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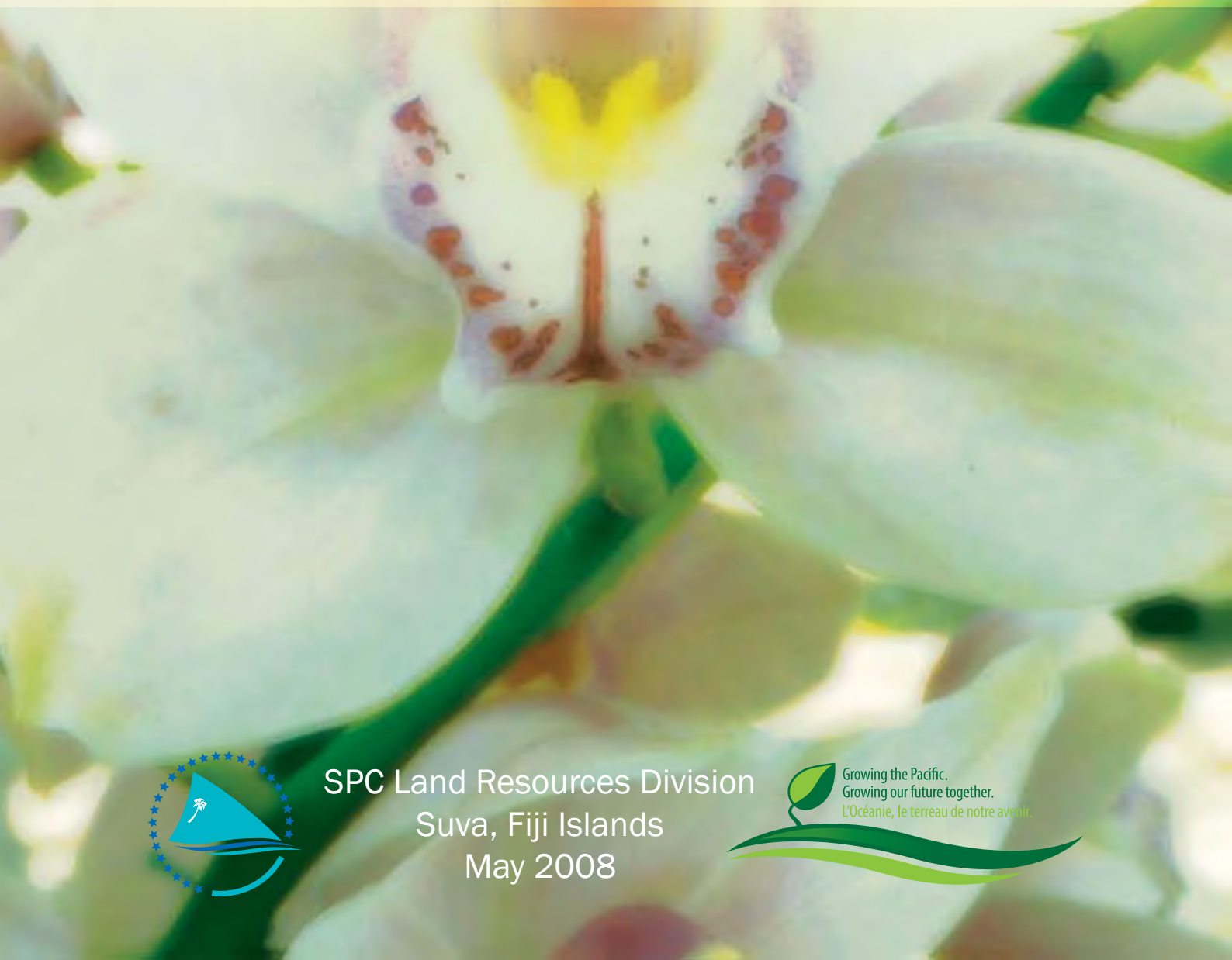

SPC Land Resources Division
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Surveys for **Plant Diseases** caused by **Viruses** and **Virus-like Pathogens** in the

US Territory of Guam, the Commonwealth of the Northern Mariana Islands, the Republic of the Marshall Islands and Nauru

by

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ABSTRACT

Surveys for virus and virus-like plant diseases were conducted in the US territory of Guam; in the Commonwealth of the Northern Mariana Islands (CNMI), on the islands of Saipan, Rota and Tinian; in the Republic of the Marshall Islands (RMI) on the atolls of Majuro and Arno; and on Nauru.

New virus records for Guam were those of *Watermelon mosaic virus* (WMV) in bitter gourd *(Momordica charantia), Citrus tristeza virus* (CTV) in several *Citrus* spp., *Potato virus Y* (PVY) in tomato *(Lycopersicon esculentum)* and chilli *(Capsicum annuum* var. *annuum)*, *Tomato mosaic virus* (ToMV) in tomato, and *Cymbidium mosaic virus* (CymMV) in ornamental orchids (*Dendrobium* spp. and *Oncidium* sp.), all detected by enzyme-linked immunosorbent assay (ELISA); and of *Taro bacilliform virus* (TaBV) in taro *(Colocasia esculenta)*, detected by polymerase chain reaction (PCR). The survey of CNMI provided the first laboratory confirmation, by ELISA, of the presence of *Banana bunchy top virus* (BBTV) in banana *(Musa* sp.*)* following many visual reports of bunchy-top-disease-like symptoms. Other new virus records for CNMI, determined by ELISA, were of *Dasheen mosaic virus* (DsMV) in taro *(C. esculenta* and *Xanthosoma* sp.), CTV in three *Citrus* sp., and both *Tobacco mosaic virus* (TMV) and ToMV in chilli. New virus records for RMI were of the cucurbit-infecting strain of *Papaya ringspot virus* (PRSV-W) in pumpkin *(Cucurbita maxima)* and cucumber *(Cucumis sativus)* and *Bean common mosaic virus* (BCMV) in *Phaseolus vulgaris* (garden bean), both detected by ELISA. New records for Nauru were of *Zucchini yellow mosaic virus* (ZYMV) in pumpkin, bitter gourd, and ridge gourd *(Luffa acutangula)*, PRSV-W in bitter gourd, BCMV in snakebean *V. unguiculata* ssp. *unguiculata)*, *Cucumber mosaic virus* (CMV) in the roadside weeds *Synedrella nodiflora* and *Physalis angulata*, and DsMV in taro *(C. esculenta)*, all detected by ELISA; plus TaBV in taro *(C. esculenta)* detected by PCR.

The first phytoplasma found on Nauru was identified by nested PCR in a roadside weed *(Crotalaria* sp.*)*.

New host records for Guam were of CMV in tomato and chilli and PRSV-W in cucumber and the cucurbit weed, *Coccinia grandis*, all detected by ELISA. New host records for CNMI, detected by ELISA, were of PRSV-W in *C. grandis*, ridge gourd and bitter gourd; ZYMV in ridge gourd; and CMV in chilli and tomato. Other detections by ELISA, were of BCMV, PRSV-W and the papaya-infecting strain of *Papaya ringspot virus* (PRSV-P) in both Guam and CNMI; and of ZYMV and DsMV on Guam.

During these surveys, banana plants were examined for symptoms of fusarium wilt (Panama disease), caused by the fungus *Fusarium oxysporum* Schlecht. f.sp. *cubense (Foc)*. An isolate of *Foc* belonging to vegetative compatibility group (VCG) 0123 was recovered from a wilting banana on the island of Rota in CNMI.

In all surveys, no evidence was found for presence of citrus huanglongbing, previously known as greening disease. Three citrus trees each on Guam and Nauru, eight in CNMI, and six in RMI indexed negative by PCR for '*Candidatus* Liberibacter asiaticus', the huanglongbing causal agent.

