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SPC Land Resources Division
Suva, Fiji

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Surveys for **PLANT DISEASES** caused by Viruses & Virus-like pathogens in the **French Pacific Overseas Country of FRENCH POLYNESIA &** the French Pacific territory of **WALLIS & FUTUNA**

By

R.I. Davis[A], L. Mu[B], A. Malau[C], P. Jones[D]

[A] Plant Protection Service, Secretariat of the Pacific Community (SPC), PMB, Suva, Fiji Islands

[B]Service du Développement Rural, Département de la Protection des Végétaux, BP 100, Papeete, French Polynesia

[C]Service de l'agriculture à Wallis, Services Territoriaux des Affaires Rurales et de la Peche, BP 19, Mata'utu, 98600 Uvea, Wallis and Futuna Islands

[D] Plant–Pathogen Interactions Division, Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ, UK

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ABSTRACT

Surveys for virus and virus-like plant diseases were conducted in French Polynesia, on the islands of Tahiti, Moorea and Tubuai, and on the islands of Wallis, Futuna and Alofi in the territory of Wallis and Futuna. New records for French Polynesia were those of *Turnip mosaic virus* (TuMV) in Chinese cabbage and pak choi (*Brassica chinensis*) and Chinese radish (*Raphanus sativus* var. *longipinnatus*); *Zucchini yellow mosaic virus* (ZYMV) in zucchini (*Cucurbita pepo* ssp*. pepo* var*. pepo*); and the cucurbit infecting strain of *Papaya ringspot virus* (PRSV-W) in zucchini and pumpkin (*Cucurbita maxima*), all detected by enzyme linked immunosorbent assay (ELISA). New records for Wallis and Futuna, detected by ELISA, were those of *Banana bunchy top virus* (BBTV) in banana plants (*Musa* sp.), *Dasheen mosaic virus* (DsMV) in taro (*Colocasia esculenta* and *Xanthosoma* sp.), and *Citrus tristeza virus* (CTV) in pomelo (*Citrus maxima*), lemon (*Citrus* x *limon*), and mandarin (*Citrus reticulata*) trees. Also in Wallis and Futuna, *Banana streak virus* (BSV) was detected by real-time polymerase chain reaction (PCR) in banana plants, *Taro vein chlorosis virus* (TaVCV) was detected by reverse transcription PCR in *C. esculenta*, and *Taro bacilliform virus* (TaBV) was detected in *C. esculenta* and *Xanthosoma* sp. by PCR.

New virus host records for French Polynesia were of *Cucumber mosaic virus* (CMV) in kava (*Piper methysticum*), banana (*Musa* sp.), snakebean (*Vigna unguiculata* ssp. *unguiculata)* and *Commelina diffusa* and *Bean common mosaic virus* (BCMV) in snakebean, detected by ELISA.

Other detections in French Polynesia were of TaBV in one *C. esculenta* plant by PCR, and of *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ringspot virus* (ORSV) in ornamental orchids, and CMV in vanilla (*Vanilla tahitiensis*) by ELISA.

Phytoplasmas were detected by nested PCR on Futuna island in cassava (*Manihot esculenta)*, noni/Indian mulberry (*Morinda citrifolia*), pineapple (*Ananas comosus*), and the roadside weeds *Emilia sonchifolia* and *Polygala paniculata*. The phytoplasmas associated with disease symptoms in cassava, noni/Indian mulberry and pineapple (*Ananas comosus*) belonged to the '*Candidatus* Phytoplasma asteris' (16SrI) group. Those associated with *E. sonchifolia* and *P. paniculata* belonged to the '*Ca.* Phytoplasma aurantifolia' (16SrII) group.

In both surveys, no evidence was found for presence of citrus huanglongbing, previously known as greening disease. Four citrus trees from French Polynesia and seven trees from Wallis and Futuna indexed negative by PCR for the causal agent, '*Candidatus* Liberibacter asiaticus'**.** In the survey of Futuna, no symptoms of banana bunchy top disease were found and two banana plants indexed negative for BBTV by ELISA.

INTRODUCTION

Surveys were conducted to assess the general plant virus and virus-like disease status of the French Pacific overseas country of French Polynesia and French Pacific territory of Wallis and Futuna. These are two locations in the Pacific where this aspect of plant health status has been particularly poorly documented. There are apparently no valid published records of plant virus disease test results from the territory of Wallis and Futuna and only a handful of published records of observations of plants showing virus-like disease symptoms (invalid records). Some of these have been included in the listing of Pearson and Grisoni (2002). In French Polynesia, a number of records resulting from specifically targeted studies, especially a series focusing on virus diseases of vanilla, do exist. These are included in the listing of Pearson and Grisoni (2002), and further vanilla virus records have also been published more recently (Grisoni et al. 2004, 2006). In addition, an outbreak of papaya ringspot disease, caused by the papaya infecting strain of *Papaya ringspot virus*, (PRSV-P) occurred in this territory recently (Davis et al. 2005d). This virus is different, but very closely related to the PRSV found in cucurbits, known as PRSV-W, which causes important disease in cucurbit crops throughout much of the world (Purcifull et al. 1984). The known records of diseases caused by plant viruses in French Polynesia for which there exists acceptable supportive evidence of the pathogen's identity are summarised in Table 1.
The records for which none or only inconclusive supportive evidence of pathogen identity is available are listed in Table 2 (French Polynesia) and Table 3 (Wallis and Futuna). In the case of French Polynesia, some are based on symptoms only and others on electron microscopy studies in which only virus particles of the correct size and description were seen. In the case of Wallis and Futuna, these appear to all be identifications based on symptoms only. Of particular concern is the issue of the presence or absence in this territory of a key quarantine pathogen in the region, *Banana bunchy top virus* (BBTV). There is a record of this virus on Wallis Island but this is based on field symptoms only (Kohler 1987). Although the disease seems to be a problem well recognised by agriculturalists on Wallis Island, a definitive diagnostic test to prove presence of the virus in the territory has never been conducted.

Very little is known of the phytoplasma disease status of the Pacific islands. Phytoplasmas (formerly known as mycoplasmalike organisms) are unculturable bacteria found only in plant phloem vessels and in the phloem-feeding insects (mostly leafhoppers) that spread them from plant to plant. They have been associated with diseases of numerous plant species throughout the world (Seemüller et al. 1998) and up-to-date information on these pathogens and the diseases they are believed to cause in the Australian tropics can be found in Streten and Gibb (2006). Phytoplasma test results from several plant species on Futuna island have recently been published in Davis et al. (2005a). This information is repeated in this technical paper, together with further details on these samples, including photographs.

