notable alternative host record for Tonga because CMV can be especially important in solanaceous crops and cucurbits. ToMV was another virus found in Tonga which also occurs worldwide, probably because it is seed transmitted at very high rates (see: http://image.fs.uidaho.edu/vide/descr832.htm).

The negative citrus HLB screening results reported here, and in Davis et al. (2005b), adds support to the widely held belief that this disease is not present in Tonga. The negative TLCV test results for tomato leaf samples is also important. The vanilla on Lifou Island appears to be free of known vanilla viruses and should therefore provide a suitable source of planting material to develop an increased production industry.

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TABLES

Table 1. Verified plant virus and phytoplasma records from Tonga

Pathogen	Host	Citation[A]	Identification Method[B]
Banana bunchy top virus (BBTV)	*Musa* sp.	Karan et al. (1994)	PCR
Banana streak virus (BSV)	*Musa* sp.	Thomas et al. (1994)	IEM
Citrus psorosis virus (CPsV)[C]	*Citrus limon*	Van Velsen (1979) [D]	Indexing and mechanical inoculation
Citrus tristeza virus (CTV)	*Citrus aurantifolia, Citrus sinensis*	Van Velsen (1979) [D]	Indexing and mechanical inoculation
Cucumber mosaic virus (CMV)	*Piper methysticum*	Pares et al. (1992)	IEM, dsRNA analysis
"	*Musa* sp.	Kiritani and Su (1999)	Serology
Cymbidium mosaic virus (CymMV)	*Vanilla planifolia*	Pearson et al. (1993)	Serology and EM
Dasheen mosaic virus (DsMV)	*Colocasia esculenta,*	Revill et al. (2005)	PCR
Odontoglossum ringspot virus (ORSV)	*Vanilla planifolia*	Pearson et al. (1993)	Serology and EM
Tobacco mosaic virus (TMV)	*Nicotiana tabacum*	Van Velsen (1979)[D]	Indexing and mechanical inoculation
Watermelon mosaic virus (WMV)	*Cucurbita maxima*	Pearson and Grisoni (2002)	Serology and PCR
WMV – Vanilla necrosis strain	*Vanilla planifolia*	Pearson et al. (1993)	Serology and EM
Zucchini yellow mosaic virus (ZYMV)	*Citrullus lanatus*	Pearson and Grisoni (2002)	Serology, PCR
	Cucurbita moschata x maxima	Cho and Gonsalves (1993)[E]	Serology
Phytoplasma	*Ipomea batatas*	Kahn et al. (1972)	EM
Phytoplasma	*Lycopersicon esculentum*	Van Velsen (1979)[D]	EM

[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 (following reverse transcription in the case of RNA viruses).
[C]Not a virus specific verification, as psorosis disease is thought to be caused by a complex of several viruses.
[D]Identification methodology outlined in an unpublished report and results summarised in Mossop and Fry (1984).
[E]Identification methodology outlined in an unpublished report and results summarised in Pearson and Grisoni (2002).

Table 2. Verified plant virus records from New Caledonia

Pathogen	Host	Citation[A]	Identification method[B]
Banana bunchy top virus (BBTV)	*Musa* sp.	Kagy et al. (2001)	Serology, RT–PCR
Banana streak virus (BSV)	*Musa* sp.	Diekmann and Putter (1996)	Serology, EM
Dasheen mosaic virus (DsMV)	*Colocasia esculenta*	Revill et al. (2005)	RT–PCR
Papaya ringspot virus-W (PRSV-W)[C]	*Citrullus lanatus*	Thouvenel (1986)[D]	Serology
"	*Cucumis melo*	Thouvenel (1986)[D]	Serology
"	*Cucumis sativas*	Thouvenel (1986)[D]	Serology
"	*Cucurbita pepo melopepe*	Thouvenel (1986)[D]	Serology
Taro bacilliform virus (TaBV)	*Colocasia esculenta*	Revill et al. (2005)	PCR
Taro vein chlorosis virus (TaVCV)	*Colocasia esculenta*	Revill et al. (2005)	RT–PCR
Tobacco mosaic virus (TMV)	*Capsicum frutescens*	Thouvenel (1986)[D]	EM, serology
"	*Lycopersicon esculentum*	Thouvenel (1986)[D]	EM, serology
"	*Nicotiana* sp.	Thouvenel (1986)[D]	EM, serology