Introduction

Surveys were conducted to assess the general plant virus and virus-like disease status of Guam, the Commonwealth of the Northern Mariana Islands (CNMI), Nauru and two of the larger atolls (Majuro and Arno) in the Republic of the Marshall Islands (RMI). These islands share in common great geographical isolation, combined with a history of particularly close linkages with distant, larger economies. It is possible that this could have exposed them to introduction of exotic plant pests. Guam is a territory of the USA and CNMI and RMI have both maintained a 'Compact of Free Association' with the USA now for several decades. Nauru is also a small island nation with close ties to several larger countries, particularly Australia, associated with phosphate exports. With the exception of Guam, little plant virus research has taken place in this region and virus/virus-like plant disease status has been relatively poorly documented. Various research works at the University of Guam, plus a focused cucurbit virus survey (Wall 1990; Yudin et al. 1990; Wall et al. 2006), have resulted in several plant virus records for that island (Table 1) and also for CNMI (Table 2). In addition, a virus disease identification of *Citrus tristeza virus* (CTV) based on field symptoms only on Guam has also been cited in Pearson and Grisoni (2002). The only records from RMI (Table 3) result from a focused taro virus disease survey (Revill et al. 2005) and there are no published records of plant virus disease test results from Nauru.

Two major virus diseases of fruit crops that have a patchy distribution in the Pacific (present on some islands but absent from others) are found on both Guam and CNMI. These are bunchy top disease of banana, caused by *Banana bunchy top virus* (BBTV) and papaya ringspot disease, caused by the papaya-infecting strain of *Papaya ringspot virus* (PRSV-P). BBTV is a virus of extreme quarantine concern in the Pacific. By late 2006, laboratory test records confirming presence of BBTV in Fiji, Tonga, Samoa (Karan et al. 1994), New Caledonia (Kagy et al. 2001) and the territory of Wallis and Futuna (Davis et al. 2006c) had been published. Laboratory test records of BBTV on Guam (University of Guam, unpublished data) also go back to 1994. There are also reliable reports, collected over many years, of the distinctive symptoms of the disease seen in the field in CNMI, Tuvalu and American Samoa. According to available published records a diagnostic test to confirm these visual observations has never been performed. PRSV-P is very closely related to the other biotype of this virus, the cucurbit infecting strain of PRSV (PRSV-W), which causes important disease in cucurbit crops through much of the world (Purcifull et al. 1984). PRSV-P is not widespread in the Australasian–Pacific region. The disease appeared in Hawai'i in 1949 (Jensen 1949) then, by the late 1980s, it was known on Guam and CNMI (Wall 1989; Wall et al. 1992; Wall and Quitugua 1995; Wall et al. 2006) as well as south-eastern Queensland in Australia (Thomas and Dodman 1993). More recently, PRSV-P was confirmed in French Polynesia and the Cook Islands (Davis et al. 2005c). Importantly, it is now known that an eradication campaign on the Cook Islands has been successful.

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 by a phloem-limited bacterium, '*Candidatus* Liberibacter asiaticus'. HLB has been a problem in certain Southeast Asian countries near to the north-west Pacific for decades. A report that this virus-like disease was also 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. The disease has, however, recently reached two new locations of significance to the region surveyed. These are the island of New Guinea, where it was found in the Indonesian province of Papua in 1999 (Davis et al. 2000), then Papua New Guinea (PNG) in 2002 (Weinert et al. 2004) and in the US state of Florida (Gottwald 2006). New Guinea is geographically very close to Guam and CNMI. The recent US outbreak is also of significance because Guam, CNMI and RMI import many goods from the USA. For these reasons, these surveys also focused on HLB.

Also in these surveys, a search was made for banana plants showing possible symptoms of fusarium wilt. Fusarium wilt (or Panama disease) is one of the worst disease problems throughout most banana production regions of the world. An important exception to this is the Pacific, where it is a new disease that is not yet widespread. Fusarium wilt is caused by the soil-borne fungus *Fusarium oxysporum* Schlecht. f.sp. *cubense (Foc)*. The first place where *Foc* was found in the Pacific was CNMI, where "race 1" of the fungus was found on Saipan, Rota and Tinian (Trujillo 1971). The race system of classifying different strains of the fungus is considered inaccurate confusing and outdated. Today, strains are named using vegetative compatibility group (VCG) analysis, a laboratory technique that uses cultures of the fungus. Different strains are given a VCG number, and this information is of practical significance because clear relationships exist between VCG and ability to cause disease in different banana types in the field. The VCG of strains of Foc present in CNMI has never been determined.

The surveys of Guam, CNMI and RMI were conducted in November 2006 and the survey of Nauru in January 2007.

Methods

Surveys

To undertake the surveys, as many different areas as possible were visited. Crop plants of economic importance and, occasionally, other plants, were examined at each location. When any kind of symptoms similar to those caused by intracellular pathogens were suspected, samples were collected. Samples 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 two different laboratories for diagnostic tests.

Four days were spent on survey on Guam. The survey of CNMI consisted of three days spent on the island of Saipan, two days on the island of Rota and one day on the island of Tinian. The survey of RMI consisted of two days spent on Majuro atoll and one day on Arno atoll. The survey of Nauru was undertaken over five days.

Enzyme-linked immunosorbent assay (ELISA) testing for viruses

Cucurbit samples from all 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 all surveys, aroid leaf samples *(Colocasia esculenta* and *Xanthosoma* sp.) were tested for *Dasheen mosaic virus* (DsMV) by DAS-ELISA, and citrus leaf samples were tested for CTV by compound direct ELISA. Orchid samples from Guam and CNMI were tested by DAS-ELISA for CMV, *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ringspot virus* (ORSV), and by indirect ELISA for the potyvirus group. Solanaceous leaf samples from Guam, CNMI and RMI were tested by DAS-ELISA for *Tomato spotted wilt virus* (TSWV), *Impatiens necrotic spot virus* (INSV), *Tobacco mosaic virus* (TMV), *Potato virus* Y (PVY), *Tomato mosaic virus* (ToMV) and CMV. Snakebean *(Vigna unguiculata* ssp. *unguiculata)* samples from Guam, CNMI and Nauru, garden bean *(Phaseolus vulgaris)* leaf samples from RMI, as well as *Passiflora foetida* leaf samples from Nauru were tested by indirect ELISA for the potyvirus group and *Bean common mosaic virus* (BCMV). Banana leaf samples from CNMI and RMI were tested for BBTV, also by DAS-ELISA. All these tests were conducted at the SPC plant virology laboratory, Suva, Fiji, using Agdia Inc. (Elkhart IN, USA) ELISA reagent sets. 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. In all tests, manufacturer-recommended buffers were used, except for the PRSV-P tests. These were done after leaf tissue was triturated in 0.25 M phosphate buffer containing 0.1 M EDTA (pH 7.5) (PE buffer) as this is known to enhance ELISA test sensitivity for this virus (Gonsalves and Ishii 1980; Thomas and Dodman 1993).

Polymerase chain reaction (PCR) testing for Taro bacilliform virus (TaBV)

Twelve aroid leaf samples (two *C. esculenta* from Guam, one from CNMI, one from RMI and two from Nauru; five *Xanthosoma* sp. from CNMI, one from Nauru) 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 PCR reaction mix.

Phytoplasma testing
A sample from one *Crotalaria* sp. on Nauru that was showing little leaf symptoms was subjected to nucleic acid extraction, followed by nested PCR at CSL, UK, as described in Davis et al. (2006a).

