VIRUS DISEASES OF TARO *(COLOCASIA ESCULENTA)* AND *XANTHOSOMA* SP. IN PAPUA NEW GUINEA

Dorothy E. Shaw†, R.T. Plumb+ and G.V.H. Jackson#

ABSTRACT

An account is given of the early reports and distribution of possibly virus induced symptoms on taro in Papua New Guinea. Also given are records of large and small bacilliform virus particles and a flexuous rod-shaped particle, as determined by electron microscopy of plant sap. The large bacilliform particle occurred in 62.3% of the samples, whereas the small bacilliform particle was confirmed in only 18.9%; bacilliform particles occurred only in Colocasia esculenta. *Flexuous rods, presumably of dasheen mosaic virus, were recorded in 10.2% of the determinations from* C. esculenta *and in 14.3% of those from* Xanthosoma *sp.. Names suggested for the bacilliform viruses are taro large bacilliform virus (TLBV) (*/*:*/*:U/*:S/Au, rhabdovirus group) and taro small bacilliform virus (TSBV) (*/*:*/*:U/*:S/Cc(Au)). The names of the diseases, host identity and chromosome numbers, occurence of vectors and control measures are discussed.*

INTRODUCTION

At least 30 genera of the Araceae are known to occur in Papua New Guinea (P.N.G.) (Anon. 1973; amended Henty, unpublished), 20 of which are indigenous. Over 70% of the latter are climbers or terrestrials in the rain forest. Some of the others prefer swampy ground, but a few occur mostly in drier grassland, although also in forested areas (Henty, pers. comm.). The most important agricultural species is taro *(Colocasia esculenta* (L.) Schott*) which was introduced in prehistoric times. It is a staple of some of the coastal and island people and is also widely grown in some inland areas. It is mainly grown for its corms and the leaves are frequently used as a vegetable. *Xanthosoma* sp.*, which was also introduced in prehistoric times, is the preferred staple in a few coastal and island areas, but is also grown in some other localities as a supplementary food. *Cyrtosperma chamissonis* (Schott) Merr., presumably introduced, is also grown to a limited extent, mainly in swampy areas on islands off the New Ireland coast. *Amorphophallus campanulatus* Bl. and *Alocasia macrorrhiza* (L.) Schott are widespread as wild plants and forms of both are cultivated to a limited extent. Species of introduced genera such as *Caladium, Dieffenbachia, Philodendron* and *Monstera,* are becoming popular in home gardens and as house plants in urban areas.

A brief literature review of overseas work on viruses of Araceae is given, followed by an account of investigations in P.N.G.

OVERSEAS RECORDS OF VIRUSES OF ARACEAE

DASHEEN MOSAIC VIRUS

Zettler *et al.* (1970), in Florida, described filamentous virus particles, naturally infecting members of the Araceae, which were mechanically

† Department of Primary Industry, Konedobu, Papua New Guinea. Present address: C.o. Plant Pathology, Department of Primary Industries, Meiers Road, Indooroopilly, Queensland, 4068, Australia.
+ Rothamsted Experimental Station, Harpenden, Herts. AL5 2JQ, United Kingdom.
# Ministry of Agriculture and Lands, P.O. Box G11, Honiara, Solomon Islands.

* Refer later section for discussion on taxonomv and nomenclature.

transmitted to seedlings of *Philodendron selloum*. The isolate from *Colocasia* was designated dasheen mosaic virus (DMV) with characteristics in common with other viruses assigned to the (then) "potato virus Y" (now poty virus group (Fenner 1976)) in being non-persistently aphid transmitted, having a mean particle length of about 750 nm and inducing characteristic cylindrical inclusions in infected plants.

DMV apparently occurs world-wide, especially in tropical and subtropical regions, having been recorded in the Caribbean, Egypt, Florida, Holland, India, Japan and Oceania (Fiji, Hawaii and the Solomon Islands) (Zettler *et al.* 1978). Gollifer *et al.* (1977) have also reported flexuous rod-shaped particles in *Colocasia* and *Xanthosoma* from Tongatapu and the Cook Islands, and in *Cyrtosperma* from the Gilbert Islands. DMV infects species of the following 13 genera of the Araceae: *Aglaonema, Alocasia, Amorphophallus, Anthurium, Arisaema, Caladium, Colocasia, Cryptocoryne, Dieffenbachia, Philodendron, Spathiphyllum, Xanthosoma* and *Zantedeschia* (Hartman 1974; Hartman and Zettler 1972; Tooyama 1975, a and b; Zettler *et al.* 1970). Zettler *et al.* (1974) reported that some aroids such as *Scindapsus* and *Syngonium* did not appear to be infected. Infection with DMV usually results in a mosaic and/or distortion of the leaves of *Aglaonema* spp., *Caladium hortulanum, Colocasia* spp., *Dieffenbachia* spp., *Xanthosoma* spp. and *Zantedeschia* spp., but many leaves of infected plants may be symptomless (Zettler *et al.*1978).

Vectors. Zettler *et al.* (1970) transmitted DMV from infected *Colocasia* to seedlings of *P. selloum* by the aphids *Aphis craccivora* and *Myzus persicae*. Gollifer and Brown (1972) and Kenten and Woods (1973) reported transmission, in a non-persistent manner, by *M. persicae*, of the flexuous rod-shaped particle to *C. esculenta*. *Colocasia* cv. Nduma from Kenya became infected with DMV when infested with viruliferous *A. gossypii* (Gollifer *et al.* 1977). *M. persicae* was a significantly better vector of a Florida isolate of DMV than *A. craccivora* but *Pentalonia nigronervosa* failed to transmit isolates of DMV fromFlorida, Egypt and Fiji (Morales and Zettler 1977).