There is some question about the distribution of one of the worst diseases of citrus in the region. This is huanglongbing (HLB, formerly known as greening disease), caused in certain Asian countries close to the Pacific islands by another phloem-limited bacterium, '*Candidatus* Liberibacter asiaticus'. HLB reached Papua New Guinea (PNG) in 2002 (Weinert et al. 2004). More recently, the disease appeared also to the east of the Pacific islands, in both Brazil (Colletta-Filho et al. 2004) and Florida (see: http://www.aphis.usda.gov/lpa/news/2005/09/greening_ppq.html). A report that this virus-like disease was present in several Pacific island countries 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. For these reasons, these surveys also focused on HLB.

In French Polynesia, the islands of Tahiti, Moorea and Tubuai were visited. In Wallis and Futuna, the two major islands plus the small island of Alofi which lies adjacent to Futuna, were surveyed.

METHODS

Surveys
To undertake the surveys, as many different areas as possible were visited. Crop plants of economic importance, and occasionally also other plants, were examined at each location. Samples thought to be infected by intracellular pathogens were returned for analyses after rapid desiccation in the field. Samples, consisting of 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 might have been present on external surfaces. The material was then rinsed in water, blotted dry and chopped finely. Each sample was desiccated over anhydrous calcium chloride (about 7 g) in sealed, 25 mL plastic vials. Samples were stored at 4°C until fully desiccated, and at –20°C thereafter. Samples were returned (under appropriate quarantine import permits) to several different laboratories for diagnostic tests.

The survey of Wallis and Futuna was undertaken over two weeks in May 2004 and the survey of French Polynesia over three weeks in September–October 2004

Enzyme linked immunosorbent assay (ELISA) testing for viruses
Cucurbit samples from both surveys 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 double antibody sandwich ELISA (DAS-ELISA). Also from both surveys, taro leaf samples (*Colocasia esculenta* and *Xanthosoma* sp.) were tested for *Dasheen mosaic virus* (DsMV) by DAS-ELISA, and citrus leaf samples were tested for *Citrus tristeza virus* (CTV) by compound direct ELISA. Vanilla (*Vanilla tahitiensis*) and other orchid samples from French Polynesia were tested by DAS-ELISA for CMV, *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ringspot virus* (ORSV), and by indirect ELISA for the potyvirus group. Snakebean (*Vigna unguiculata* ssp. *unguiculata*) and kava (*Piper methysticum*) samples from French Polynesia were tested by indirect ELISA for the potyvirus group, and the snakebean samples were also tested by indirect ELISA specifically for the potyvirus, *Bean common mosaic virus* (BCMV). Leaf samples from two of the snakebeans, plus kava, banana (*Musa* sp.), and the weed *Commelina diffusa* in French Polynesia were tested for CMV, and two *Brassica* spp. were tested for *Turnip mosaic virus* (TuMV) by DAS-ELISA. From Wallis and Futuna, one kava leaf sample was tested for CMV, and several banana leaf samples were tested for *Banana bunchy top virus* (BBTV), also by DAS-ELISA. All these tests were conducted at the SPC plant virology laboratory, Suva, Fiji Islands, using Agdia Inc. (Elkhart IN, USA) ELISA reagent sets. At Rothamsted Research, UK, two tomato (*Lycopersicon esculentum*) leaf samples from French Polynesia were tested by indirect ELISA for the potyvirus group and by DAS-ELISA for CMV. One tomato leaf sample from French Polynesia was tested by ELISA for *Tomato spotted wilt virus* (TSWV), *Impatiens necrotic spot virus* (INSV), *Alfalfa mosaic virus* (AMV), *Tomato yellow leaf curl virus* (TYLCV), and *Pepino mosaic virus* (PepMV) using antisera made by the Central Science Laboratory (CSL), York, UK. 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.

Reverse transcription polymerase chain reaction (RT-PCR) testing for viruses
Aroid and kava leaf samples from Wallis and Futuna were returned to the molecular biology laboratory of the Institute of Applied Sciences (IAS), University of the South Pacific (USP), Suva, Fiji Islands. Here, the aroid samples were tested for *Taro vein chlorosis virus* (TaVCV), and two kava leaf samples were tested for CMV by RT-PCR using the methods described in Revill et al. (2005) and Davis et al. (2005c), respectively.

Real-time PCR testing for viruses
Banana leaf samples from Wallis and Futuna were subjected to a multiplex real-time PCR test for presence of *Banana streak virus* (BSV), *Banana bract mosaic virus* (BBMV), *Banana mild mosaic virus* (BMMV), CMV and BBTV at CSL, York, UK.

Polymerase chain reaction (PCR) testing for Taro bacilliform virus (TaBV)
Aroid leaf samples were tested for TaBV by PCR at the USP IAS laboratory. A modification of the diagnostic test of Revill et al. (2005) was used. This modification was the use of the REDExtract-N-Amp Plant PCR kit (Sigma, USA) for DNA extraction and PCR. This was done according to the manufacturers instructions, except for the addition of 1 mM $MgCl_2$ to the reaction mix.

PCR testing for HLB
Citrus leaf material from both surveys was tested for HLB at the USP IAS molecular biology laboratory using the PCR techniques described in Davis et al. (2005b).

Phytoplasma testing
Samples from several different plant species on Futuna island showing phytoplasma-like symptoms were subjected to nucleic acid extraction, followed by nested PCR at Rothamsted Research, as described in Davis et al. (2005a).

Electron microscopy testing for viruses
Several *Passiflora foetida* leaf samples from Wallis and Futuna were tested for potyvirus infection by immunosorbent electron microscopy (ISEM) at the laboratory of J. Thomas, Department of Primary Industries and Fisheries, Queensland, Australia.

RESULTS

The plant virus and virus-like pathogens recorded on these surveys are presented in Table 4 (French Polynesia) and Table 5 (Wallis and Futuna).