PCR testing for HLB
Citrus leaf material was tested for HLB at the USP IAS molecular biology laboratory using the PCR techniques described in Davis et al. (2005a). The PCR integrity of DNA extracts that tested negative for HLB was verified by amplifying 16SrDNA of other bacteria present in the preparations using the PCR primers rP1/fD1 (Weisburg et al. 1991)

Fusarium wilt of banana
Banana plants (local name of the variety is Manila, or Latundan, international name, Silk, AAB genotype) suspected to be affected by fusarium wilt were found on the islands of Saipan and Rota in CNMI. Although yellowing of leaves was not visible, they were cut down because older leaves had died and this was considered by banana growers on these islands to be a good external symptom of the disease. Discoloured vascular strands were found in the pseudostems and these were excised and air-dried and forwarded to the Queensland Department of Primary Industries and Fisheries (QDPIF) plant pathology laboratory, Brisbane, Australia, for characterisation by volatile production (Moore et al. 1991) and VCG analysis (Correll et al. 1987).

Results

The results of the survey of Guam are presented in Table 4, of CNMI in Table 5, of RMI in Table 6, and of Nauru in Table 7.

Viruses on Guam
Of the five viruses screened for by ELISA in cucurbit samples from Guam, PRSV was detected in *Momordica charantia* (bitter gourd) at three locations, and in *Coccinia grandis* and *Cucumis sativus* (cucumber) at one location each. WMV and ZYMV were detected in *M. charantia* at one location. Several marginally positive ELISA test results were also obtained for cucurbit viruses, including two more for WMV. The papaya-infecting strain of PRSV (PRSV-P) was detected at three locations. When solanaceous species from several plots at one location were screened for selected viruses, CMV and PVY were detected in *Lycopersicon esculentum* (tomato) and *Capsicum annuum* var. *annuum* (chilli) and TMV and ToMV were found only in *L. esculentum*. At one location, DsMV was detected by ELISA and TaBV was detected by PCR in *Colocasia esculenta* (taro). The TaBV-positive plant also gave a marginally positive DsMV ELISA test result. CymMV was found in orchids *(two Dendrobium* sp. and one *Oncidium* sp.*)* at one location. *Vigna unguiculata* ssp. *unguiculata* (snakebean) leaf samples from one location tested positive to BCMV and also the potyvirus group, by ELISA. CTV was detected in citrus trees at two locations.

Viruses in CNMI
BBTV was detected on Saipan at one location. PRSV-P was detected by ELISA at three locations on Saipan and one location each on Rota and Tinian. Cucurbit virus testing by DAS-ELISA of leaf samples from CNMI gave fully positive results only on Saipan. These were of PRSV–W in *C. sativus* and *C. grandis* at one location each and *C. maxima, M. charantia* and *Luffa acutangula* (ridge gourd) at two locations each. ZYMV was detected in *M. charantia* at three locations and in *L. acutangula* at one location. In addition, WMV was found in *L. acutangula* and *M. charantia* at one location each.

Viruses detected in solanaceous-species leaf samples from CNMI were CMV in *L. esculentum* at one location on Saipan and in *C. annuum* var. *annuum* at two locations on Rota and one on Saipan. TMV and ToMV were found also in the two leaf samples from Rota. DsMV ELISA testing detected this virus in *Xanthosoma* sp. (taro) at one location each on Saipan, Rota and Tinian and in *C. esculenta* at one location on Saipan. *V. unguiculata* ssp. *unguiculata* (snakebean) leaf samples from two places on Saipan and one on Tinian tested positive to BCMV and also the potyvirus group, by ELISA. CTV was detected by ELISA in citrus trees at two locations each on all three islands surveyed.

Viruses in RMI
Cucurbit virus testing by ELISA of leaf samples from RMI detected only PRSV-W, on Majuro in *C. maxima* at two locations and in *C. sativus* at one location. *Phaseolus vulgaris* (garden bean) leaf samples from one place on Majuro tested positive (by ELISA) to BCMV and also the potyvirus group.

Viruses on Nauru
Cucurbit virus ELISA screening of Nauru leaf samples detected ZYMV in *C. maxima*, *L. acutangula* and *M. charantia* and PRSV-W in *M. charantia* (one location each record). In addition, CMV was detected by ELISA in the roadside weeds, *Synedrella nodiflora* and *Physalis angulata* at one location each. Two *C. esculenta* leaf samples each were infected with DsMV, detected by ELISA, and with TaBV, detected by PCR. Two *V. unguiculata* ssp. *unguiculata* leaf samples from one location and six from the roadside weed *Passiflora foetida* sampled at four locations, tested positive to BCMV and also the potyvirus group, by ELISA.

A phytoplasma on Nauru
A phytoplasma was detected by nested PCR in a *Crotalaria* species showing little leaf symptoms (a proliferation of undersize leaves) on Nauru. However, the PCR reaction gave only a weak positive, making it impossible to successfully conduct sequence analysis for further characterisation.

Fusarium wilt of banana
In Australia, an isolate of *F. oxysporum* was recovered from a wilting banana (var. Manila/Latundan or Silk, AAB genotype) growing at Gagani on Rota, CNMI. It was found to be *Foc* VCG 0123.

Important negative results
HLB indexing returned negative PCR test results from three citrus leaf samples from Guam (Table 8), eight from CNMI (Table 9), six from RMI (Table 10) and three from Nauru (Table 11). The leaf samples from RMI and Nauru also tested negative by ELISA for CTV. Three *Musa* sp. leaf samples from banana plants showing an upright posture on RMI tested negative by ELISA for BBTV (Table 10). A number of solanaceous plants *(L. esculentum* and *C. annuum* var. *annuum)* showing unusual leaf symptoms were indexed negative by ELISA for the two important tospoviruses, INSV and TSWV. These were nine samples from Guam (Table 8), seven from CNMI (Table 9), and three from RMI (Table 10). One of the *L. esculentum* samples from Guam (RID 4387, from Dededo) initially tested positive for INSV, but this result could not be replicated in two subsequent repeat ELISA tests.

Figures 1-16 show the symptoms caused by the viruses found in a number of hosts.

Discussion

These surveys provide the first records of WMV, CTV, PVY, ToMV, TaBV and CymMV on Guam; BBTV, DsMV, CTV, ToMV and TMV in CNMI; PRSV-W and BCMV in RMI; and ZYMV, PRSV-W, CMV, DsMV, TaBV, and BCMV on Nauru. This is also the first time that a phytoplasma-associated disease has been found on Nauru. Additionally, the survey of both Guam and CNMI lists more records of BCMV, CMV, ZYMV, PRSV-P and PRSV-W as well as of DsMV on Guam only. Importantly, for both places, these surveys generated new host records of PRSV-W in *C. grandis*.

Most notably, this study provides the first laboratory test confirmation of the presence of BBTV in CNMI, following visual observations of symptoms made for several years on all three main islands. Many banana plants were examined during the survey of CNMI and bunchy-top-like symptoms were seen only occasionally on Saipan, were found only once on Tinian and could not be found on Rota. The sample from Tinian, together with five samples from Guam, tested negative for BBTV in three repeated ELISA tests, the last one using new antisera reagent sets. Positive controls worked well in each test, suggesting the reason for failure to detect the virus may be because the leaf midrib material, which had a particularly high water content, had deteriorated too much during desiccation. Apparently, the low incidence of bunchy top disease in CNMI banana crops results from a successful public awareness campaign, aimed at both commercial and backyard banana growers. The campaign has been implemented by extension agents of the Northern Marianas College Cooperative Research Extension and Education Service. It focuses on simple cultural control measures, similar to those described in Jackson and Wright (2005). Preventing the movement of banana planting material (suckers) from islands affected by bunchy top disease to islands still free of the disease is one of the biggest plant quarantine issues in the Pacific. The surveys of RMI and Nauru indicate that these islands are likely to be free of BBTV, as no bunchy-top-disease-like symptoms were found anywhere. Three banana leaf samples from RMI were included in the screening that followed the surveys because they had an upright growth habit, but they tested negative.