LARGE AND SMALL BACILLIFORM VIRUSES

Johnston (1960) described a mosaic disease of taro in Solomon Islands which, he suspected, was caused by a virus. A severe form of the disease only occurred on Malaita Island, whereas milder symptoms were observed on other islands. The severe form of the disease was known as "alomae" (literally meaning "death of taro") and the milder form as "bobone" by the Malaitan growers (Gollifer and Brown 1972). Symptoms for both diseases were similar, beginning with a feathery mosaic. Plants with the milder form tended to become more stunted with curled twisted leaves and usually recovered whereas plants with a severe form showed progressive necrosis of the leaves, with death of all foliage in four to six weeks. The taro called "male" by the Malaitan growers, with one large corm, appeared susceptible to alomae disease, whereas the taro called "female", with a smaller central corm and many cormels, was resistant to alomae but susceptible to the milder form. Gollifer and Brown (1972) also speculated that large so-called "male" and smaller "female" types of taro on Malaita may be related to a difference in chromosome number.

Electron microscopy of diseased plants associated large bacilliform particles with plants with bobone and large and small bacilliform particles with plants with alomae (Kenten and Woods 1973). Flexuous rods, like DMV, were sometimes detected in alomae or bobone diseased material but it was uncertain whether they played a part in these diseases (James *et al.* 1973). The large particles measured 300-335 × 50-55 nm. The small bacilliform particles were morphologically similar to the cocoa swollen shoot virus group (which are all transmitted by mealy bugs) and measured 125 × 28-29 nm (James *et al.* 1973).

Jackson and Gollifer (1975) reported that a lethal disease of taro, called "joa", occurred on Santa Ysabel apparently as a result of infection by small bacilliform particles alone. Gollifer *et al.* (1977) recorded the presence of large and small particles (and sometimes flexuous rods) in various aroids of the Pacific. Jackson and Gollifer (1975) and Gollifer *et al.* (1978) reported effects on yield of alomae and bobone in Solomon Islands.

Vectors. Neither of the bacilliform particles has been manually transmitted. The large particle is transmitted by *Tarophagus proserpina* (Kirk.). The small particle was transmitted in 7 out of 50 tests by mealy bugs, once by *Pseudococcus longispinus* (Targ.) in Solomon Islands and six times by *Planococcus citri* (Risso) at Rothamsted (Gollifer *et al.* 1977). However, in the field either bobone or alomae can follow feeding by *T. proserpina*. Alomae occurred when vegetatively propagated test plants but not when true seedlings were used, suggesting that the small particle may be present in most, if not all, field grown taro on Malaita (Gollifer *et al.* 1977).

MISCELLANEOUS VIRUS RECORDS

Tomato spotted wilt virus (TSWV) was reported infecting calla lily (*Zantedeschia* spp.) in many countries (Tompkins and Severin 1950); cucumber mosaic virus (CMV) was reported from *Arum italicum* Mill. (Lovisolo and Conti 1969) and on taro near Tokyo (Kumuro and Asuyama 1955); "chirke" disease of large cardomon (*Amomum subulatum*) infected the aroid *Acorus calamus* in India (Ganguly and Raychaudhuri 1971), and a mechanically transmissible "filterable" virus infected aroids of the genera *Anthurium*, *Monstera*, *Philodendron* and *Zantedeschia*, as well as the non-aroid *Datura stramonium* (Verplancke 1930). CMV, "chirke" and TSWV have isometric particles 30, 40 and 70-90 nm in diameter respectively so can be distinguished by electron microscopy from DMV and from the two viruses with bacilliform particles.

Flexuous rods have been found in *Anthurium andraeanum* in Venezuela (Herold 1967) and in *Zantedeschia aethiopica* in the Soviet Union (Kolbasina and Protsenko 1973) but their relationship to DMV is unknown.

PREVIOUS RECORDS OF SYMPTOMS IN P.N.G.

Taro with suspected virus symptoms was first reported in P.N.G. by O'Connor in 1945 who stated (in an unpublished report) that in the Jacquinot Bay area of New Britain two diseases were seen. One was widely distributed and in some gardens attacked a large percentage of plants. It bore some resemblance to a virus disease, the symptoms being distortion and malformation of the midrib and veins of the leaf and thickening and crinkling of the leaf tissue. The disease tended to reduce yield but only a few plants died. The other was thought to be a type of wilt but no description of the symptoms was given.

Magee (1954) described a mosaic of taro which had an acute and a chronic form. The acute form caused marked stunting of affected plants, with chlorosis, twisting and malformation of the central leaves. The symptoms of the chronic form were variable, ranging from a prominent yellow mottling or streaking of the leaves without much malformation to an almost imperceptible minor streaking of the foliage.

Van Velsen (unpublished) considered that virus was the cause of stunting of taro near Madang but that petiole galls and severe stunting occurring in some other areas were due to physiological disturbances as they could not be transmitted to seedlings by grafting, mechanical inoculation or by *Aphis gossypii.*

After 1955 malformed taros with tightly rolled leaves with small, thickened, wrinkled blades were found during field surveys in some areas. They resembled the condition described by O'Connor and the acute form of Magee (1954) and were listed as "many records" by Shaw (1963) with the causal organism unspecified. Later, similarly diseased taros were observed in other areas, and various agricultural officers also reported the disease and gave information on its incidence.

Up to 1972 symptoms in taro had been noted or were reported from the following localities: *New Guinea mainland:* Madang, Lae, Morobe Highlands (Gawam and district), Waria River and Wewak; *Papua mainland:* Popondetta, Sangara, and Wedau and other Milne Bay sites; *New Britain:* Jacquinot Bay, Hoskins area, Keravat and Warangoi; *North Solomons*:* Kieta. Magee (1954) reported that the disease was present in "most areas", which, apart from Lae and Keravat, were unspecified.

In 1973 Putter (pers. comm.) reported a condition of taro at Vudal in the Gazelle Peninsula of New Britain, about 160 km (100 miles) north of Jacquinot Bay, which involved the rotting of the leaves from the tip down, eventually leaving only short, curved and rotted petioles, very similar to the condition described by Johnston (1960) and Gollifer and Brown (1972). Many leaf hoppers *(Tarophagus* sp.) were present on the crop which was completely destroyed. Bourke (pers. comm.) reported a similar condition at Keravat, not far from Vudal.