[A]The original or earliest available citation of a reliably verified record is provided.
[B]EM: electron microscopy, PCR: polymerase chain reaction, RT–PCR: reverse transcription polymerase chain reaction.
[C]The cucurbit infecting strain of PRSV, listed as *Watermelon mosaic virus-1* (WMV-1), the name used at that time for this virus.
[D]The status of these records is 'unpublished data' as this report is not generally available, or electronically abstracted.

Table 3. Other records indicating possible presence of plant infecting viruses and virus-like pathogens in Tonga

Pathogen	Host	Citation	Identification method
Dasheen mosaic virus (DsMV)	*Alocasia macrorrhiza*	Van Velsen (1979)[A]	EM[B]
"	*Xanthosoma sp.* (taro talua)	Van Velsen (1979)[A]	EM[B]
Fiji disease virus (FDV)	*Saccharum* sp.	Van Velsen (1979)[A]	EM[B]
Sweet potato feathery mottle virus (SPFMV)	*Ipomoea batatas*	Anon. (1978)	Russet crack symptom observation
Watermelon mosaic virus (WMV)	*Citrullus lanatus*	Van Velsen (1979)[A]	EM[B]

[A]Identification methodology outlined in an unpublished report and results summarised in Mossop and Fry (1984).
[B]Virus particles of correct size and shape were observed using electron microscopy.

Table 4. Other records indicating possible presence of plant infecting viruses and virus-like pathogens in New Caledonia

Pathogen	Host	Citation	Identification method
Cymbidium mosaic virus (CymMV)	*Phalaenopsis* sp.	Thouvenel (1986)	EM[A], indicator host inoculation
Dasheen mosaic virus (DsMV)	*Anthurium* sp.	Thouvenel (1986)	EM[A]
"	*Xanthosoma* sp.	Thouvenel (1986)	EM[A]
Fiji disease virus (FDV)	*Saccharum* sp.	Frison and Putter (1993)	Not stated
Hippeastrum mosaic virus (HiMV)	*Hymenocallis speciosa*	Thouvenel (1986)	EM[A]
Maize stripe virus (MSpV)	*Oryza sativa*	Thouvenel (1986)	EM[A]
"	*Saccharum officinarum*	Thouvenel (1986)	EM[A]
"	*Zea mays*	Thouvenel (1986)	EM[A]
Potato virus Y (PVY)	*Physalis* sp.	Thouvenel (1986)	EM[A], indicator host inoculation
"	*Solanum melongena*	Thouvenel (1986)	EM[A], indicator host inoculation
"	*Solanum tuberosum*	Thouvenel (1986)	EM[A], indicator host inoculation
Turnip mosaic virus (TuMV)	*Brassica chinensis*	Thouvenel (1986)	EM[A]
"	*Brassica oleraceae*	Thouvenel (1986)	EM[A]
"	*Brassica rapa*	Thouvenel (1986)	EM[A]
Unknown Potyvirus	*Arachis hypogea*	Thouvenel (1986)	EM[A]
"	*Cajanus cajan*	Thouvenel (1986)	EM[A]
"	*Dioscorea alata*	Thouvenel (1986)	EM[A], serology[B]
"	*Dioscorea bulbifera*	Thouvenel (1986)	EM[A]
"	*Dioscorea cayanensis*	Thouvenel (1986)	EM[A]
"	*Glycine max*	Thouvenel (1986)	EM[A]
"	*Phaseolus vulgaris*	Thouvenel (1986)	EM[A]
"	*Psophocarpus tetragonolobus*	Thouvenel (1986)	EM[A]
"	*Vigna unguiculata* ssp. *sesquipedalis*	Thouvenel (1986)	EM[A]
Phytoplasma	*Lycopersicon esculentum*	Thouvenel (1986)	Big bud[C] symptoms observed
"	*Ipomoea batatas*	Thouvenel (1986)	Little leaf[C] symptoms observed

[A]Virus particles of the correct size and shape observed using electron microscopy.
[B]A doubtful reaction to *Yam mosaic virus* (YMV) antisera obtained in ELISA tests.
[C]Distinctive symptoms of diseases associated with phytoplasma infection elsewehere were observed in the field.