The survey of CNMI has provided a specific identification of the strain of *Foc* (VCG0123) that has been causing a serious wilt of Manila/Latundan or Silk (AAB genotype) bananas on the islands since the 1970s. This adds valuable information to the map of *Foc* VCGs in the Pacific, which lists VCG 0123 also on Yap in the Federated States of Micronesia (FSM) (Smith et al. 2002); VCG 0126 in PNG (Shivas and Philemon 1996) and Pohnpei in FSM (Davis 2004); and VCG 0128 in Tonga (Davis et al. 2004). *Foc* strains in VCG 0123 and 0126 attack certain dessert (AAA and AAB genotype) and cooking bananas in Southeast Asia (Bentley et al. 1998), so are considered to be “race” 1, as they are not known to cause disease in Cavendish cultivars. VCG 0128 has been found before infecting only cooking bananas in north Queensland and in Africa, and is considered to be “race” 2. In addition to these fully characterised isolates of *Foc*, there are also two not-so-well verified records from the Pacific. On Guam, *“Fusarium oxysporum-musae”* was isolated from banana plants in the early 1980s (Russo et al. 1985) and fusarium wilt is still a recognised problem in Manila plantings today. No affected banana plants could be found on Guam in the survey reported here, possibly because destruction of this susceptible genotype has been so widespread. Continuing efforts will be made to confirm the identity of the fungus on Guam. The only other remaining record dates back to 1934, when *Fusarium cubense* was reported to be causing a severe wilt of bananas in Fiji (Parham 1935). Fusarium wilt is now completely unknown in Fiji, possibly because susceptible genotypes were not grown in the affected areas again. An important observation was made at the diseased site in CNMI. Externally, susceptible plants did not show severe symptoms. Instead of a strong yellowing of progressively younger leaves, as observed with fusarium wilt elsewhere, the affected plants were identified only because older leaves had died and were hanging down, and growers reported poor fruit yields. However, when these plants were cut down, strong and advanced characteristic internal symptoms of fusarium wilt were seen.

The record of PRSV in several *C. grandis*, including one showing no symptoms, is of some interest with respect to controlling ringspot disease in papaya. Symptomless PRSV-W infections of *C. grandis* have also been found in Fiji (R. Davis, unpublished data). As PRSV-P and PRSV-W are very closely related, there is presently no way to distinguish the two forms of this virus, other than by host-range testing. Whilst PRSV-W infects only cucurbits, PRSV-P can infect both papaya and cucurbits. Although natural transmission from papaya to cucurbits is apparently rare (Bateson et al. 1994), it is possible that nearby *C. grandis* may be significant sources of inoculum initiating new papaya infections.

The viruses causing mosaic diseases in cucurbits in these surveys were the potyviruses ZYMV, PRSV-W and, to a lesser extent, WMV. The survey of Wall et al. (2006) returned similar findings for these potyviruses in Guam and CNMI. 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 spread the virus within the crop and 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 and wild susceptible crop plants can be significant reservoirs of potyvirus inoculum for new plantings. For this reason, incidence of mosaic disease in cucurbit crops tends to be higher on more intensively cropped islands. Certain weeds can also be important initial inoculum sources. Natural hosts of PRSV-W and ZYMV are mostly in the Cucurbitaceae (see: http://image.fs.uidaho.edu/vide/sppindex.htm#S). ZYMV has spread throughout the world in recent years, and it is speculated that this long-distance spread may have been via infected seeds (Desbiez and Lecoq 1997). 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 is 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.

Mosaic diseases of snakebean have been studied on Guam and in CNMI before (Wall and Kimmons 1996). In that study, the virus was identified as *Blackeye cowpea mosaic virus.* Today, this virus is considered to be a strain of BCMV (see: http://image.fs.uidaho.edu/vide/descr068.htm). BCMV is transmitted at high rates in legume seeds and is spread from plant to plant non-persistently by several aphid species. A successful cultural control program followed on Guam, implemented by extension staff of the University of Guam. This focused on removing sources of inoculum within plots, and use of uninfected seed. Growers were advised to rogue-out mosaic affected plants, and use only clean seed sourced from commercial suppliers or seed collected only from non-infected plants. Mosaic-affected snakebean samples from Guam, Saipan, Tinian and Nauru, plus garden bean samples from RMI, all reacted to BCMV (and potyvirus group) antisera following the surveys reported here. This suggests that the same virus may be responsible for mosaic diseases of these important legume crops in all these locations. However, according to the manufacturers of the BCMV antisera, positive reactions to other potyviruses are possible, indicating that other slightly different viral pathogens, may be responsible (see: http://www.agdia.com/cgi_bin/catalog.cgi/46000). Similarly, all *P. foetida* samples from Nauru tested positive to potyvirus group and BCMV antisera. *Passionfruit woodiness virus* (PWV) is a potyvirus that causes important diseases in commercial passionfruit in many parts of the world. Another, as yet unassigned potyvirus (tentatively named *Passiflora virus Y,* PaVY) has recently been investigated in Australia and the island of New Guinea (Parry et al. 2004). The symptoms shown by the potyvirus-positive *P. foetida* leaves on Nauru are identical to those of

PaVY in *P. foetida* found in northern Australia (R. Davis, unpublished data). Further work is needed to determine the exact identity of the potyviruses found on these surveys in legumes and *P. foetida.* A molecular diagnostic method using potyvirus specific degenerate primers followed by sequence analysis originally developed for vanilla infecting potyviruses (Grisoni et al. 2006) may be suitable for this work. CMV is also important in commercial passionfruit production and all *P. foetida* samples from Nauru also tested negative for CMV by ELISA (R. Davis, unpublished data).

Amongst the viruses detected in solanaceous species, CMV, TMV and ToMV were most prominent, found more than once on both Guam and CNMI. Also on Guam, PVY was found more than once, and CMV was detected on Nauru in one solanaceous weed *(P. angulata)* as well as in the roadside weed *S. nodiflora.* Removal of alternative hosts in and around the crop is a key control measure for many non persistently transmitted viruses such as CMV. However, CMV is hard to combat in this way, as this virus has an extremely broad host range, infecting over 800 plant species in 85 families. Because of this, the record of CMV in *S. nodiflora* on Nauru is of interest as it is the second in the Pacific, after one from Vanuatu (Davis et al. 2006b). *S. nodiflora* is not included in previous known CMV host listings (Douine et al. 1979; CABI 2002). PVY is also non-persistently transmitted by several aphids, but has alternative hosts only in the family Solanaceae (see: http://image.fs.uidaho.edu/vide/descr652.htm#Range). TMV, in contrast, is not transmitted by any known insect vectors, instead moving extremely readily from plant to plant by mechanical contact between plants and through seed (see: http://image.fs.uidaho.edu/vide/descr803.htm). ToMV occurs worldwide, probably because it is seed transmitted at very high rates (see: http://image.fs.uidaho.edu/vide/descr832.htm).

These surveys provide some useful negative qualitative data on certain diseases of concern in the region. For example, there was no testing done for viruses, viroids or phytoplasmas on betel nuts or coconuts, because no disease symptoms were found. In addition, the surveys provide 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, 2006b,c,d) in which citrus trees targeted for testing because of their disease-like symptom expression, have been indexed HLB negative by molecular methods. Diseases caused by tospoviruses are emerging problems elsewhere in the world, including Australia (Persley et al. 2006). Symptoms of these diseases are often distinctive and on these surveys were rarely suspected (and samples collected). Negative results were obtained from 19 solanaceous species leaf samples tested for the two tospoviruses, INSV and TSWV. However, further investigation may be warranted into plots of tomato at Dededo on Guam, as one initial INSV-positive ELISA test result was obtained from here. As this could not be repeated in later tests, it must be assumed for now that this was some sort of experimental error.

It was surprising that every HLB leaf sample from RMI and Nauru also tested negative for tristeza disease by ELISA. Citrus tristeza disease is exceptionally widespread across citrus growing areas of the world (see: http://image.fs.uidaho.edu/vide/descr222.htm). In contrast to these results, CTV was readily detected in similar samples collected for HLB screening from other islands in the Pacific (Davis et al. 2005b, 2006b,c). A wider CTV-focused survey is needed to determine if these islands really are free of tristeza disease.