In 1974 a survey of taro gardens was carried out in the Layege area near Hoskins in New Britain. Thirty-six gardens averaging 0.25 acre each were inspected and means were: 120 plants in each garden showed severe wrinkling and stunting, 75 showed symptoms on only some leaves and 105 plants had only slightly affected leaves (Rotscheid, pers. comm.). At a spacing of 0.8 m between plants in rows 1 m apart (Benjamin, pers. comm.), the three means correspond to 9.5%, 5.9% and 8.3% respectively, with 23.7% of the total plants affected.

RECENT RECORDS IN PAPUA NEW GUINEA

During 1973 extracts negatively stained with phosphotungstate on grids and later (up to 1977) diseased material consisting mainly of young leaf blades plus petioles, were sent to Rothamsted Experimental Station, where sap was expressed from the leaves and prepared for electron microscopy as described by James *et. al.* (1973). In a few cases, material from symptomless but unthrifty plants and occasionally from apparently healthy plants was also sent for checking.

SOURCE LOCALITIES

The source localities of material sent for E.M. determination are given in *Table 1,* summarized in *Table 2,* and discussed in a later section on disease and particle distribution.

SYMPTOMS

The symptoms of material sent for E.M. determination are given in *Table 1.* Symptom descriptions by some collectors were often very brief and mostly could not be amplified on receipt at Konedobu because material often arrived with all expanded leaves dead.

Symptoms in *Colocasia* in the field included the following: faint mosaic to

---

* The island of North Solomons, once Bougainville, is part of Papua New Guinea not Solomon Islands.

Table 1. — Details of accessions and electron microscope determination of particles at Rothamsted

SOURCE LOCALITY*	ACC. NO.	SYMPTOMS	VIRUSES DETECTED+		
			Lb	Sb	Fr
Colocasia esculenta					
	PNG				
Koil Is., off N.G.m.	8047	Unthrifty	—	—	—
Telefomin, N.G.m.	8282	2 plants; tops appear normal, many roots	—	?	—
Coastal Melkoi, N.B.	8767	1 corm, said to be from plants "severely affected"	—	—	—
Boroko, P.m.	8843	Apparently healthy	—	?	—
Keravat, N.B.	8852	Apparently healthy	—	—	—
Keravat, N.B.	8853	Rolled and dwarfed leaves	+	—	—
Keravat, N.B.	8854	Rolled and dwarfed leaves	+	—	—
Coastal Melkoi, N.B.	8858	1 corm, plant said to be malformed	+	—	—
Keravat, N.B.	8861	Plant said to be healthy	—	—	—
Keravat, N.B.	8939	Leaves abnormal, dwarfed	+?	—	+
Keravat, N.B.	8940i	Plant small, abnormal	+f	—	+
Keravat, N.B.	8940ii	Plant small, abnormal	+f	—	++
Vudal, N.B.	8941	Plant with 2 rolled leaves and enations on petiole	++	—	—
Vudal, N.B.	8942	Strongly feathered pattern on leaves; 2 enations on otherwise smooth petiole	—	—	+
Vudal, N.B.	8943	Leaf with slight feathered pattern	—	—	—
Vudal, N.B.	8944	Only expanded leaf with slight feathered pattern; younger leaf small but normal in shape, feathered pattern but not pronounced; petioles normal in length; no enations	+	—	+
Pomio, N.B.		Dwarfed, rolled and deformed leaves	—	—	—
Situm, N.G.m.	9316	Leaves thickened and distorted; short petioles with enations	+	—	—
Situm, N.G.m.	9317	Leaves as above	+	—	—
Situm, N.G.m.	9318	Leaves as above; enations conspicuous	+	—	—
Keravat, N.B.	9320	Death of leaves; youngest petiole shortened	++	+f	—
Keravat, N.B.	9322	Death of leaves	+	—	—
Vudal, N.B.	9323	Death of leaves leaf 1	+	—	—
		leaf 2	+	—	—
Buin, N.S.	9358i	First wild taro plant: leaf blades thickened and some distortion	+	—	—
Buin, N.S.	9358ii	Second wild taro: leaf blades thickened and some distortion	+f	—	—
Buin, N.S.	9358iii	Third wild taro: enations on spathe base			
Buin, N.S.	9359	Small plant with slight puckering of younger leaf blades leaf 1	++	++	—
		leaf 2	—	++	—

(continued overleaf)

*Locality: N.G.M. = New Guinea mainland; P.m. = Papua mainland; N.B. = New Britain; and N.S. = North Solomons (formerly Bougainville).

+ Viruses: Lb = Large bacilliform; Sb = Small bacilliform; Fr = Flexuous rod; += particles present; ++= many particles; +f = particles few; n.i. = no information; - = particles absent.

Tabel 1. cont. — **Details of accessions and electron microscope determination of particles at Rothamtsed**

SOURCE LOCALITY	ACC. NO.	SYMPTOMS	VIRUSES DETECTED Lb	Sb	Fr
Buin, N.S.	9360	Larger plant with 9359; older leaves with feathery mosaic; younger leaves rolled with shorter petioles leaf 1	++	—	—
		leaf 2	++	+f	—
		leaf 3	+f	—	—
Buin, N.S.	9361	Very large plant; death of oldest leaf blades but shortening of youngest rolled leaf only leaf 1	++	+f	—
		leaf 2	++	+f	—
Hoskins, N.B.	9488	Large plant, very rolled leaves	+	+	—
Hoskins, N.B.	9489	Smaller plant, rolled leaves	—	—	—
Sogeri, P.m.	9529	Vein yellowing over 2 oldest leaves, young leaves normal	+f	—	—
Sogeri, P.m.	9530	Apparently normal	—	—	—
Sogeri, P.m.	9531	One large leaf with a few yellow veins, otherwise normal	+f	—	—
Madang, N.G.m.	9538i	Plant unthrifty, with mites	—	—	—
Madang, N.G.m.	9538ii	Plant unthrifty, with mites	—	—	—
Karkar Is., off N.G.m.	9682	Large plant, rolled leaves, no enations	++	—	—
Karkar Is., off N.G.m.	9683	Slightly smaller plant, leaves rolled, no enations	++	—	—
Karkar Is., off N.G.m.	9684	Small plant, leaves not rolled, but feathered pattern; no enations	+	—	—
Karkar Is., off N.G.m.	9685	Youngest leaf unfurled, not rolled, but a little crinkly; no enations	?	—	—
Karkar Is., off N.G.m.	9686	Youngest leaf rolled; second youngest unfurled but a little crinkly and blotchy yellow; no enations	?	—	—
Karkar Is., off N.G.m.	9687	Youngest leaf a little rolled, but would probably unfurl; little crinkly	—	—	—
Karkar Is., off N.G.m.	9688	Youngest leaf still rolled, but could unfurl, probably a little crinkly	?	+f	—
Takuba Village, N.B.	10535	Feathered pattern, slight wrinkling on older leaf, roots appeared normal	+	+f	n.i.
Takuba Village, N.B.	10536	Older leaf blades dead; production of side shoots with rolled deformed leaves; deterioration of some roots	+	—	n.i.
Takuba Village, N.B.	10537	Leaf blades dead, including those of side shoots, except one with rolled blade; many roots deteriorated	+	+f	n.i.
Takuba Village, N.B.	10538	Leaf blades dead; side shoots nearly all dead; roots very deteriorated, only few healthy root tips left	+f	—	n.i.
Takuba Village, N.B.	10539	Older leaves not greatly deformed; increasing rolling of leaf blades and dwarfing of side shoots	++	—	n.i.
Babauguina, P.m.	10552	Faint mosaic-like symptoms	—	—	—