Table 5. Plant virus and phytoplasma records from Tonga, September 2002

Host plant Family Genus, species Araceae	Field collection number	Approximate Location	Symptoms[A]	Pathogen[B]
Alocasia macrorhiza (kape)	2978	Fotua, 'Eua	Feathery WOGM	DsMV, TaBV
Xanthosoma sp. (talo futuna)	2963	Nomuka, Ha'apai	Feathery YOGM	DsMV
	2977	Fotua, 'Eua	Strong feathery YOGM	DsMV , TaBV
	3041	Lifuka, Ha'apai	Feathery WOGM	DsMV
Asteraceae				
Cyanthileum cinereum	2996	Makaunga, Tongatapu	Little leaf, witches' broom, phyllody	Phytoplasma in '*Ca*. P. aurantifolia' 16SrII group[C]
Commelinaceae				
Commelina diffusa	3070	Mata Ki 'Eua, Tongatapu	YOGM – ringspot-like	CMV
Convulvulaceae				
Ipomoea batatas (sweet potato)	3045	Lifuka, Ha'apai	Little leaf and chlorosis	Phytoplasma in '*Ca*. P. aurantifolia' 16SrII group[C]
	3046	Lifuka, Ha'apai	Little leaf and chlorosis	Phytoplasma in '*Ca*. P. aurantifolia' 16SrII group[C]
Cucurbitaceae				
Citrullus lanatus (watermelon)	3031	Feletoa, Vava'u	Mild YOGM	ZYMV +m
	3050	Lifuka, Ha'apai	YOGM	ZYMV +m
	3061	Foa, Ha'apai	YOGM	ZYMV +m
Cucurbita maxima x moschata (squash)	2997	Makaunga, Tongatapu	Mild YOGM – older leaves	ZYMV
	2998	Makaunga, Tongatapu	Severe YOGM	ZYMV
	2999	Makaunga, Tongatapu	YOGM	ZYMV
	3002	Lapaha, Tongatapu	Chlorosis, with green patches	ZYMV +m
	3003	Lapaha, Tongatapu	Severe YOGM	ZYMV
	3010	Toloa, Tongatapu	Mild YOGM	ZYMV
	3011	Toloa, Tongatapu	Severe YOGM	ZYMV
	3013	Toloa, Tongatapu	Severe YOGM	ZYMV
	3021	Ahau, Tongatapu	Mild chlorotic mottle	ZYMV
Fabaceae				
Desmodium sp.	2995	Makaunga, Tongatapu	Slight YOGM	ZYMV +m
Macroptilium atropurpureum (Siratro)	2970	Ha'atau, 'Eua	YOGM	ZYMV +m
	3053	Pangai, Ha'apai	YOGM	ZYMV +m
Musaceae				
Musa sp. ABB	2964	Nomuka, Ha'apai	Very slight chlorosis: diffuse	BSV
Musa sp AAA	2972	Ha'atau, 'Eua	BBTV-like symptoms[D]	BBTV
Musa sp AAA	3036	Koloa, Vava'u	BBTV-like symptoms[D]	BSV, BBTV
Musa sp ABB (cv. Lehia)	3038	Leimatu'a, Vava'u	Chlorotic streaks on leaves and leaf sheaths separating	BSV
Musa sp ABB (cv. Lehia)	3039	Leimatu'a, Vava'u	Chlorotic streaks on leaves and leaf sheaths separating	BSV
Musa sp AAA	3058	Foa, Ha'apai	BBTV-like symptoms[D]	BSV, BBTV
Rubiaceae				
Morinda citrifolia	3065	Foa, Ha'apai	Blotchy yellow on green mosaic	Phytoplasma in '*Ca*. P. solani' 16SrXII group[C]
Solanaceae				
Lycopersicon esculentum (tomato)	3018	Vaini, Tongatapu	YOGM	ToMV
	3047	Lifuka, Ha'apai	Mild TLCV-like symptoms[D]	ToMV
	3072	Tokomololo, Tongatapu	YOGM	ToMV