Viruses in French Polynesia

Of the five viruses screened for by ELISA in cucurbit samples from French Polynesia, PRSV was detected in both *Cucurbita maxima* (pumpkin) and *Cucurbita pepo* ssp. *pepo* var. *pepo* (zucchini) on Tahiti, and ZYMV was detected in a *C. pepo* ssp. *pepo* var. *pepo* on Tubuai. A number of cucurbit samples from French Polynesia showing virus-like symptoms on young leaves did not test positive for any of the five viruses indexed for. These were six *Citrullus lanatus* (watermelon) samples, seven *C. pepo* ssp. *pepo* var. *pepo*, two *C. maxima*, one *Cucumis sativus* (cucumber) and one *Momordica charantia* (bitter gourd). DsMV was detected in *C. esculenta* by DAS-ELISA on both Tahiti and Moorea, and a marginally positive test result was obtained from one leaf sample from Tubuai. CTV was detected by ELISA in *Citrus* x *limon* (lemon) trees from two locations on Tahiti and one on Moorea. TuMV was detected by ELISA in *Brassica chinensis* (Chinese cabbage and pak choi), in three locations on Tahiti and two on Moorea, and in *Raphanus sativus* var. *longipinnatus* (Chinese radish) on Tahiti. CMV was detected in *P. methysticum* (kava) leaves from two locations on Tahiti and one on Moorea, in a *Musa* sp. (banana) leaf sample from Tahiti, in three *C. diffusa* plants from two locations on Tahiti, and in one *L. esculentum* (tomato) leaf sample from Tahiti. Several *V. unguiculata* ssp. *unguiculata* (snakebean) leaf samples from two locations on Tahiti were infected with BCMV, testing positive by ELISA for this virus and also for the potyvirus group, and two were also positive for CMV by ELISA. In ELISA tests on orchids and *V. tahitiensis* (vanilla) samples, CymMV was detected in several orchid (*Dendrobium* sp. and hybrids) leaf samples, and CMV was detected in *V. tahitiensis* on both Tahiti and Tubuai. ORSV was also detected on Tahiti and Tubuai as co-infections with CymMV in both types of ornamental orchids. Potyvirus group ELISA tests gave positive results for two *L. esculentum* plants from Tahiti and negative results for all *P. methysticum* leaf samples. TaBV was detected by PCR in one *C. esculenta* leaf sample from Tahiti that also tested positive for DsMV by ELISA.

Viruses in Wallis and Futuna

BBTV was detected by ELISA in two *Musa* sp. leaf samples from one location on Wallis, and two more samples from different locations returned marginally positive results. Three *Xanthosoma* sp. leaf samples from Futuna, one from Wallis and one from Alofi, and one *C. esculenta* sample from Wallis were positive for DsMV by ELISA. TaVCV was detected by RT-PCR in *C. esculenta* and *Xanthosoma* sp. samples from both Wallis and Futuna. TaBV was detected by PCR in *C. esculenta* and *Xanthosoma* sp. leaf samples from both Wallis and Futuna and in one *Xanthosoma* sp. on Alofi. These results included two mixed infections of TaBV with TaVCV and two with DsMV. A strong real-time PCR positive result (in which a mean Ct value of two replicate wells of <30 in a 40-cycle reaction was obtained) was recorded for BSV, but not the other banana infecting viruses, in three banana leaf samples from Futuna and two from Wallis. CTV was detected by ELISA in one *Citrus maxima* (pomelo), one *Citrus* x *limon* (lemon) and one *Citrus reticulata* (mandarin) tree on Wallis. Only one cucurbit plant was showing mosaic symptoms and a leaf sample was tested for five cucurbit infecting viruses by ELISA. This was a *C. lanatus* that gave a marginally positive reaction only to ZYMV. Potyvirus infection was confirmed by ISEM in three *P. foetida* plants from Futuna, two from Wallis and one from Alofi.

Phytoplasmas on Futuna

Phytoplasmas belonging to the '*Candidatus* Phytoplasma asteris' (16SrI) group were associated with *Manihot esculenta* (cassava) with symptoms of witches' broom (proliferation of axillary buds), *Morinda citrifolia* (Indian mulberry or noni) with severe yellowing, and *Ananas comosus* (pineapple) with symptoms of shoot proliferation. Phytoplasmas belonging to the '*Ca.* Phytoplasma aurantifolia' (16SrII) group were associated with *Emilia sonchifolia* (red tassel) and *Polygala paniculata* both showing phyllody (leaf like structures replacing petals and sepals). One additional sample from *M. citrifolia*, *E. sonchifolia* and *P. paniculata* were positive for phytoplasma but the PCR amplimers were not sequenced.

Important negative results

HLB indexing returned negative results from three citrus leaf samples from Tahiti and one from Moorea in French Polynesia (Table 6), four from Wallis and three from Futuna (Table 7).

One tomato leaf sample from French Polynesia tested negative by ELISA for TSWV, INSV, AMV, TYLCV and PepMV.

In Wallis and Futuna, two *Musa* sp. leaf samples from Futuna tested negative by ELISA for BBTV and three *P. methysticum* leaf samples from Alofi tested negative for CMV (two by RT-PCR, one by ELISA).

Figures 1–26 show the symptoms caused by the viruses and phytoplasmas found in a number of hosts.

DISCUSSION

These surveys provide the first records in French Polynesia of TuMV, PRSV-W and ZYMV, and in Wallis and Futuna of BBTV, BSV, DsMV, TaVCV, and CTV. Additionally, the survey of French Polynesia records, for the first time, CMV in kava, banana and snakebean, and *C. diffusa* and BCMV in snakebean, and lists more records of CymMV, ORSV and CMV in orchidaceous hosts. The phytoplasma testing conducted following the survey of Futuna provided phytoplasma host records for Wallis and Futuna (cassava, Indian mulberry, pineapple, and the roadside weeds *E. sonchifolia* and *P. paniculata*) first published in the paper of Davis et al. (2005a).

Most notably, this study provides first laboratory test confirmation of the presence of BBTV in the territory of Wallis and Futuna, following visual observations of symptoms made since the 1980s. The disease and the virus were present on Wallis but not on Futuna. BBTV is a virus of extreme quarantine concern in the Pacific. This is because its distribution is patchy: it is present on some islands but absent from others. By late 2005, laboratory test records confirming presence of BBTV in Fiji Islands, Tonga, Samoa (Karan et al. 1994) and New Caledonia (Kagy et al. 2001) had been published. There are also unpublished laboratory test records of BBTV in Guam, plus reliable reports, collected over many years, of the distinctive symptoms of the disease seen in the field 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 the survey of Futuna and no bunchy-top-like symptoms were seen. The nearest thing to such symptoms found on Futuna were two banana plants showing thin strap-like leaves. Samples were collected and included in the BBTV screening that followed and both tested negative for BBTV by ELISA. It is likely that the apparent absence of bunchy top disease on Futuna is because the island has simply escaped introduction of BBTV. This raises an important domestic quarantine concern for the territory. BBTV moves most readily from island to island in infected planting material. Movement of banana planting material (suckers) from Wallis to Futuna should therefore be prevented. In addition, the risk to Futuna could be reduced if levels of bunchy top disease on Wallis were minimised. This can be achieved by employing simple cultural control measures such as those described in Jackson and Wright (2005).