continued

Table 1. cont. — Details of accessions and electron microscope determination of particles at Rothamsted

SOURCE LOCALITY	ACC. NO.	SYMPTOMS	VIRUSES DETECTED Lb	Sb	Fr
Xanthosoma sp.					
Rossel Is., off P.m.	8314	Unthrifty plant	—	—	—
Doa Plantation, P.m.	9503	Plant said to have rolled leaves; young leaf checked Sept. 1974	—	—	—
		Same plant potted outside at Konedobu; leaves appeared normal until March 1976, when new leaf developed a mottle pattern	—	—	++
		First leaf produced after mottled leaf; faint mottle only			
		Second leaf produced after mottled leaf; no discernible mottle			
Keravat, N.B.	9512i	Unthrifty plant, dwarfed	—	—	—
Keravat, N.B.	9512ii	Unthrifty plant, dwarfed	—	—	—
Keravat, N.B.	9512iii	Unthrifty plant, dwarfed	—	—	—
Keravat, N.B.	9512iv	Unthrifty plant, dwarfed	—	—	—
Keravat, N.B.	9512v	Unthrifty plant, dwarfed	—	—	—
Mageri, P.m.	9528	Slight mosaic pattern on one leaf; slight puckering, some yellowing around veins	—	—	—
Keravat, N.B.	10335	Distinct "V" shaped yellow wedges on green leaves; checked August 1976	—	—	—
		Plant potted, rechecked Nov. 1976	—	—	—
Keravat, N.B.	10402	Distinct yellow "V" shaped wedges on green leaves	—	—	++
Keravat, N.B.	10403	Unthrifty plant, root checked	—	—	—
Keravat, N.B.	10404	Unthrifty plant; root checked	—	—	—
		leaf checked	—	—	+f
Keravat, N.B.	10405	Unthrifty plant, root checked	—	—	—
		leaf checked	—	—	—
Keravat, N.B.	10554	Oldest leaf with ring spotting; younger leaf with few ring spots; youngest leaf no symptoms	—	—	+?
Caladium sp.					
Port Moresby, P.m.	10206	Some leaf distortion	—	—	—
Port Moresby, P.m.	10207	Some feathering	—	—	—

more pronounced patterns *(Plate 1)*; slight rugosity (wrinkling) of the leaf blades (and once with small enations (galls) on the spathe base) *(Plate II)*; some leaves apparently normal but with younger leaves rolled and stunted (showing the speed of onset of symptoms) *(Plate III)*; plant with enations on the petiole *(Plate IV)*; plants with leaf blades hardly visible due to nearly complete rolling and stunting, with thick, fleshy, stunted petioles *(Plate V)*; lethal disease symptoms on taro with lateral shoots *(Plate VI)* and with one shoot *(Plate VII)* and with rolling and stunting of lateral shoots *(Plate VIII)*. Some plants with rolled leaves *(Plate IX*, top) often showed multiple shoots when grown in pots *(Plate IX*, bottom).

Table 2. — Summary of data in Table 1 on locality *+ and frequency of virus particles confirmed by electron microscopy

HOST, PARTICLE AND LOCALITY	DETER-MINATIONS	OCCURRENCE OF PARTICLES		
		Doubtful	Confirmed	
	No.	No.	No.	%
Colocasia esculenta				
Large bacilliform	53			
N.G.m: Karkar Is., Situm (Lae) P.m.: Sogeri N.B.: Coastal Melkoi, Hoskins, Keravat, Vudal N.S.: Buin			33	62.3
N.G.m.: Karkar Is. N.B.: Keravat		4		
Small bacilliform	53			
N.G.m: Karkar Is., N.B.: Keravat, Takubar Village, Hoskins N.S.: Buin			10	18.9
N.G.m.: Telefomin P.m.: Boroko		2		
Flexuous rod	49			
N.B.: Keravat, Vudal			5	10.2
Xanthosoma sp.				
Large bacilliform	22		0	0
Small bacilliform	22		0	0
Flexuous rod	21			
P.m.: Doa Plantation, or possibly Konedobu N.B.: Keravat			3	14.3
N.B.: Keravat		1		
Caladium sp.	2			
Large bacilliform			0	0
Small bacilliform			0	0
Flexuous rod			0	0

* Samples from selected areas, not random

\+ See text for localities with symptoms noted or reported prior to the availability of electron microscope facilities at Rothamsted

Table 3. — Summary taken from Table 1 of occurrence of particles together and separately

PARTICLES*	HOST *Colocasia* No.	*Xanthosoma* No.	*Caladium* No.
Large bacilliform, Small bacilliform, Flexuous rod	0	0	0
Large bacilliform, Small bacilliform	8	0	0
Large bacilliform, Flexuous rods	3	0	0
Small bacilliform, Flexuous rod	0	0	0
Large bacilliform only	22	0	0
Small bacilliform only	2	0	0
Flexuous rod only	2	3	0

* Confirmed determinations only

It was often impossible to predict, from the appearance of the plant (especially if in the early stages of infection) whether and which particles would be found.