[A]WOGM: White on green mosaic, YOGM: yellow on green mosaic.
[B]Viruses were: BBTV: Banana bunchy top virus, BSV: Banana streak virus, CMV: *Cucumber mosaic virus,* DsMV: *Dasheen mosaic virus,* TaBV: Taro bacilliform virus, ToMV: Tomato mosaic virus, ZYMV: *Zucchini yellow mosaic virus*.
[C] Data previously published in Davis et al. (2006).
[D]BBTV-like symptoms include narrow upright short leaves with marginal yellowing; TLCV-like symptoms include chlorosis and stunt, leaves curled down, leaflets curled and cupped up, purple tinge to undersurface of leaf veins and marginal necrosis of leaves.

DsMV was detected by RT–PCR, TaBV was detected by PCR, BSV and BBTV were detected by real-time PCR. Phytoplasmas were detected by nested PCR, then identified by sequence analysis. CMV, ZYMV and ToMV were detected by ELISA. ELISA test results were considered positive when absorbance readings (405nm) exceeded 3 x mean of healthy controls (+m: marginal positive result, absorbance exceeded twice the mean of negative controls, but not three times the mean).

Table 6. Plant virus and phytoplasma records from New Caledonia, October 2002

Host plant Family Genus, species	**Field**	**Approximate Location[A]**	**Symptoms[B]**	**Pathogen[C]**
Amaryllidaceae				
Allium cepa (onion)	3159	La Foa, GT	Grassy growth	Phytoplasma in 16SrXII group[D]
Allium sativum (garlic)	3111	Gouaro, Bourail, GT	Grassy growth	Phytoplasma, in '*Ca* P. solani' 16SrXII group[D]
Araceae				
Colocasia esculenta (taro)	3138	Poindimie, GT	Reduced leaf size plus some WOGM	TaBV[E], TaVCV[E]
	3139	Poindimie, GT	Large crease in leaf	DsMV[E]
	3140	Poindimie, GT	WOGM – feathery	DsMV[E], TaBV[E]
	3143	Tiwaka, Poindimie, GT	Large crease in leaf	DsMV[E], TaBV[E]
	3144	Tiwaka, Poindimie, GT	General chlorosis and GOYVB	DsMV[E] TaBV[E]
	3145	Tiwaka, Poindimie, GT	Crinkle and feathery WOGM plus some GOYVB	DsMV[E], TaBV[E]
	3146	Tiwaka, Poindimie, GT	Lamina greatly reduced, curled, thick and brittle	DsMV[E]
Bromeliaceae				
Ananas comosus (pineapple)	3161	Farino, La Foa, GT	Excessive secondary bud growth (proliferation)	Phytoplasma in '*Ca.* P. solani' 16SrXII group[D]
Convulvulaceae				
Ipomoea batatas (sweet potato)	3174	Hnai, Thuahaik, Lifou	Little leaf, chlorosis and witches' broom	Phytoplasma in '*Ca*. P. aurantifolia' 16SrII group[D]
	3175	Hnai, Thuahaik, Lifou	Little leaf, chlorosis and mild witches' broom	Phytoplasma in 16SrXIII group[D]
Cucurbitaceae				
Cucumis melo (rockmelon)	3104	Tamoa, GT	YOGM	ZYMV, WMV
	3105	Tamoa, GT	YOGM	ZYMV, WMV
Cucurbita maxima (pumpkin)	3088	Mouirange, GT	Diffuse and scattered YOGM	PRSV
	3089	Mouirange, GT	YOGM	PRSV, ZYMV
	3090	Mouirange, GT	Strong YOGM	PRSV, ZYMV
Cucurbita maxima x moschata (squash)	3158	La Foa, GT	YOGM	PRSV, ZYMV
	3166	La Foa, GT	YOGM	ZYMV
	3094	Saint Louis, GT	YOGM	PRSV
	3115	Mekounia, Boghen, GT	YOGM	ZYMV
	3133	Bourail, GT	YOGM	ZYMV
	3116	Mekounia, Boghen, GT	Extreme YOGM plus leaf distortion	ZYMV
	3117	Mekounia, Boghen, GT	Diffuse YOGM, plus warty fruits	ZYMV
	3118	Boghen, GT	YOGM	ZYMV
	3123	Nemeaora, Bourail, GT	YOGM, and leaf distortion	ZYMV
	3124	Nemeaora ?, Bourail, GT	Diffuse YOGM	ZYMV
Cucurbita pepo var. *melopepo* (zucchini)	3106	Tamoa, GT	Claw-like leaves and YOGM	PRSV, WMV
	3136	La Coulee, Mt Dore, GT	Claw-like leaves and YOGM	PRSV
	3150	Pouembout, GT	Claw-like leaves and YOGM	PRSV
	3155	La Foa, GT	Claw-like leaves and YOGM	PRSV