The survey of Futuna island provided the world's first records of a phytoplasma associated with disease symptoms in Indian mulberry and pineapple (Davis et al. 2005a). Leaf proliferation symptoms in pineapple had been observed in the territory before (Kohler 1987), but no diagnostic testing was conducted on these plants. Later in 2006, phytoplasma records from both crops showing similar symptoms in surveys elsewhere in the Pacific were published (Davis et al. 2006a, 2006d). However, the phytoplasmas involved in each location are different. The ones found in these crops on Futuna both belonged to the '*Candidatus* Phytoplasma asteris' (16SrI) group. Those 'infecting' noni in Tonga and pineapple in New Caledonia belonged instead to the '*Ca.* Phytoplasma solani' group (16SrXII). The finding of a phytoplasma in cassava is also the first for this crop in the region. Previously, phytoplasmas were known to be associated with only cassava frog skin disease in Colombia (Alvarez 2002), which lies directly to the east of the Pacific. Here again, a different phytoplasma was involved, one belonging to the '*Ca.* Phytoplasma pruni' group. The cassava phytoplasma could be causing a significant disease, as the plot from which it came contained many plants showing similar symptoms, grouped together in patches.

Importantly, the '*Ca.* Phytoplasma asteris' (16SrI) group and '*Ca.* Phytoplasma aurantifolia' (16SrII) group phytoplasmas found on Futuna are unrelated to some of the principal phytoplasma quarantine threats to the Pacific region. Perhaps ranking highest amongst these are the phytoplasmas associated with lethal diseases of coconuts and white leaf disease of sugarcane. Coconut-infecting phytoplasmas belong to the Coconut lethal yellowing (16SrIV) group. This group includes the phytoplasma associated with coconut lethal yellowing disease tentatively named '*Candidatus* Phytoplasma palmae' and phytoplasmas associated with similar diseases of coconut on the African continent, tentatively named '*Candidatus* Phytoplasma cocostanzaniae' and '*Candidatus* Phytoplasma cocosnigeriae' (IRPCM 2004). Coconut lethal yellowing

disease has devastated coconut populations in Central America and the Caribbean (Bourdeix et al. 2004), resulting in a significant economic impact on tourism and other industries. The phytoplasma associated with sugarcane white leaf disease is a member of the '*Candidatus* Phytoplasma cynodontis' (16SrXIV) group. Sugarcane white leaf is an important disease of sugarcane in South-East Asia. In the Pacific, sugarcane is the major agricultural crop in the Fiji Islands and is also of importance in PNG. This study provides further evidence that the major phytoplasma threats to certain Pacific island plant commodities are probably still present only outside the Pacific region, highlighting the importance of maintaining a high level of quarantine vigilance.

These surveys provided more negative quantitative data that support the widely held belief that HLB is not present in the Pacific islands east of New Guinea. The negative citrus HLB screening results reported here adds to the body of evidence published recently (Davis et al. 2005b, 2006c, 2006d) in which citrus trees targeted for testing because of their disease-like symptom expression, have been indexed HLB negative by molecular methods.

The tomato leaf sample from French Polynesia was tested for a number of viruses because this crop, growing in a hydroponics glasshouse (belonging to Hortiplus Co.), has been showing unusual disease symptoms for several years. The testing conducted has possibly eliminated some key geminivirus (TYLCV) and tospovirus (TSWV and INSV) possibilities, as well as PepMV (genus *Potexvirus*) and AMV (genus *Alfamovirus*) from further investigation.

The survey of Wallis and Futuna suggests that kava dieback disease may be absent. This is an important observation, as kava is a major commodity there. Kava dieback disease, which is caused by CMV in combination with other factors (Davis et al. 1996), is the worst production problem for this crop in the Pacific. No symptoms of kava dieback disease or leaf symptoms typical of infection by CMV (yellow on green mosaic and leaf distortions) were found on any kava plants examined on Futuna or Alofi. The nearest thing to leaf symptoms found were slight mosaic-like discolourations and crinkling on Alofi island. One leaf sample from Alofi tested negative for the virus by ELISA and two more were negative using the far more sensitive RT-PCR test. Although reports of kava dieback disease symptoms are known from many Pacific islands, verified records of CMV infection in kava are known only for Tonga, Fiji, Vanuatu, Samoa (Davis et al. 1996), Cook Islands (Davis et al 2005e) and Hawai'i (see: http://www.ctahr.hawaii.edu/fb/). These surveys add French Polynesia to this list, although kava was only a minor crop in French Polynesia at the time the survey was conducted. CMV infection of kava was confirmed on Tahiti but, in each case, no dieback symptoms were seen. CMV infection that does not lead to dieback disease development is possible if interacting abiotic factors are not present (Davis et al. 2006b). The CMV detected in two *C. diffusa* plants on Tahiti is also of note because a kava dieback disease management strategy that includes control of key alternative hosts (Davis et al. 2006b) is now being promoted. *C. diffusa* may be an important alternative host for dieback-causing strain(s) of CMV. In 2001, potyvirus particles were seen in kava leaves from Tahiti (Table 2). These leaf samples came from one of the locations where kava plants were sampled again in this study (authors' unpublished data). This was why all kava leaf samples were tested for potyvirus. This time no potyvirus infection was found.

The viruses causing mosaic diseases in cucurbits in French Polynesia were the potyviruses PRSV-W and ZYMV, and the only cucurbit mosaic record for Wallis and Futuna was a marginally positive test result for ZYMV on Wallis. Other potyviruses were prevalent in French Polynesia, causing significant levels of disease in crops. These were BCMV in snakebean and TuMV in brassicas. Members of the genus *Potyvirus* share some common characteristics of significance when considering control. They cause systemic infections, meaning that infected plants cannot be cured with any spray treatment or by removing parts of the plant showing symptoms. They also cannot survive in the soil or in decayed plant material. These potyviruses are all spread from plant to plant by many different species of aphid vectors in a non-persistent manner. This means 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. In this way, aphids move from crop host to crop host and spread the virus within the crop. They can also introduce virus from weed hosts into 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, the insects are disturbed, fly to other nearby plants and feed and transmit virus before they die. Older susceptible crops, wild susceptible crop plants and certain weeds can be significant reservoirs of potyvirus inoculum for new plantings. Natural hosts of PRSV-W and ZYMV

are mostly in the Cucurbitaceae (see: http://image.fs.uidaho.edu/vide/sppindex.htm#S). Whilst BCMV has many hosts in the Fabaceae (see: http://image.fs.uidaho.edu/vide/descr068.htm), and TuMV has many hosts in the Brassicaceae (see: http://image.fs.uidaho.edu/vide/descr855.htm), both viruses have natural hosts in other families. Another important way of introducing virus into a crop can be with seed. BCMV can be seed transmitted at high rates (see: http://image.fs.uidaho.edu/vide/descr068.htm), and 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 New Zealand (Burgmans and Fletcher 2000; Fletcher et al. 2000). In contrast, PRSV-W and TuMV are not thought to be seed transmitted. The best method to combat these viruses is to use resistant or tolerant cultivars, which are available for several cucurbit crops.