Symptoms in *Xanthosoma* included mosaic types *(Plate X,* L.H.); definite yellow "Vs" *(Plate X,* R.H. and bottom) and patterns *(Plate XI).* In some cases (e.g. *Plate XI* (L.H. and R.H.)) a strongly-marked first leaf was followed by a slightly-marked second, with no symptoms evident on the third.

PARTICLES

The particles found in each sample are given in *Table 1.* A summary of the localities and frequency of occurence of the particles identified by electron microscopy is given in *Table 2.* The large bacilliform particle was the most common of those detected in *Colocasia,* being confirmed in 62.3% of the determinations, whereas the small bacilliform particle was confirmed only in 18.9% and the flexuous rod in 10.2%. Only the flexuous rod was recorded from *Xanthosoma,* occurring in 14.3% of samples.

A summary of the particle occurence is given in *Table 3.* In 33 records of the large bacilliform particle, it occurred 22 times alone, eight times with the small bacilliform particle and three times with the flexuous rod. The small bacilliform particle was found twice alone, and the flexuous rod was also confirmed twice alone in *Colocasia* and three times alone in *Xanthosoma.*

In some cases, diseased plants whose particle content was known were potted

Plate I. — *C. esculenta* (PNG 10535); two leaves with feathering pattern and some puckering of the older leaf. Large and a few small bacilliform particles present. (No determination for flexuous rods.)

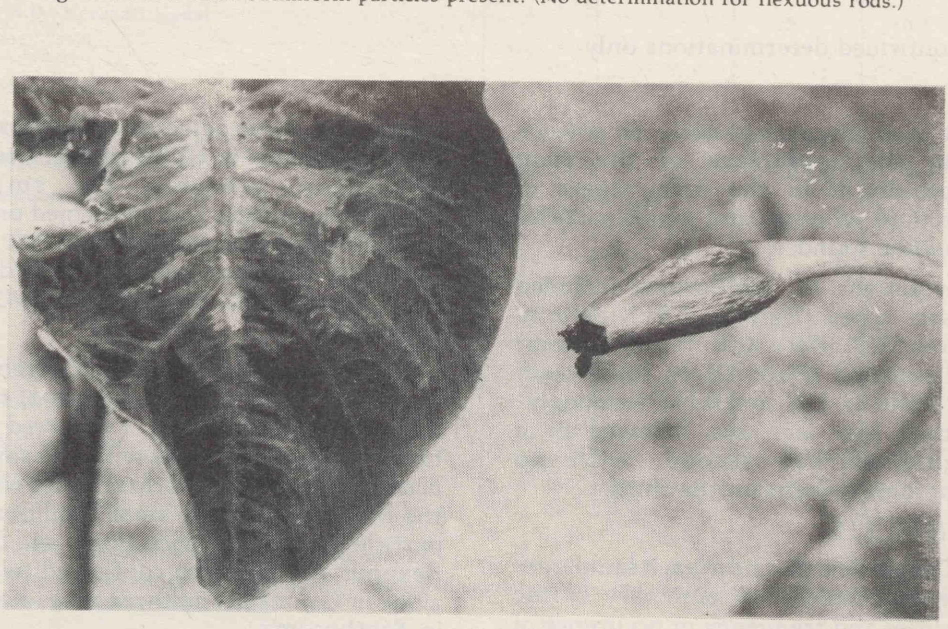

Plate II. — *C. esculenta* (wild taro, PNG 9458iii) with feathering and puckering of leaf and fine ridged enations on spathe base. No particle determinations, but two similar plants growing alongside with large bacilliform particles.

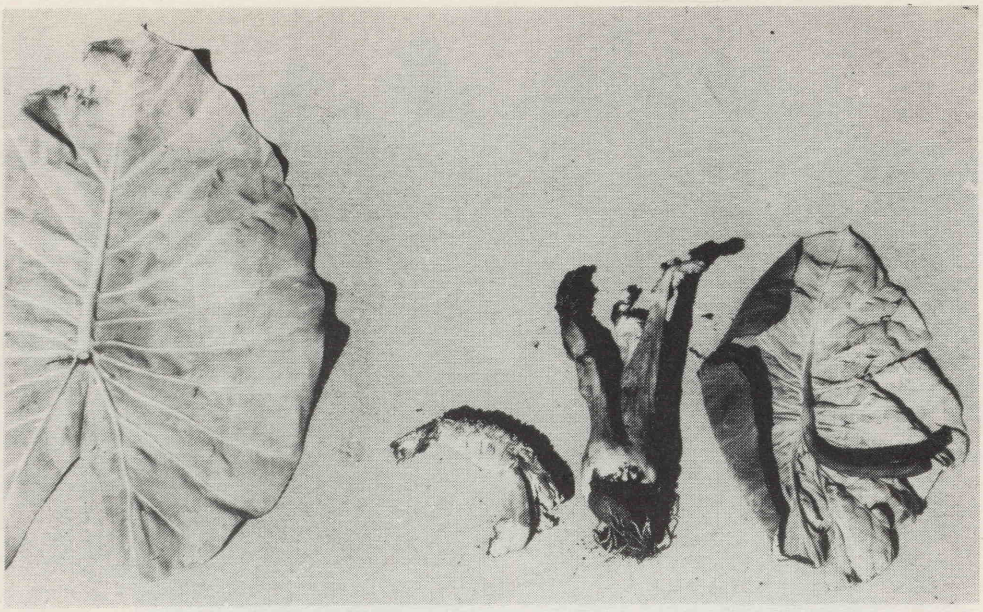

Plate III. — *C. esculenta* (PNG 5869); plant showing sequence of stunting of leaves, with youngest leaf and plant base in centre (prior to electron microscope facilities).