	3156	La Foa, GT	Claw-like leaves and YOGM	ZYMV
	3163	La Foa, GT	Claw-like leaves and YOGM	ZYMV
	3107	Tamoa, GT	Mild YOGM	WMV
	3108	Tamoa, GT	Mild YOGM	WMV
	3128	Nemeaora, Bourail, GT	Patchy YOGM	ZYMV
	3129	Nemeaora, Bourail, GT	Claw-like leaves and YOGM	ZYMV
	3137	La Coulee, Mt Dore, GT	Minor leaf distortions and YOGM	ZYMV
Cucumis sativus (cucumber)	3164	La Foa, GT	YOGM	ZYMV +m
Solanaceae				
Lycopersicon esculentum (tomato)	3152	Pouembout, GT	Big bud: swollen green floral structures, upright shoots, stunt	Phytoplasma in '*Ca*. P. aurantifolia' 16SrII group[D]
	3102	Dumbea, GT	Yellow on green mosaic	Many rods seen by EM[F]
Solanum tuberosum (potato)	3130	Bourail, GT	Chlorosis and upward curling of leaves, plus general stunting and abnormal plant stature	816 nm filaments seen under EM
Rosaceae				
Fragaria sp. Strawberry	3100	Dumbea, GT	Virescence and fruit/seed abortion and chlorosis/stunt	Phytoplasma in '*Ca*. P. australiense' 16SrXII group[D]
	3101	Dumbea, GT	Virescence and fruit/seed abortion and chlorosis/stunt	Phytoplasma in '*Ca*. P. australiense' 16SrXII group[D]
	3134	Paita, GT	Small leaves and general stunt	Isometric particles seen by EM[F]

[A]GT: Grande Terre Island.
[B]GOYVB: green on yellow vein banding, WOGM: white on green mosaic, YOGM: yellow on green mosaic.
[C]Viruses were DsMV: *Dasheen mosaic virus,* PRSV: *Papaya ringspot virus*, TaBV: *Taro bacilliform viru*s, TAVCV: *Taro vein chlorosis virus*, WMV: *Watermelon mosaic virus*, ZYMV: *Zucchini yellow mosaic virus*
[D]Results previously published by Davis et al. (2006)
[E]Results previously published by Revill et al. (2005)
[F]Preliminary electron microscopy results only available, further investigations are planned.