During the surveys reported here, BSV-like symptoms were fairly common in the banana cv. Mysore on both Wallis and Futuna and virus presence was confirmed by real-time PCR in representative leaf samples plus one Cavendish group banana plant. Although BSV is widespread in Wallis and Futuna, losses may not be serious since it is known that Queensland strains of this virus cause yield losses of only 7–15% (Daniells et al. 1999). In contrast to Wallis and Futuna, banana streak disease symptoms could not be found in French Polynesia. The incidence of banana streak disease can be kept low if planting material is selected carefully. This is because most virus transmission occurs through infected planting material and plant-to-plant spread by mealybug vectors is not great (Lockhart and Jones 1999).

TaBV, TaVCV and DsMV are widespread across the Pacific (Revill et al. 2005). In the study of Revill et al. (2005), DsMV was found in every country and territory visited and TaBV was present in all but one. TaVCV was more unevenly distributed in those surveys, being found on just over half of the states. Results of the surveys reported here add these two French territories to the distribution map and reveal a similar pattern. DsMV was again widespread, confirmed on every island surveyed except for Tubuai, where a taro leaf sample gave only a marginally positive test result. TaVCV symptoms were seen often (and virus presence confirmed) on Futuna, only once on Wallis (also confirmed) and not at all in French Polynesia. TaBV was not associated with any particular leaf symptoms in the surveys reported here and was widespread in Wallis and Futuna, but detected only once in French Polynesia. Whilst the importance of TaBV and TaVCV is still unclear (Revill et al. 2005), DsMV has been implicated in causing yield losses in taro (Jackson et al. 2001) and ornamental aroids (Chase and Zettler 1982).

Mosaic symptoms were common on *P. foetida* on all three islands visited in the territory of Wallis and Futuna. However, it was possible to confirm potyvirus infection only for the *P. foetida* samples sent for analysis from Wallis and Futuna. The potyvirus may be *Passionfruit woodiness virus* (PWV), an important constraint to passionfruit production in Queensland, Australia (Persley 1993). This was the case when a high incidence of similar symptoms were seen in *P. foetida* in Samoa (Davis et al. 2006c). However, it could also be a different potyvirus, as co-infections of PWV with an as yet unassigned potyvirus (tentatively named *Passiflora virus Y,* PaVY) have recently been investigated in Australia and the island of New Guinea (Parry et al. 2004). The symptoms shown by the PWV-positive *P. foetida* leaves in Wallis and Futuna are identical to those of PaVY in *P. foetida* found in northern Australia (authors' unpublished data). Further virus-specific testing of these samples in Australia is planned.

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Table 1. Verified plant virus records from French Polynesia

Pathogen	Host	Citation[A]	Identification method[B]
Bean common mosaic virus (BCMV)	*Vanilla tahitiensis*	Grisoni et al. (2004)	Serology, RT-PCR
Citrus tristeza virus (CTV)	*Citrus* spp.	Wong et al. (1997)	Serology
Cucumber mosaic virus (CMV)	*Vanilla tahitiensis*	Farreyrol et al. (2001)	Serology, RT-PCR
Cymbidium mosaic virus (CymMV)	*Spathoglottis plicata*	Davidson and Grisoni (1999)	Serology
Cymbidium mosaic virus (CymMV)	*Vanilla tahitiensis*	Wisler et al. (1987)	Serology
Dasheen mosaic virus (DsMV)	Araceae	Hammes et al. (1989)	Serology
Hop stunt viroid (HSVd)	*Citrus reticulata*	Vogel (1976)	Indicator hosts
Odontoglossum ringspot virus (ORSV)	Orchidaceae	Wisler et al. (1987)	Serology
Odontoglossum ringspot virus (ORSV)	*Vanilla tahitiensis*	Grisoni et al. (2004)	Serology
Papaya ringspot virus-P (PRSV)	*Carica papaya*	Davis et al.(2005d)	Serology
Taro baciliform virus (TaBV)	*Colocasia esculenta*	Pearson and Grisoni (2002)[C]	Nucleic acid analysis
Tomato mosaic virus (ToMV)	*Lycopersicon esculentum*	SPC unpublished data[D]	ISEM
Vanilla mosaic virus (VanMV)	*Vanilla tahitiensis*	Wisler et al. (1987)	Serology
Watermelon mosaic virus (WMV) Vanilla necrosis strain	*Vanilla planifolia*	Davidson and Grisoni (1999)	Serology

[A]The original or earliest available citation of a reliably verified record is provided.
[B] ISEM: immunosorbent electron microscopy; RT-PCR: reverse transcription polymerase chain reaction.
[C]Personal communication that virus specific DNA sequences were detected is cited.
[D]Sample analysed by P. Jones, 2001.

Table 2. Other records indicating possible presence of plant infecting viruses and virus-like pathogens in French Polynesia

Pathogen	Host	Citation	Identification method[A]
Citrus psorosis virus (CPsV, plus other viruses in a complex)	*Citrus* spp.	Hammes et al. (1989)	Symptoms observed
Citrus exocortis viroid (CEVd)	*Citrus* spp.	Hammes et al. (1989)	Symptoms observed
--	*Poncirus trifoliata*	Hammes et al. (1989)	Symptoms observed
Cucumber mosaic virus (CMV)	Cucurbitaceae	Hammes et al. (1989)	EM
--	*Musa* sp.	Hammes et al. (1989)	Symptoms observed
Potato leaf roll virus (PLRV)	*Solanum tuberosum*	Hammes et al. (1989)	Symptoms observed
Potato virus X (PVX)	*Lycopersicon esculentum*	Hammes et al. (1989)	EM
Potyvirus	*Piper methysticum*	SPC unpublished data[B]	EM
Turnip mosaic virus (TuMV)	*Brassica napus*	Hammes et al. (1989)	EM
Tobacco mosaic virus (TMV)	*Lycopersicon esculentum*	Hammes et al. (1989)	EM
Tobacco mosaic virus (TMV)	*Nicotiana tabacum*	Hammes et al. (1989)	Symptoms observed
Watermelon mosaic virus (WMV)	Cucurbitaceae	Hammes et al. (1989)	EM

[A]EM: electron microscopy
[B]Sample analysed by P. Jones, 2001.
Observation of particles of correct size and shape by electron microscopy (EM) alone is not considered a definitive identification method unless combined with some other technique.