In the taro virus survey of Revill et al. (2005), TaBV and DsMV were both found to be widespread across the Pacific. DsMV was found in every country and territory visited, and TaBV was detected in all but one of the countries/territories surveyed. Results of the surveys reported here add CNMI and Nauru to the DsMV distribution map, and Guam and Nauru to the TaBV distribution map. DsMV has been implicated in causing yield losses in taro (Jackson et al. 2001) and ornamental aroids (Chase and Zettler 1982). 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 known as alomae (Revill et al. 2005).

On most of the islands surveyed, banana-streak-disease-like symptoms were fairly common in cv. Mysore. These are a chlorotic streaking with brown/black markings supermimposed. Representative leaf samples from Guam, Saipan and Tinian in CNMI, Majuro and Arno in RMI and Nauru were forwarded to the QDPIF plant virology laboratory, Brisbane, Australia to be tested for presence of BSV. However, testing of these samples had not been possible at the time of preparation of this technical paper, due to circumstances beyond the laboratory's control.

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Table 1. Verified plant virus and virus-like pathogen records from Guam

Pathogen	Host	Citation[A]	Identification method[B]
Banana bunchy top virus (BBTV)	*Musa sp.*	University of Guam laboratory test records	Serology
Banana streak virus (BSV)	*Musa sp.* (cv. Mysore)	University of Guam laboratory test records	Serology, EM
Blackeye cowpea mosaic virus[C]	*Vigna unguiculata ssp. sesqui-pedalis*	Wall and Kimmons (1996)	Serology
Cucumber mosaic virus (CMV)	*Cucurbita pepo ssp. pepo var. pepo*	Wall et al. (2006)	Serology
Coconut tinangaja viroid (CTiVd)	*Cocos nucifera*	Hodgson et al. (1998)	Hybridisation, RT-PCR
Dasheen mosaic virus (DsMV)	*Colocasia esculenta*	University of Guam laboratory test records	Serology
Papaya ringspot virus (PRSV-W)	*Citrullus lanatus*	Wall (1990) Yudin et al. (1990)	Serology
	Cucumis melo	Wall et al. (2006)	Serology
	Cucurbita maxima	Wall et al. (2006)	Serology
	Cucurbita pepo ssp. pepo var. pepo	Wall et al. (2006)	Serology
	Luffa acutangula	Wall et al. (2006)	Serology
	Momordica charantia	Wall et al. (2006)	Serology
Papaya ringspot virus (PRSV-P)	*Carica papaya*	Wall (1989)	Serology
Tobacco mosaic virus (TMV)	*Solanaceae*	Pearson and Grisoni (2002)[D]	Serology
Zucchini yellow mosaic virus (ZYMV)	*Citrullus lanatus*	Wall (1990) Yudin et al. (1990)	Serology
	Cucurbita pepo ssp. pepo var. pepo	Wall et al. (2006)	Serology
	Momordica charantia	Wall et al. (2006)	Serology

[A]The original or earliest available citation of a reliably verified record is provided.
[B]EM, electron microscopy; RT-PCR, reverse transcription polymerase chain reaction.
[C]Blackeye cowpea mosaic virus is now considered to be a strain of Bean common mosaic virus (BCMV) (see: http://image.fs.uidaho.edu/vide/descr068.htm).
[D]Identification method outlined in an unpublished report and results summarised in Pearson and Grisoni (2002).

Table 2. Verified plant virus records from the Commonwealth of the Northern Mariana Islands

Pathogen	Host	Citation[A]	Identification method
Blackeye cowpea mosaic virus[B]	*Vigna unguiculata* ssp. *sesquipedalis*	Wall and Kimmons (1996)	Serology
Cucumber mosaic virus (CMV)	*Boerhavia erecta*	Wall et al. (2006)	Serology
	Carica papaya	Wall et al. (2006)	Serology
	Citrullus lanataus	Wall et al. (2006)	Serology
	Cucurbita maxima	Wall et al. (2006)	Serology
	Cucurbita pepo ssp. pepo var. *pepo*	Wall et al. (2006)	Serology
	Cucumis melo	Wall et al. (2006)	Serology
	Cucumis sativus	Wall et al. (2006)	Serology
	Nicandria physalodes	Wall et al. (2006)	Serology
Papaya ringspot virus (PRSV-W)	*Citrullus lanataus*	Wall et al. (2006)	Serology
	Cucumis melo	Wall et al. (2006)	Serology
	Cucumis sativus	Wall et al. (2006)	Serology
	Cucurbita maxima	Wall et al. (2006)	Serology
	Cucurbita pepo ssp. pepo var. *pepo*	Wall et al. (2006)	Serology
Papaya ringspot virus (PRSV-P)	*Carica papaya*	Wall et al. (2006)	Serology
Squash mosaic virus (SqMV)	*Cucumis sativus*	Wall et al. (2006)	Serology
	Citrullus lanataus	Wall et al. (2006)	Serology

	Cucurbita pepo ssp. *pepo* var. *pepo*	Wall et al. (2006)	Serology
	Momordica charantia	Wall et al. (2006)	Serology
Watermelon mosaic virus (WMV)	*Amaranthus spinosus*	Wall et al. (2006)	Serology
	Cucumis melo	Wall et al. (2006)	Serology
	Cucumis sativus	Wall et al. (2006)	Serology
	Cucurbita maxima	Wall et al. (2006)	Serology
	Cucurbita pepo ssp. *pepo* var. *pepo*	Wall et al. (2006)	Serology
	Citrullus lanataus	Wall et al. (2006)	Serology
	Momordica charantia	Wall et al. (2006)	Serology
Zucchini yellow mosaic virus (ZYMV)	*Carica papaya*	Wall et al. (2006)	Serology
	Citrullus lanataus	Wall et al. (2006)	Serology
	Cucurbita pepo ssp. *pepo* var. *pepo*	Wall et al. (2006)	Serology
	Cucumis melo	Wall et al. (2006)	Serology
	Cucumis sativus	Wall et al. (2006)	Serology
	Cucurbita maxima	Wall et al. (2006)	Serology
	Momordica charantia	Wall et al. (2006)	Serology

[A]The original or earliest available citation of a reliably verified record is provided.
[B]Blackeye cowpea mosaic virus is now considered to be a strain of Bean common mosaic virus (BCMV) (see: http://image.fs.uidaho.edu/vide/descr068.htm).

Table 3. Verified plant virus records from the Republic of the Marshall Islands

Pathogen	Host	Citation[A]	Identification method[B]
Dasheen mosaic virus (DsMV)	*Colocasia esculenta*	Revill et al. (2005)	RT-PCR
Taro bacilliform virus (TaBV)	*Colocasia esculenta*	Revill et al. (2005)	PCR

[A]The original or earliest available citation of a reliably verified record is provided.
[B] PCR, polymerase chain reaction; RT-PCR, reverse transcription polymerase chain reaction.