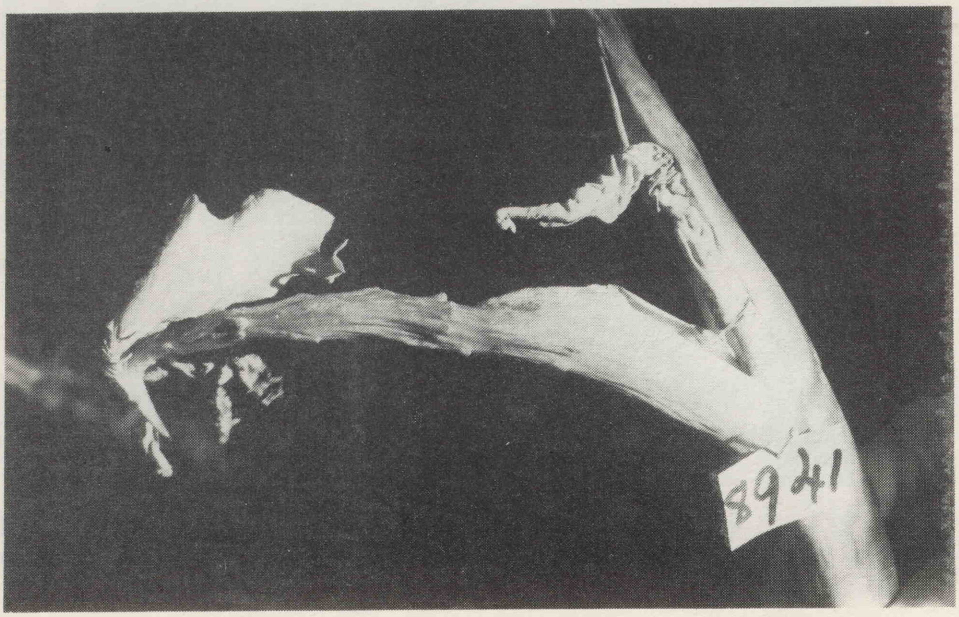

Plate IV. — *C. esculenta* (PNG 8941) with enations on petiole of older leaf, and rolled, twisted emerging leaf. Many large bacilliform particles present.

Plate V. — Two plants of *C. esculenta* (top, PNG 4946; bottom, PNG 7034) with rolled, malformed leaves with tip deterioration and thickened, stunted petiole bases (prior to E.M. facilities).

Plate VI. — Lethal disease of *C. esculenta* on plants with lateral shoots. Top: susceptible plants in foreground. Bottom: plants with no or few symptoms on left; prematurely dead plant on right.

Plate VII. — Lethal disease of *C. esculenta* on plants with one shoot only. Top : row of susceptible plants. Bottom: near view of susceptible plant.

Plate VIII. Opposite page. — Lethal disease of *C. esculenta;* both plants with mature leaf blades and distortion of immature laterals. Top: Large bacilliform particles (PNG 10536). Bottom: Large and small bacilliform particles present. (No determinations made for flexuous rods).