Table 3. Other records indicating possible presence of plant infecting viruses in Wallis and Futuna

Pathogen	Host	Citation	Identification method
Banana bunchy top virus (BBTV)	*Musa* sp.	Kohler (1987)	Symptoms observed
Citrus psorosis virus (CPsV, plus other viruses in a complex)	*Citrus* spp.	Kohler (1987)	Symptoms observed
Dasheen mosaic virus (DsMV)	*Alocasia macrorhiza*	Kohler (1987)	Symptoms observed
Dasheen mosaic virus (DsMV)	*Xanthosoma* sp.	Kohler (1987)	Symptoms observed

Table 4. Plant virus records from a survey of French Polynesia, September–October 2004

Host plant family and species	Field collection number	Approximate location	Symptoms[A]	Pathogen[B]
Araceae				
Colocasia esculenta (taro)	3783	Papara, Tahiti	WOGM	DsMV, TaBV
	3870	Opunohu, Moorea	WOGM and distortion	DsMV
	3890	Tamatoa, Tubuai	WOGM	DsMV + m
Brassicaceae				
Brassica chinensis (Chinese cabbage)	3776	Papara, Tahiti	YOGM	TuMV
	3777	Papara, Tahiti	YOGM	TuMV + m
	3810	Toahotu, Tahiti	YOGM	TuMV
	3858	Haapiti, Moorea	YOGM	TuMV
	3859	Haapiti, Moorea	YOGM	TuMV
	3866	Opunohu, Moorea	YOGM	TuMV
Brassica chinensis (pak choi)	3800	Taravao, Tahiti	YOGM	TuMV
Raphanus sativus var. *longipinnatus* (Chinese radish)	3812	Toahotu, Tahiti	YOGM and distortion	TuMV
Commelinaceae				
Commelina diffusa	3770	Tiare, Tahiti	Strong and streaky YOGM	CMV
	3784	Papara, Tahiti	Strong and streaky YOGM	CMV
	3796	Papara, Tahiti	Strong and streaky YOGM	CMV
Cucurbitaceae				
Cucurbita maxima (pumpkin)	3781	Papara, Tahiti	YOGM	PRSV
	3782	Papara, Tahiti	YOGM	PRSV
	3794	Papara, Tahiti	YOGM	PRSV
	3833	Faaa, Tahiti	YOGM	PRSV
Cucurbita pepo ssp. *pepo* var. *pepo* (zucchini)	3803	Taravao, Tahiti	Feint YOGM	PRSV
	3804	Taravao, Tahiti	Feint YOGM	PRSV
	3805	Taravao, Tahiti	Feint YOGM	PRSV
	3808	Taravao, Tahiti	YOGM and strap-like leaves	PRSV
	3905	Taahueia, Tubuai	YOGM	ZYMV
Fabaceae				
Vigna unguiculata ssp. *sesquipedalis* (snake bean)	3826	Tautira, Tahiti	YOGM	BCMV[C]
	3828	Tautira, Tahiti	YOGM	BCMV[C], CMV
	3829	Tautira, Tahiti	YOGM	BCMV[C], CMV
	3840	Faaa, Tahiti	YOGM	BCMV[C]
	3842	Faaa, Tahiti	YOGM	BCMV[C]
	3843	Faaa, Tahiti	YOGM – strong	BCMV[C]
	3845	Faaa, Tahiti	YOGM	BCMV[C]
	3846	Faaa, Tahiti	YOGM – strong	BCMV[C]
	3856	Faaa, Tahiti	YOGM	BCMV[C]
	3857	Faaa, Tahiti	YOGM – strong	BCMV[C]

Musaceae				
Musa sp. (AAB)	3814	Toa Hotu, Tahiti	Chlorotic streaks	CMV
Orchidaceae				
'Arunda' hybrid	3821	Toahotu, Tahiti	Chlorotic streaks	CymMV, ORSV
	3822	Toahotu, Tahiti	Chlorotic streaks	CymMV, ORSV
Dendrobium sp.	3818	Toahotu, Tahiti	Chlorotic spots	CymMV
	3819	Toahotu, Tahiti	Chlorotic spots	CymMV
	3820	Toahotu, Tahiti	Chlorotic blotch	CymMV
	3883	Taahueia, Tubuai	Chlorotic blotch	CymMV
	3884	Taahueia, Tubuai	Chlorotic streaks	CymMV, ORSV
Vanilla tahitiensis	3835	Faaa, Tahiti	Distortion and chlorotic blotch	CMV
	3885	Taahueia, Tubuai	Distortion	CMV
Piperaceae				
Piper methysticum (kava)	3787	Mataeia, Tahiti	YOGM	CMV
	3788	Mataeia, Tahiti	YOGM	CMV
	3792	SDR, Papara, Tahiti	YOGM at veins	CMV
	3793	SDR, Papara, Tahiti	Blotchy chlorosis	CMV
	3863	Opunohu, Moorea	YOGM	CMV
Rutaceae				
Citrus x *limon* (lemon)	3806	Taravao, Tahiti	Chlorotic blotch	CTV
	3807	Taravao, Tahiti	Chlorotic blotch	CTV
	3836	Faaa, Tahiti	Chlorotic blotch	CTV
	3871	Opunohu, Moorea	Chlorotic blotch, vein clearing	CTV
Solanaceae				
Lycopersicon esculentum	3780	Papara, Tahiti	YOGM	CMV, Potyvirus
	3844	Faaa, Tahiti	YOGM	Potyvirus

[A]WOGM: white on green mosaic; YOGM: yellow on green mosaic.
[B]Viruses were: BCMV, *Bean common mosaic virus*; CMV, *Cucumber mosaic virus*; CTV, *Citrus tristeza virus*; CymMV, *Cymbidium mosaic virus*; DsMV, *Dasheen mosaic virus*; ORSV, *Odontoglossum ringspot virus*; PRSV, *Papaya ringspot virus*; TaBV , *Taro bacilliform virus*; TuMV, *Turnip mosaic virus*; ZYMV, *Zucchini yellow mosaic virus*. Potyvirus: identified to genus only.
[C]All BCMV-positive leaf samples were also positive when tested with potyvirus group antisera.
All viruses were identified by enzyme-linked immunosorbent assay (ELISA). ELISA test results were considered positive when A405 > 3 x mean of healthy controls. Marginally positive results (+m) were those of A405 > 2 x mean of healthy controls, but < 3 x mean.