Table 4. Plant virus records from Guam, October 2006

Host plant Family Genus, species	Field colletion number	Approximate location	Symptoms[A]	Pathogen[B]
Araceae				
Colocasia esculenta (taro)	4355	Inarajan Station	Feathery WOGM	DsMV
	4356	Inarajan Station	Feathery WOGM	TaBV, DsMV +m
Caricaceae				
Carica papaya (papaya)	4349	Yigo	YOGM	PRSV-P
	4350	Yigo	YOGM	PRSV-P
	4369	Dededo	YOGM	PRSV-P
	4405	Hagana	YOGM	PRSV-P
	4395	Yigo	YOGM	PRSV-P
Cucurbitaceae				
Coccinia grandis	4390	Yigo	None	PRSV-W
Cucumis sativus (cucumber)	4413	Malolo	Slight chlorosis	PRSV-W
Luffa acutangula (ridge gourd)	4385	Dededo	Mild mottle	ZYMV +m, PRSV-W +m
Momordica charantica (bitter gourd)	4367	Yigo	YOGM	ZYMV +m, PRSV-W +m
	4368	Yigo	Slight YOGM	PRSV-W
	4372	Dededo	YOGM	ZYMV, PRSV-W, WMV +m
	4373	Dededo	YOGM	ZYMV, PRSV-W, WMV +m
	4415	South	YOGM	PRSV-W, ZYMV +m
	4415	South	YOGM	WMV
	4417	South	YOGM	PRSV-W +m, ZYMV +m
	4418	South	YOGM	PRSV-W +m, ZYMV +m
Fabaceae				
Vigna unguiculata ssp. *sesquipedalis* (snake bean)	4381	Dededo	YOGM	BCMV
	4382	Dededo	YOGM	BCMV
Orchidaceae				
Dendrobium sp.	4397	Nr UoG campus	Chlorotic blotch	CymMV
	4407	Nr UoG campus	Chlorotic blotch	CymMV +m
	4408	Nr UoG campus	Chlorotic blotch	CymMV
Oncidium sp.	4401	Nr UoG campus	Chlorotic spots and YOGM	CymMV

Rutaceae				
Citrus × *limon* (lemon)	4358	Inarajan	Chlorosis	CTV
Citrus reticulata (mandarin)	4411	Malolo	Chlorotic blotch	CTV
	4412	Malolo	Slightly corky veins	CTV
Solanaceae				
Capsicum annuum var. *annuum* (chilli)	4374	Dededo	Strong YOGM/GOYVB	PVY, TMV +m, CMV +m
	4377	Dededo	Strong golden YOGM	CMV
Lycopersicon esculentum (tomato)	4386	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	ToMV, CMV +m
	4387	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	CMV, PVY, ToMV
	4388	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	ToMV +m
	4389	Dededo	Interveinal chlorosis and crinkle	TMV, ToMV

[A]GOYVB: green on yellow vein banding, WOGM: White on green mosaic, YOGM: yellow on green mosaic
[B]Viruses detected were: BCMV, Bean common mosaic virus; CMV, Cucumber mosaic virus; CTV, Citrus tristeza virus; CymMV, Cymbidium mosaic virus; DsMV, Dasheen mosaic virus; PRSV-P, papaya infecting strain of Papaya ringspot virus; PRSV-W, cucurbit infecting strain of Papaya ringspot virus; PVY, Potato virus Y; TaBV, Taro bacilliform virus; TMV, Tobacco mosaic virus; ToMV, Tomato mosaic virus; WMV, Watermelon mosaic virus; ZYMV, Zucchini yellow mosaic virus.

Cucurbit leaf samples were screened by ELISA for the five most common cucurbit infecting viruses (PRSV, ZYMV, WMV, CMV and Squash mosaic virus (SqMV)). Snake bean leaf samples were screened for BCMV (genus Potyvirus) and the potyvirus group by ELISA and were positive for both antisera. Orchid samples were screened by ELISA for Cymbidium mosaic virus (CyMV), Odontoglossum ringspot virus (ORSV), BCMV, CMV, and the potyvirus group. Solanaceous leaf samples were screened by ELISA for CMV, Impatiens necrotic spot virus (INSV), PVY, Tomato spotted wilt virus (TSWV), TMV, and ToMV. ELISA test results were considered positive (+) when absorbance readings (405 nm) exceeded three times the mean of healthy controls. Marginally positive test results (+m) were those that exceeded twice the mean of the healthy controls, but were less than three times the mean.
TaBV was identified by polymerase chain reaction (PCR).

Table 5. Plant virus records from Commonwealth of the Northern Mariana Islands, October / November 2006

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Pathogen[B]
Araceae				
Colocasia esculenta (taro)	4424	Kagman, Saipan	Feathery WOGM	DsMV
Xanthosoma sp. (taro)	4423	Kagman, Saipan	Feathery WOGM	DsMV +m
	4442	As Lito, Saipan	Feathery WOGM	DsMV
	4481	Makpo, Tinian	Feathery WOGM	DsMV
	4492	Central, Rota	Feathery WOGM	DsMV
Caricaceae				
Carica papaya (papaya)	4471	Town area, Tinian	YOGM	PRSV-P
	4484	Chugai, Rota	YOGM	PRSV-P
	4485	Chugai, Rota	YOGM	PRSV-P
	4430	As Lito, Saipan	YOGM	PRSV-P
	4480	Airport, Saipan	YOGM	PRSV-P
	4445	Kagman, Saipan	YOGM	PRSV-P
Cucurbitaceae				
Coccinia grandis	4431	As Lito, Saipan	Slight mottle	PRSV-W
	4440	As Lito, Saipan	YOGM	PRSV-W
Cucurbita maxima (pumpkin)	4456	Nr Kagman, Saipan	Mild YOGM	PRSV-W
	4457	Nr Kagman, Saipan	Strong YOGM	PRSV-W

	4461	As Teo, Saipan	YOGM	ZYMV +m, PRSV-W
	4462	As Teo, Saipan	YOGM	PRSV-W
Cucumis sativus (cucumber)	4426	Kagman, Saipan	YOGM	PRSV-W
	4427	Kagman, Saipan	YOGM	PRSV-W
	4465	As Teo, Saipan	Mild YOGM	PRSV-W
Luffa acutangula (ridge gourd)	4432	As Lito, Saipan	YOGM	ZYMV, PRSV-W, WMV
	4433	As Lito, Saipan	YOGM	ZYMV, PRSV-W, WMV
	4453	Nr Kagman, Saipan	YOGM	ZYMV +m, PRSV-W
Momordica charantica (bitter gourd)	4425	Kagman, Saipan	Chlorotic centres	ZYMV, PRSV-W, WMV +m
	4439	As Lito, Saipan	Chlorotic centres	ZYMV, PRSV-W +m
	4441	As Lito, Saipan	Slight YOGM	ZYMV, WMV
	4454	Nr Kagman, Saipan	YOGM	ZYMV, PRSV-W, WMV +m
	4455	Nr Kagman, Saipan	YOGM	ZYMV, PRSV-W, WMV +m
	4478	Makpo, Tinian	Slight YOGM	ZYMV +m, PRSV-W +m
Fabaceae				
Vigna unguiculata ssp. *sesquipedalis* (snake bean)	4435	As Lito, Saipan	YOGM	BCMV
	4436	As Lito, Saipan	YOGM	BCMV
	4450	Kagman, Saipan	Strong YOGM	BCMV
	4451	Kagman, Saipan	Strong YOGM	BCMV
	4452	Kagman, Saipan	Strong YOGM	BCMV
	4476	Makpo, Tinian	Strong, golden YOGM	BCMV

Musaceae				
Musa sp. (banana)	4469	As Teo, Saipan	BBTD	BBTV
Rutaceae				
Citrus japonica (kumquat)	4493	Central Rota	GOYVB	CTV
Citrus × *limon* (lemon)	4446	Kagman, Saipan	Slight chlorosis and prominent veins	CTV
	4466	As Teo, Saipan	Chlorosis	CTV
	4488	Songsong, rota	Chlorosis and GOYVB	CTV
Citrus × *microcarpa?* (calimensis?)	4482	College, Tinian	Chlorosis and GOYVB	CTV
Citrus reticulata (mandarin)	4458	Kagman, Saipan	Slight Chlorotic blotch	CTV
	4473	Town, Tinian	Chlorosis and blotch	CTV
	4474	Town, Tinian	Chlorosis and GOYVB	CTV
Solanaceae				
Capsicum annuum var. *annuum* (chilli)	4467	As Teo, Saipan	Chlorosis / crinkle	CMV
	4483	Chugai, Rota	Mild YOGM	CMV, TMV, ToMV
	4486	North East Rota	General chlorosis	CMV, TMV, ToMV
Lycopersicon esculentum (tomato)	4447	Nr Kagman, Saipan	Mild YOGM	CMV

[A]BBTD, banana bunchy top disease symptoms; GOYVB, green on yellow vein banding; WOGM, white on green mosaic; YOGM, yellow on green mosaic.
[B]Viruses detected were: BBTV, Banana bunchy top virus; BCMV, Bean common mosaic virus; CMV, Cucumber mosaic virus; CTV, Citrus tristeza virus; DsMV, Dasheen mosaic virus; PRSV, Papaya ringspot virus; TMV, Tobacco mosaic virus; ToMV, Tomato mosaic virus; WMV, Watermelon mosaic virus; ZYMV, Zucchini yellow mosaic virus.