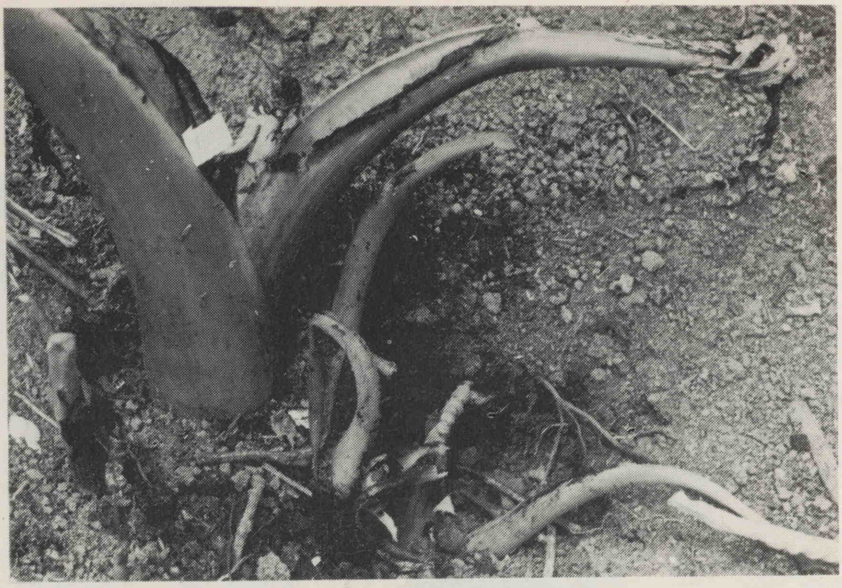

Plate VIII: —See opposite page for caption

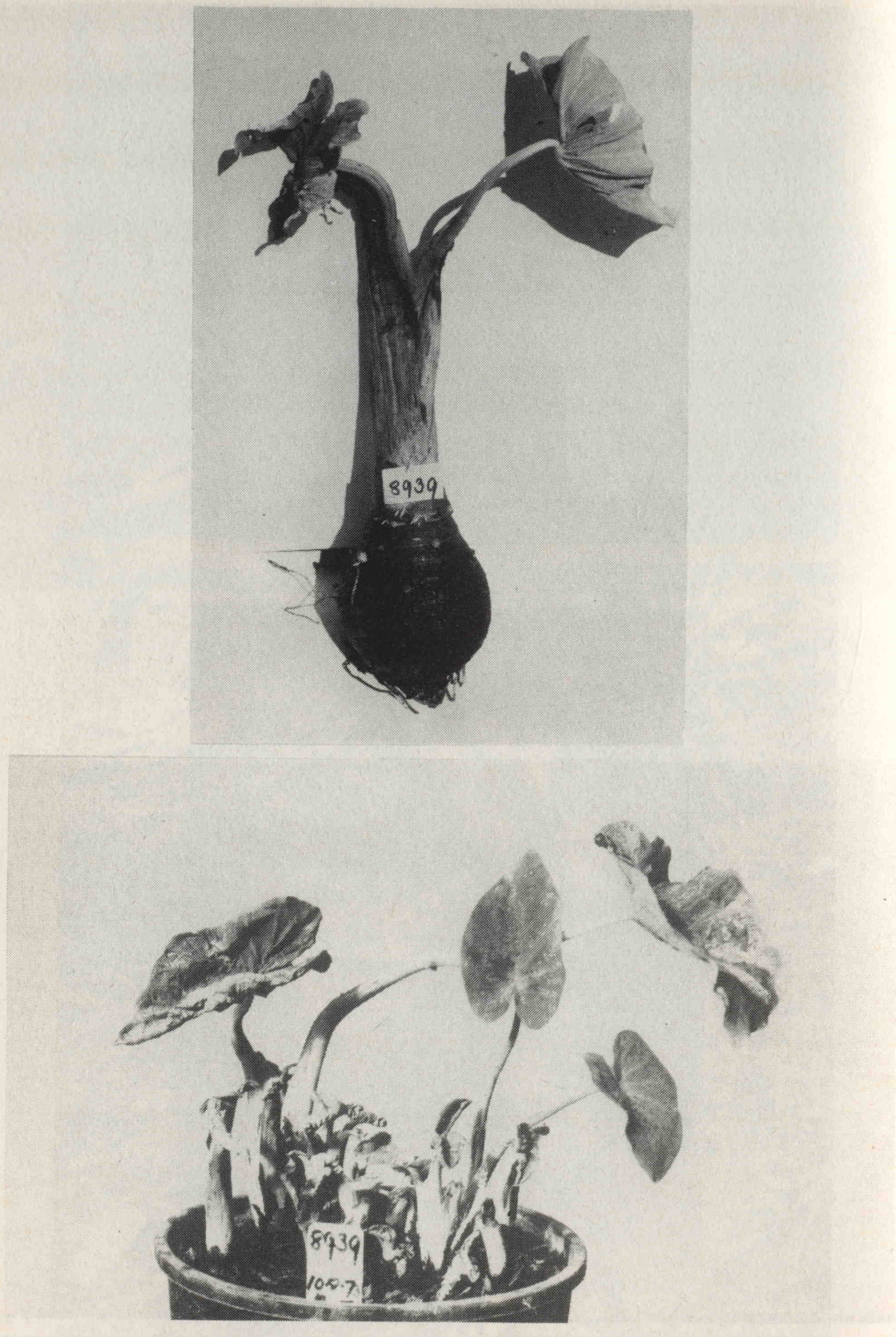

Plate IX. — *C. esculenta* (PNG 8939). Top: plant with thickened, stunted petiols; flexuous rods present and large bacilliform particles doubtfully present. Bottom: same plant as above after being potted for six months. Note prolific production of secondary shoots.

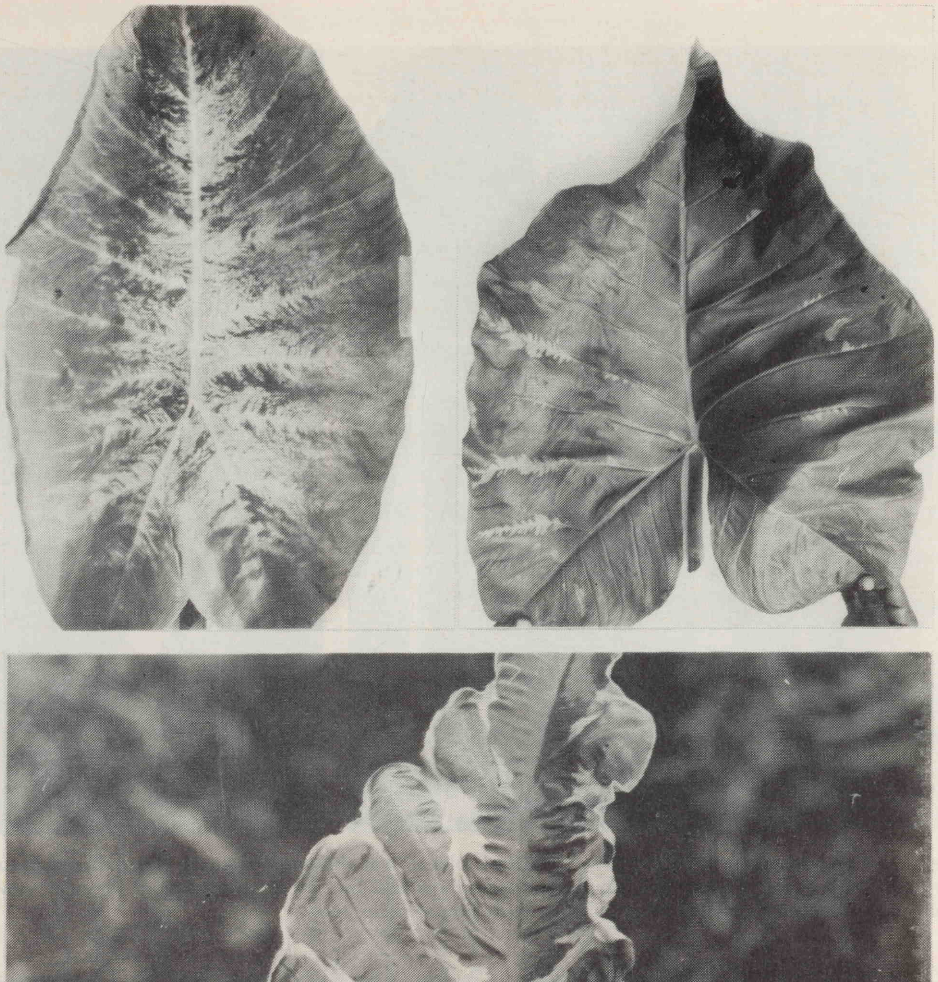

Plate X. — *Xanthosoma* sp. Top: L.H., pronounced pattern, flexuous rods present (PNG 9503). Top: R.H., definite yellow "Vs" along veins. Bottom: definite yellow "Vs" along veins, flexuous rods present (PNG 10402).