Table 5. Plant virus and phytoplasma records from a survey of Wallis and Futuna, May 2004

Host plant family and species	Field collection number	Approximate location	Symptoms[A]	Virus/phytoplasma[B]
Araceae				
Colocasia esculenta (taro)	3632	South, Futuna	Chlorotic veins	TaVCV, TaBV
	3645	Somalama, Futuna	Chlorotic and necrotic veins	TaVCV
	3689	Mataitai, Wallis	Chlorotic veins	TaVCV, TaBV
	3688	Mata Utu, Wallis	WOGM	DsMV
	3687	Mata Utu, Wallis	Chlorotic veins	TaBV
Xanthosoma sp. (taro)	3626	Asoa, Futuna	WOGM and distortion	DsMV
	3627	Asoa, Futuna	WOGM and distortion	DsMV
	3633	South, Futuna	WOGM and distortion	DsMV
	3664	Alofi	WOGM and distortion	DsMV, TaBV
	3682	Nr Loka, Wallis	WOGM and distortion	DsMV, TaBV
	3629	South, Futuna	Mild chlorotic veins	TaBV
Asteraceae				
Emilia sonchifolia	3657	Asipa, Futuna	Phyllody	Phytoplasma in '*Ca.* P. aurantifolia' (16SrII) group[C]
	3640	Peka, Futuna	Phyllody and witches' broom	Phytoplasma, not sequenced
Bromeliaceae				
Ananas comosus (pineapple)	3641	Peka, Futuna	Proliferation of thin leaves	Phytoplasma in '*Ca.* P. asteris' (16SrI) group[C]
Cucurbitaceae				
Citrullus lanatus (watermelon)	3669	Ahoa, Wallis	YOGM	ZYMV +m
Euphorbiaceae				
Manihot esculenta (cassava)	3650	Airstrip, Futuna	Little leaf, witches' broom and yellowing	Phytoplasma in '*Ca.* P. asteris' (16SrI) group[C]
Musaceae				
Musa sp. (AAB: Maia Maoli–Popoulu sub group)	3670	Ahoa, Wallis	Bunchy-top-like leaf symptoms only[D]	BBTV +m
Musa sp. (AAB)	3685	Mata Utu, Wallis	Bunchy-top-like[D]	BBTV
Musa sp. (ABB)	3686	Mata Utu, Wallis	Bunchy-top-like[D]	BBTV
Musa sp. (Cavendish)	3691	Ahoa Rd, Wallis	Bunchy-top-like[D]	BBTV +m
Musa sp. (cv. Mysore/Somuso)	3628	Asoa, Futuna	Chlorotic streaks plus brown black markings	BSV
Musa sp. (cv. Mysore/Somuso)	3644	Samalama, Futuna	Chlorotic streaks plus brown black markings	BSV
Musa sp. (cv. Mysore/Somuso)	3684	Mata Utu, Wallis	Chlorotic streaking only	BSV
Musa sp. (cv. Mysore/Somuso)	3694	Mua, Wallis	Chlorotic streaks plus brown black markings	BSV
Musa sp. (Cavendish group)	3638	Nr Bouma, Futuna	Chlorotic streaks on bract only	BSV
Passifloraceae				
Passiflora foetida	3623	Asoa, Futuna	YOGM	Potyvirus
	3631	South, Futuna	YOGM	Potyvirus
	3635	Sigave, Futuna	YOGM – strong	Potyvirus
	3663	Alofi	YOGM	Potyvirus
	3672	Ahoa, Wallis	YOGM	Potyvirus
	3680	Loka, Wallis	YOGM	Potyvirus

Polygalaceae				
Polygala paniculata	3642	Peka, Futuna	Phyllody	Phytoplasma in '*Ca.* P. aurantifolia' (16SrII) group[C]
	3656	Asipa, Futuna	Phyllody and little leaf	Phytoplasma, not sequenced
Rubiaceae				
Morinda citrifolia (noni/Indian mulberry)	3643	Peka, Futuna	Yellowing	Phytoplasma in '*Ca.* P. asteris' (16SrI) group[C]
	3692	Ahoa Rd, Wallis	Chlorotic blotch	Phytoplasma, not sequenced
Rutaceae				
Citrus maxima (pomelo)	3675	Apala, Wallis	GOYVB and chlorosis	CTV
Citrus x *limon* (lemon)	3677	Apala, Wallis	Bark scaling and some chlorotic flecks on leaf	CTV
Citrus reticulata (mandarin)	3676	Apala, Wallis	GOYVB and upright leaf growth	CTV

[A]GOYVB, green on yellow vein banding; 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*; CTV, *Citrus tristeza virus*; DsMV, *Dasheen mosaic virus*; TaBV , *Taro bacilliform virus*; TaVCV, *Taro vein chlorosis virus*; ZYMV, *Zucchini yellow mosaic virus*. Potyvirus: identified to genus only.
[C]Data also published in Davis et al. (2006a).
[D]Symptoms similar to those of banana bunchy top seen on the leaves: leaves thin and chlorotic at the margins and showing a 'running W' leaf shape in profile, or on the leaves and also the whole plant: upright bunchy-top-like growth habit plus thin upright leaves.
TaVCV was detected by reverse transcription polymerase chain reaction (RT-PCR); phytoplasmas were detected by nested PCR, then identified by sequence analysis; BSV was detected by real-time PCR; and the potyvirus identifications were achieved by immunosorbent electron microscopy only. BBTV, CMV, CTV, DsMV and ZYMV were identified by ELISA. ELISA test results were considered positive when A405 > 3 x mean of healthy controls. Marginally positive results (+m) were those of A405 > 2 x mean of healthy controls, but < 3 x mean.

Table 6. Notable samples from French Polynesia in which no pathogen was detected in specific tests

Host plant family and species	Field collection number	Approximate location	Symptoms	Tested negative for
Rutaceae				
Citrus x *limon* (lemon)	3806	Taravao, Tahiti	Chlorotic blotch	HLB[A]
	3807	Taravao, Tahiti	Chlorotic blotch	HLB[A]
	3836	Faaa, Tahiti	Chlorotic blotch	HLB[A]
	3871	Opunohu, Moorea	Chlorotic blotch, vein clearing	HLB[A]
Solanaceae				
Lycopersicon esculentum	3773	Papara, Tahiti	Thin, strap-like, curling leaves with purple colouration	TSWV, INSV, AMV, TYLCV, PepMV[B]

[A]Tested by PCR for presence of '*Candidatus* Liberibacter asiaticus'.
[B]Tested negative by ELISA for *Tomato spotted wilt virus* (TSWV), *Impatiens necrotic spot virus* (INSV), *Alfalfa mosaic virus* (AMV), *Tomato yellow leaf curl virus* (TYLCV), and *Pepino mosaic virus* (PepMV).