PRSV, WMV and ZYMV were identified by DAS–ELISA. ELISA test results were considered positive when A405 > 3 x mean of healthy controls. Absorbance readings >2 x mean of healthy controls, but < 3 x mean, were recorded as marginal positive results (+m). DsMV and TaVCV were identified by RT–PCR and TaBV was identified by PCR. Phytoplasmas were identified by nested PCR followed by sequence analysis of the 16SrRNA gene.

Table 7. Notable samples from Tonga in which virus or virus-like pathogens were not detected in specific tests

Host plant **Family** Genus, species	**Field collection number**	**Approximate Location**	**Symptoms**[A]	**Tested negative for**
Rutaceae				
Citrus x limon (lemon)	3055	Pangai, Ha'apai	GOYVB, chlorosis	Huanglongbing[B]
Citrus x limon (lemon)	3076	Pangai, Ha'apai	General chlorosis	Huanglongbing[B]
Citrus reticulata (mandarin)	3504	Tefisi, Vava'u	Diffuse chlorotic blotch	Huanglongbing[B]
	3505	Utulei, Vava'u	Diffuse chlorotic blotch	Huanglongbing[B]
	3506	Neiafu, Vava'u	GOYVB, chlorotic blotch	Huanglongbing[B]
Solanaceae				
Lycopersicon esculentum (tomato)	3007	Lapaha, Tongatapu	Strong TLCV-like symptoms	TLCV[C]
	3008	Lapaha, Tongatapu	Strong TLCV-like symptoms	TLCV[C]
	3035	Koloa, Vava'u	Strong TLCV-like symptoms	TLCV[C]
	3047	Lifuka, Ha'apai	Mild TLCV-like symptoms	TLCV[C]
	3051	Lifuka, Ha'apai	Leaves curled down, chlorosis	TLCV[C]
	3057	Foa, Ha'apai	Mild TLCV-like symptoms	TLCV[C]
	3068	Lapaha, Tongatapu	TLCV-like symptoms	TLCV[C]
	3069	Lapaha, Tongatapu	Strong TLCV-like symptoms	TLCV[C]

[A]GOYVB: green on yellow vein banding, TLCV-like symptoms include chlorosis and stunt, leaves curled down, leaflets curled and cupped up, purple tinge to undersurface of leaf veins and marginal necrosis of leaves.
[B]Tested by PCR for presence of '*Ca.* L. asiaticus', data summarised in Davis et al. (2005b).
[C]Negative in tests for TLCV using DNA probes.

Table 8. Notable samples from New Caledonia in which no virus particles were detected using electron microscopy

Host plant **Family** Genus, species	**Field**	**Approximate Location**	**Symptoms**
Orchidaceae			
Vanilla planifolia	3167	Mou, Lifou	Mild chlorotic blotching
	3168	Mou, Lifou	Chlorotic streaks
	3169	Weniko/Jozip, Lifou	Chlorotic blotching, on youngest leaves
	3170	Weniko/Jozip, Lifou	Chlorotic blotching, and general chlorosis (and failure to flower)
	3172	Hnathalo, Lifou	Brown necrotic patches on older leaves
	3173	Hnathalo, Lifou	Chlorotic blotching

FIGURES

Fig. 1. RID 2978: *Alocasia macrorhiza* (kape) infected with *Dasheen mosaic virus* (DsMV) and *Taro bacilliform virus* (TaBV) in Tonga.

Fig. 2. RID 2996: *Cyanthilium cinereum* (Syn. *Vernonia cinerea*) infected with a phytoplasma in the '*Ca*. P. aurantifolia' 16SrII group, on the left, with an uninfected plant of the same species on the right in Tonga.

Fig. 3. RID 3045: *Ipomoea batatas* (sweet potato) infected with a phytoplasma in the '*Ca*. P. aurantifolia' 16SrII group showing reduced leaf size and chlorosis in Tonga. Infected plant is in the right foreground, with uninfected sweet potatoes showing normal leaf size, in the left foreground and in the background.

Fig. 4. RID 2997: *Cucurbita maxima x moschata* (squash) infected with *Zucchini yellow mosaic virus* (ZYMV), showing mild yellow on green mosaic symptoms in Tonga.