Cucurbit leaf samples were screened by ELISA for the five most common cucurbit infecting viruses (PRSV, ZYMV, WMV, CMV and Squash mosaic virus (SqMV)). Snake bean leaf samples was screened for BCMV (genus Potyvirus) and the potyvirus group by ELISA and were positive for both antisera. Solanaceous leaf samples were screened by ELISA for CMV, Impatiens necrotic spot virus (INSV), PVY, Tomato spotted wilt virus (TSWV), TMV, and ToMV. ELISA test results were considered positive (+) when absorbance readings (405 nm) exceeded three times the mean of healthy controls. Marginally positive test results (+m) were those that exceeded twice the mean of the healthy controls, but were less than three times the mean.

Table 6. Plant virus records from the Republic of the Marshall Islands, November 2006

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Pathogen[B]
Cucurbitaceae				
Cucurbita maxima (pumpkin)	4496	Laura, Majuro	YOGM	PRSV-W
	4500	Laura, Majuro	YOGM	PRSV-W
	4507	Farm, Majuro	Mild YOGM	PRSV-W
Cucumis sativus (cucumber)	4506	Farm, Majuro	Slight YOGM	PRSV-W
Fabaceae				
Phaseolus vulgaris (garden bean)	4501	ROC Station, Majuro	Strong YOGM	BCMV
	4502	ROC Station, Majuro	Strong YOGM	BCMV

[A]YOGM, yellow on green mosaic.
[B]Viruses detected were: BCMV, Bean common mosaic virus; PRSV-W, cucurbit infecting strain of Papaya ringspot virus.

Cucurbit leaf samples were screened by ELISA for the five most common cucurbit infecting viruses (PRSV, Zucchini yellow mosaic virus, Watermelon mosaic virus, Cucumber mosaic virus and Squash mosaic virus). Garden bean leaf samples was screened for BCMV (genus Potyvirus) and the potyvirus group by ELISA and were positive for both antisera. ELISA test results were considered positive (+) when absorbance readings (405 nm) exceeded three times the mean of healthy controls.

Table 7. Plant virus records from Nauru

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Pathogen[B]
Araceae				
Colocasia esculenta (taro)	4545	Bua Da	Feathery WOGM	DsMV
	4546	Bua Da	Feathery WOGM	TaBV
	4549	Bua Da	Feathery WOGM	DsMV, TaBV
Asteraceae				
Synedrella nodiflora	4573	Anabar	YOGM	CMV
	4574	Anabar	YOGM	CMV
	4575	Anabar	YOGM	CMV
	4576	Anabar	YOGM	CMV
Cucurbitaceae				
Cucurbita maxima (pumpkin)	4544	Bua Da	YOGM	ZYMV
	4545	Bua Da	YOGM	ZYMV
Luffa acutangula (ridge gourd)	4572	Anabare	YOGM	ZYMV
	4577	Anabare	YOGM	ZYMV
	4578	Anabare	YOGM	ZYMV
Momordica charantica (bitter gourd)	4552	Interior road	None	ZYMV, PRSV-W, WMV +m
	4560	Interior road	None	ZYMV +m
Fabaceae				
Vigna unguiculata ssp. sesquipedalis (snake bean)	4547	Bua Da	YOGM	BCMV
	4548	Bua Da	YOGM	BCMV
Passifloraceae				
Passiflora foetida	4550	Aiwo	YOGM	BCMV
	4554	Mine road	YOGM	BCMV

	4556	Mine road	YOGM	BCMV
	4557	Mine road	YOGM	BCMV
	4569	Uaboe	YOGM	BCMV
	4581	Airport	YOGM	BCMV
Solanaceae				
Physalis angulata	4561	Yaren	YOGM	CMV

[A]WOGM, white on green mosaic; YOGM, yellow on green mosaic.
[B]Viruses detected were: BCMV, Bean common mosaic virus; CMV, Cucumber mosaic virus; DsMV, Dasheen mosaic virus; PRSV, Papaya ringspot virus; TaBV, Taro bacilliform virus; WMV, Watermelon mosaic virus; ZYMV, Zucchini yellow mosaic virus.

Cucurbit leaf samples were screened by ELISA for the five most common cucurbit infecting viruses (PRSV, ZYMV, WMV, CMV and Squash mosaic virus (SqMV)). BCMV-positive snake bean and P. foetida leaf samples were screened for BCMV (genus Potyvirus) and the potyvirus group by ELISA and were positive for both antisera. ELISA test results were considered positive (+) when absorbance readings (405 nm) exceeded three times the mean of healthy controls. Marginally positive test results (+m) were those that exceeded twice the mean of the healthy controls, but were less than three times the mean.
TaBV was identified by polymerase chain reaction (PCR).

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Table 8. Notable samples in which no pathogen was detected in specific tests on Guam

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Tested negative for[B]
Rutaceae				
Citrus × *limon* (lemon)	4358	Inarajan	Chlorosis	HLB
Citrus reticulata (mandarin)	4411	Malolo	Chlorotic blotch	HLB
	4412	Malolo	Slightly corky veins	HLB
Solanaceae				
Capsicum annuum var. *annuum*	4374	Dededo	Strong YOGM/GOYVB	INSV, TSWV
	4375	Dededo	YOGM	INSV, TSWV
	4377	Dededo	Strong golden YOGM	INSV, TSWV
Lycopersicon esculentum (tomato)	4362	Yigo	Mild mosaic, chlorosis, leaflets curling up	INSV, TSWV
	4363	Yigo	Mild mosaic	INSV, TSWV
	4364	Yigo	Mild YOGM	INSV, TSWV
	4386	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	INSV, TSWV
	4387	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	INSV, TSWV
	4388	Dededo	Leaflets curling up with purple undersides and edges, plus chlorosis	INSV, TSWV

[A]GOYVB, green on yellow vein banding; YOGM, yellow on green mosaic.
[B]HLB (huanglongbing) tested negative by PCR for presence of 'Candidatus Liberibacter asiaticus'; INSV tested negative by ELISA for Impatiens necrotic spot virus; TSWV tested negative by ELISA for Tomato spotted wilt virus.