Table 7. Notable samples from Wallis and Futuna in which no pathogen was detected in specific tests

Host plant family and species	Field collection number	Approximate Location	Symptoms[A]	Tested negative for
Rutaceae				
Citrus maxima (pomelo)	3675	Apala, Wallis	GOYVB and chlorosis	HLB[B]
Citrus x *limon* (lemon)	3677	Apala, Wallis	Chlorotic flecks on leaf	HLB[B]
	3696	SW Wallis	Chlorotic blotch and corky veins	HLB[B]
Citrus reticulata (mandarin) mandarin, tangerine	3676	Apala, Wallis	GOYVB, upright leaves	HLB[B]
	3634	Sigave, Futuna	GOYVB	HLB[B]
	3653	Hospital, Futuna	Chlorosis and stunt and small upright leaves	HLB[B]
	3654	Hospital, Futuna	Chlorotic blotch, small upright leaves, corky veins	HLB[B]
Musaceae				
Musa sp. (AAB)	3625	Asoa, Futuna	Thin strap like leaves with chlorotic streaks	BBTV[C]
Musa sp. (Cavendish group)	3652	Nr hospital, Futuna	Thin strap like leaves	BBTV[C]
Piperaceae				
Piper methysticum (kava)	3665	Alofi	Slight YOGM plus crinkle	CMV[D]
	3666	Alofi	Crinkle on one stem only	CMV[E]
	3667	Alofi	Crinkle on one stem only	CMV[E]

[A]GOYVB, green on yellow vein banding; YOGM, yellow on green mosaic.
[B]Tested by PCR for presence of '*Candidatus* Liberibacter asiaticus'.
[C]Tested negative for *Banana bunchy top virus* (BBTV) by ELISA.
[D] Tested negative for *Cucumber mosaic virus* (CMV) by ELISA.
[E] Tested negative for *Cucumber mosaic virus* (CMV) by RT-PCR.

FIGURES

Fig. 1. RID 3870: *Colocasia esculenta* (taro) infected with *Dasheen mosaic virus* (DsMV) showing white on green mosaic symptoms and leaf distortion: French Polynesia.

Fig. 2. RID 3776: *Brassica chinensis* (Chinese cabbage) infected with *Turnip mosaic virus* (TuMV) showing yellow on green mosaic symptoms: French Polynesia.

Fig. 3. RID 3812: *Raphanus sativus* var. *longipinnatus* (Chinese radish) infected with *Turnip mosaic virus* (TuMV) showing yellow on green mosaic symptoms: French Polynesia.

Fig. 4. RID 3833: *Cucurbita maxima* (pumpkin) infected with *Papaya ringspot virus* (PRSV-W) showing yellow on green mosaic symptoms: French Polynesia.

Fig. 5. RID 3842: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean) infected with *Bean common mosaic virus* (BCMV) showing yellow on green mosaic symptoms: French Polynesia.

Fig. 6. RID 3843: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean) infected with *Bean common mosaic virus* (BCMV) showing strong yellow on green mosaic symptoms: French Polynesia.

Fig. 7. RID 3821: Ornamental orchid ('Arunda' hybrid) infected with *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ringspot virus* (ORSV) showing chlorotic streak symptoms: French Polynesia.

Fig. 8. RID 3818: *Dendrobium* sp. infected with *Cymbidium mosaic virus* (CymMV) showing chlorotic spot symptoms: French Polynesia.

Fig. 9. RID 3820: *Dendrobium* sp. infected with *Cymbidium mosaic virus* (CymMV) showing chlorotic blotch symptoms: French Polynesia.

Fig. 10. RID 3835: *Vanilla tahitiensis* (vanilla) infected with *Cucumber mosaic virus* (CMV) showing distorted leaf shape: French Polynesia.

Fig. 11. RID 3780: *Lycopersicon esculentum* (tomato) infected with *Cucumber mosaic virus* (CMV) and an unidentified potyvirus showing yellow on green mosaic symptoms: French Polynesia.

Fig. 12. RID 3844: *Lycopersicon esculentum* (tomato) infected with an unidentified potyvirus showing yellow on green mosaic symptoms: French Polynesia.

Fig. 13. RID 3632: *Colocasia esculenta* (taro) infected with *Taro vein chlorosis virus* (TaVCV) and *Taro bacilliform virus* (TaBV) showing chlorotic vein symptoms: Wallis and Futuna.

Fig. 14. RID 3645: *Colocasia esculenta* (taro) infected with *Taro vein chlorosis virus* (TaVCV) showing chlorotic and necrotic vein symptoms: Wallis and Futuna.

Fig. 15. RID 3689: *Colocasia esculenta* (taro) infected with *Taro vein chlorosis virus* (TaVCV) and *Taro bacilliform virus* (TaBV) showing strong chlorotic vein symptoms: Wallis and Futuna.

Fig. 16. RID 3627: *Xanthosoma* sp. (taro) infected with *Dasheen mosaic virus* (DsMV) showing white on green mosaic symptoms and leaf distortion: Wallis and Futuna.

Fig. 17. RID 3641: *Ananas comosus* (pineapple) 'infected' with a Phytoplasma in the '*Ca.* P. asteris' (16SrI) group showing a proliferation of thin leaves: Wallis and Futuna.

Fig. 18. RID 3650: *Manihot esculenta* (cassava) 'infected' with a Phytoplasma in '*Ca.* P. asteris' (16SrI) group showing little leaf, witches' broom and yellowing: Wallis and Futuna.

Fig. 19. Planting of *Manihot esculenta* (cassava) in Wallis and Futuna from which sample RID 3650 was taken. Patches of plants show yellowing and growth abnormalities, possibly all caused by a phytoplasma in '*Ca.* P. asteris' (16SrI) group.

Fig. 20. RID 3686: *Musa* sp. (banana) suckers infected with *Banana bunchy top virus* (BBTV) showing typical banana bunchy top disease symptoms (thin, upright leaves, chlorotic at the margins plus upright bunchy growth habit): Wallis Island.

Fig. 21. RID 3628: *Musa* sp. (banana, cv. Mysore) infected with *Banana streak virus* (BSV) showing chlorotic streaks with brown/black markings superimposed: Wallis and Futuna.

Fig. 22. RID 3680: *Passiflora foetida* (wild passionfruit) infected with an unidentified potyvirus showing yellow on green mosaic symptoms: Wallis and Futuna.

Fig. 23. RID 3638: *Musa* sp. (banana, Cavendish subgroup) infected with *Banana streak virus* (BSV) showing chlorotic streaks on bracts: Wallis and Futuna.

Fig. 24. RID 3643: *Morinda citrifolia* (noni/Indian mulberry) 'infected' with a phytoplasma in the '*Ca.* P. asteris' (16SrI) group showing yellowing symptoms: Wallis and Futuna.

Fig. 25. RID 3692: *Morinda citrifolia* (noni/Indian mulberry) 'infected' with a phytoplasma of unknown strain group showing chlorotic blotch symptoms: Wallis and Futuna.