Fig. 5. RID 2999: *Cucurbita maxima x moschata* (squash) infected with *Zucchini yellow mosaic virus* (ZYMV), showing yellow on green mosaic symptoms in Tonga.

Fig. 6. RID 2998: *Cucurbita maxima x moschata* (squash) infected with *Zucchini yellow mosaic virus* (ZYMV), showing severe yellow on green mosaic symptoms in Tonga.

Fig. 7. RID 2964: *Musa* sp. (unknown cv., ABB genotype) infected with *Banana streak virus* (BSV) showing slight and diffuse chlorotic streaking symptoms in Tonga.

Fig. 8. RID 3038: *Musa* sp. (cv. Lehia, ABB genotype) infected with *Banana streak virus* (BSV) showing mild chlorotic streaking symptoms in Tonga.

Fig. 9. RID 3039: *Musa* sp. (cv. Lehia, ABB genotype) infected with *Banana streak virus* (BSV) showing mild chlorotic streaking symptoms plus dark markings superimposed in Tonga.

Fig. 10. RID 3018: *Lycopersicon esculentum* (tomato) infected with *Tomato mosaic virus* (ToMV) showing yellow on green mosaic symptoms in Tonga.

Fig. 11. RID 3072: *Lycopersicon esculentum* (tomato) infected with *Tomato mosaic virus* (ToMV) showing yellow on green mosaic symptoms in Tonga.

Fig. 12. RID 3138: *Colocasia esculenta* (taro) infected with *Taro bacilliform virus* (TaBV) and Taro vein chlorosis virus (TaVCV) showing reduced leaf size and white on green feathery mosaic in New Caledonia.

Fig. 13. RID 3146: *Colocasia esculenta* (taro) infected with *Dasheen mosaic virus* (DsMV) showing greatly reduced leaf size and curling and thickening of leaf in New Caledonia.

Fig.14. RID 3174: *Ipomoa batatas* (sweet potato) infected with a phytoplasma in the '*Ca*. P. aurantifolia' 16SrII group showing reduced leaf size, chlorosis and witches' broom. Older leaves of normal size can be seen in the bottom right hand corner in New Caledonia.

Fig. 15. RID 3123: *Cucurbita maxima x moschata* (squash) infected with *Zucchini yellow mosaic virus* (ZYMV), showing yellow on green mosaic symptoms and distortion in New Caledonia.

Fig. 16. RID 3124: *Cucurbita maxima x moschata* (squash) infected with *Zucchini yellow mosaic virus* (ZYMV), showing diffuse yellow on green mosaic symptoms in New Caledonia.

Fig. 17. RID 3094: *Cucurbita maxima x moschata* (squash) infected with *Papaya ringspot virus* (PRSV-W) showing yellow on green mosaic symptoms in New Caledonia.

Fig. 18. RID 3128: *Cucurbita pepo* var. *melopepo* (zucchini) infected with *Zucchini yellow mosaic virus* (ZYMV), showing patchy yellow on green mosaic symptoms in New Caledonia.

Fig. 19. RID 3128: *Cucurbita pepo* var. *melopepo* (zucchini) infected with *Zucchini yellow mosaic virus* (ZYMV), showing warty growths on young fruits in New Caledonia.

Fig. 20. RID 3137: *Cucurbita pepo* var. *melopepo* (zucchini) infected with *Zucchini yellow mosaic virus* (ZYMV), showing yellow on green mosaic and minor leaf distortions in New Caledonia.

Fig. 21. RID 3152: *Lycopersicon esculentum* (tomato) infected with a phytoplasma in the '*Ca*. P. aurantifolia' 16SrII group showing symptoms of tomato big bud disease (swollen green floral organs, upright shoots and stunt) in New Caledonia.

Fig. 22. RID 3100: *Fragaria* sp. (strawberry) infected with a phytoplasma in the '*Ca*. P. australiense' 16SrXII group showing extreme virescence and fruit abortion in New Caledonia.

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