Table 9. Notable samples in which no pathogen was detected in specific tests in the Commonwealth of the Northern Mariana Islands

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Tested negative for[B]
Rutaceae				
Citrus japonica (kumquat)	4493	Central Rota	GOYVB	HLB
Citrus × *limon* (lemon)	4446	Kagman, Saipan	Slight chlorosis and prominent veins	HLB
	4466	As Teo, Saipan	Chlorosis	HLB
	4488	Songsong, rota	Chlorosis and GOYVB	HLB
Citrus × *microcarpa?* (calimensis?)	4482	College, Tinian	Chlorosis and GOYVB	HLB
Citrus reticulata (mandarin)	4458	Kagman, Saipan	Slight chlorotic blotch	HLB
	4473	Town, Tinian	Chlorosis and blotch	HLB
	4474	Town, Tinian	Chlorosis and GOYVB	HLB
Solanaceae				
Capsicum annuum var. *annuum*	4444	As Lito, Saipan	YOGM, chlorosis	INSV, TSWV
	4467	As Teo, Saipan	Chlorosis/crinkle	INSV, TSWV
	4483	Chugai, Rota	Mild YOGM	INSV, TSWV
	4486	North East Rota	General chlorosis	INSV, TSWV
Lycopersicon esculentum (tomato)	4447	Nr Kagman, Sipan	Mild YOGM	INSV, TSWV
	4448	Nr Kagman, Sipan	Leaves drooping, leaflets curling up	INSV, TSWV
	4449	Nr Kagman, Sipan	Dark colour to all leaves and leaflets curling down	INSV, TSWV

[A]GOYVB, green on yellow vein banding; YOGM, yellow on green mosaic.
[B]HLB (huanglongbing) tested negative by PCR for presence of 'Candidatus Liberibacter asiaticus'; INSV tested negative by ELISA for Impatiens necrotic spot virus; TSWV tested negative by ELISA for Tomato spotted wilt virus

Table 10. Notable samples in which no pathogen was detected in specific tests in the Republic of the Marshall Islands

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Tested negative for[B]
Citrus × *aurantifolia* (lime)	4495	Laura, Majuro	General chlorosis	HLB, CTV
	4499	Laura, Majuro	General chlorosis	HLB, CTV
	4504	ROC Station, Majuro	Chlorotic blotch and mottle	HLB, CTV
	4521	Mid Arno	GOYVB and chlorosis	HLB, CTV
	4524	Rita, Majuro	GOYVB and chlorosis	HLB, CTV
Citrus × *limon* (lemon)	4513	Tip, Arno	General chlorosis	HLB, CTV
Musaceae				
Musa sp. cv. Mysore (AAB)	4514	Tip, Arno	Upright posture	BBTV
--	4515	Tip, Arno	Upright posture	BBTV
--	4522	Rita, Majuro	Upright posture	BBTV
Solanaceae				
Lycopersicon esculentum (tomato)	4516	Rainer Fm, Arno	Leaflets curled up with purple edges	INSV, TSWV
	4517	Rainer Fm, Arno	Leaflets curled up slightly and chlorosis	INSV, TSWV
	4518	Rainer Fm, Arno	Leaflets curled up slightly and strong chlorosis	INSV, TSWV

[A]GOYVB, green on yellow vein banding.
[B]HLB (huanglongbing) tested negative by PCR for presence of 'Candidatus Liberibacter asiaticus'; BBTV tested negative by ELISA for Banana bunchy top virus; CTV tested negative by ELISA for Citrus tristeza virus; INSV tested negative by ELISA for Impatiens necrotic spot virus; TSWV tested negative by ELISA for Tomato spotted wilt virus.

Table 11. Notable samples in which no pathogen was detected in specific tests in Nauru

Host plant Family Genus, species	Field collection number	Approximate location	Symptoms[A]	Tested negative for
Citrus × *aurantifolia* (lime)	4571	Aiwo	GOYVB	HLB, CTV
Citrus × *aurantium* (orange)	4570	Denig	Chlorotic blotch	HLB, CTV
Citrus × *limon* (lemon)	4562	Yaren	General chlorosis	HLB, CTV

[A]GOYVB, green on yellow vein banding.
[B]HLB (huanglongbing) tested by polymerase chain reaction for presence of 'Candidatus Liberibacter asiaticus' and CTV by ELISA for Citrus tristeza virus.

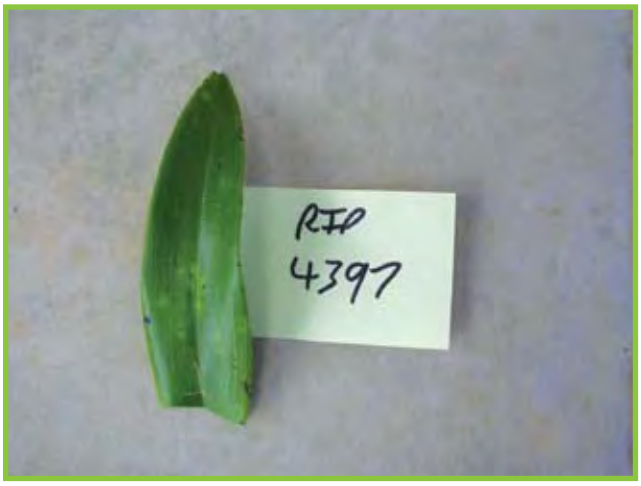

Fig. 1. RID 4397: *Dendrobium* sp. infected with *Cymbidium mosaic virus* showing chlorotic blotch: on Guam

Fig. 2. RID 4423: *Xanthosoma* sp. (taro) infected with *Dasheen mosaic virus* showing a feathery white on green mosaic: on Saipan, Common wealth of the Northern Mariana Islands

Fig. 3. RID 4430: *Carica papaya* (papaya) infected with the papaya infecting strain of *Papaya rings pot virus*, showing a yellow on green mosaic: on Saipan, Commonwealth of the Northern Mariana Islands

Fig. 4. RID 4426: *Cucumis sativus* (cucumber) infected with the cucurbit infecting strain of *Papaya ringspot virus*, showing a yellow on green mosaic: on Saipan, Commonwealth of the Northern Mariana Islands

Fig. 5. RID 4427: *Cucumis sativus* (cucumber) infected with the cucurbit infecting strain of *Papaya ringspot virus*, showing a yellow on green mosaic: on Saipan, Commonwealth of the Northern Mariana Islands

Fig. 6. RID 4433: *Luffa acutangula* (ridge gourd) infected with the cucurbit infecting strain of *Papaya ringspot virus*, *Watermelon mosaic virus*, and *Zucchini yellow mosaic virus*, showing a yellow on green mosaic: on Saipan, Common wealth of the Northern Mariana Islands

Fig. 7. RID 4435: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean) which gave a positive ELISA test result for *Bean common mosaic virus*, showing a yellow on green mosaic: on Saipan, Commonwealth of the Northern Mariana Islands

Fig. 8. RID 4476: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean) which gave a positive ELISA test result for *Bean common mosaic virus*, showing a strong golden yellow mosaic: on Saipan, Commonwealth of the Northern Mariana Islands

Fig. 9. RID 4544: *Cucurbita maxima* (pumpkin) infected with *Zucchini yellow mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 9. RID 4545: *Cucurbita maxima* (pumpkin) infected with *Zucchini yellow mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 10. RID 4577: *Luffa acutangula* (ridge gourd) infected with *Zucchini yellow mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 11. RID 4578: *Luffa acutangula* (ridge gourd) infected with *Zucchini yellow mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 12. RID 4547: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean which gave a positive ELISA test result for *Bean common mosaic virus*, showing a strong yellow on green mosaic: on Nauru

Fig. 13. RID 4548: *Vigna unguiculata* ssp. *sesquipedalis* (snake bean) which gave a positive ELISA test result for *Bean common mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 14. RID 4554: *Passiflora foetida*, which gave a positive ELISA test result for *Bean common mosaic virus*, showing a yellow on green mosaic: on Nauru

Fig. 15. *Musa* sp. (banana, local name Manila/ Latundan, international name, Silk, AAB genotype) affected by fusarium wilt, caused by the fungus *Fusarium oxysporum* f.sp. *cubense* (Foc). Rings of discoloured vascular tissue can be seen in longitudinal section in the pseudostem.

Fig. 16. *Musa* sp. (banana, local name Manila /Latundan, international name, Silk, AAB genotype) affected by fusarium wilt, caused by the fungus *Fusarium oxysporum* f.sp. *cubense* (Foc). Rings of discoloured vascular tissue can be seen in cross section in the pseudostem. Affected vascular bundles appear as continuous brown and yellow streaks.

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