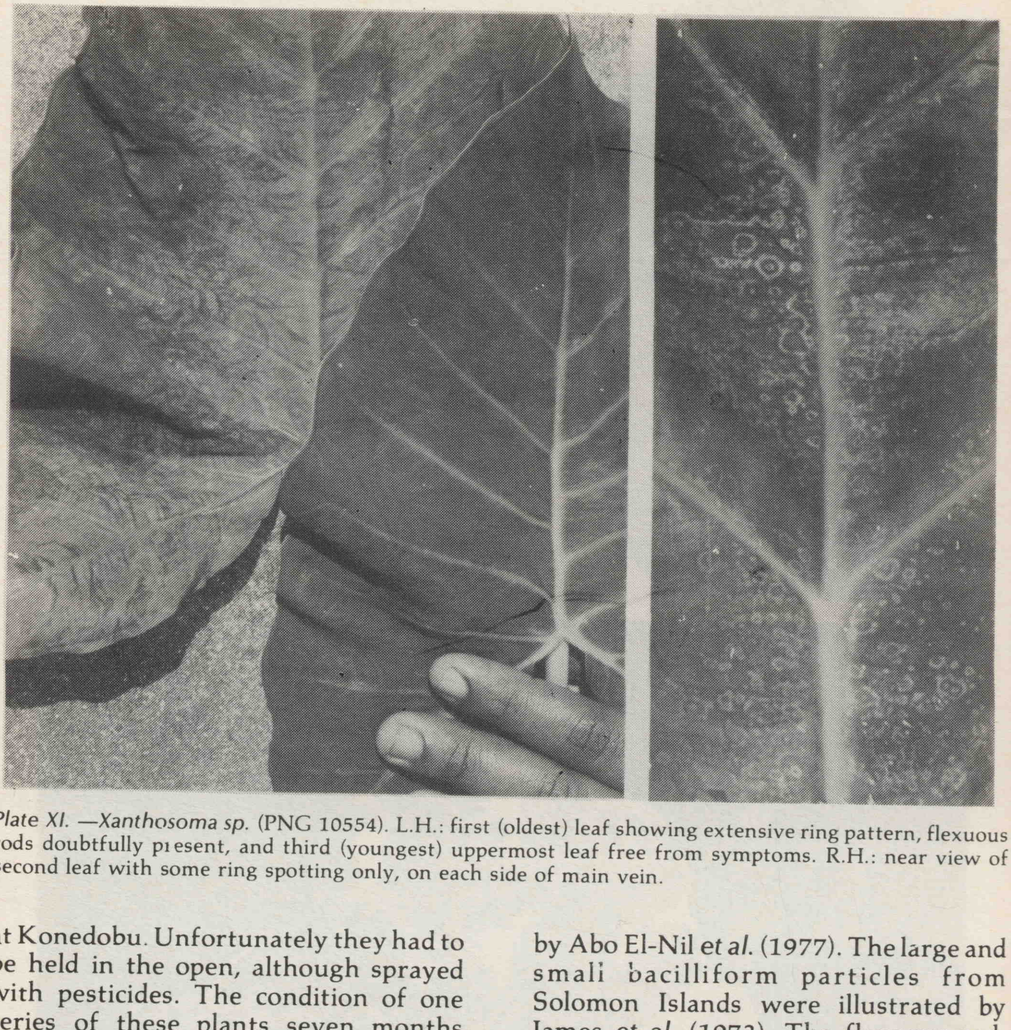

Plate XI. —*Xanthosoma sp.* (PNG 10554). L.H.: first (oldest) leaf showing extensive ring pattern, flexuous rods doubtfully present, and third (youngest) uppermost leaf free from symptoms. R.H.: near view of second leaf with some ring spotting only, on each side of main vein.

at Konedobu. Unfortunately they had to be held in the open, although sprayed with pesticides. The condition of one series of these plants seven months after potting is summarized in *Table 4.*

Although no serological tests have been carried out, it is presumed that the flexuous rods are particles of DMV, because of their size and shape, and because serological and other checks of Fiji material (Abo El-Nil *et al.* 1977) have confirmed the presence of DMV in the Pacific.

The particles and inclusions of DMV were illustrated by Zettler *et al.* (1970; 1978) and Abo El-Nil and Zettler (1976), and the particles in purified preparation by Abo El-Nil *et al.* (1977). The large and small bacilliform particles from Solomon Islands were illustrated by James *et al.* (1973). The flexuous rod, and the large and small bacilliform particles from P.N.G. material are shown in *Plate XII.*

ABSENCE OF PARTICLES

Failure to find particles, particularly flexuous rods, does not necessarily mean that the viruses are absent; many leaves of plants infected with DMV may be symptomless (Zettler *et al.* 1970). Some types of taro infected with large, and even with small, bacilliform particles, may recover (Gollifer *et al.* 1977; 1978). In the present study, no

Table 4. — Comparison of particles, field symptoms and eventual state of some affected *Colocasia* seven months after potting

ACC. NO. PNG	PARTICLES PRESENT*	SYMPTOMS IN FIELD	BEHAVIOUR AFTER SEVEN MONTHS IN POTS	
			Summary of symptoms	State
9316	L	Leaves thickened and distorted; short petioles with enations	Many new leaves; slight rugosity on 2 leaves only	Apparently healthy
9317	L	Leaves thickened and distorted; short petioles with enations	Original plant died down; 4 small shoots present at 3 months; later died; no re-shooting	Dead
9318	L	Leaves thickened and distorted; enations conspicuous	Six new leaves; no symptoms	Apparently healthy
9320	L,S	Some leaves already wilted	Dead by 3 months; no re-shooting	Dead
9322	L	Some leaves already wilted	Very unthrifty with one small shoot only by 3 months; later died; no re-shooting	Dead
9358i	L	Leaf blades thickened and some distortion	Dead by 3 months; no re-shooting	Dead
9358ii	L	Leaf blades thickened and some distortion	New leaves and 2 flowers; no symptoms	Apparently healthy
9358iii	n.d.+	Small enations on spathe base	New leaves and 2 flowers; no symptoms	Apparently healthy
9359	L,S	Small plant with slight puckering of younger blades	By 3 months only one short shoot; later died, no re-shooting	Dead
9360	L,S	Larger plant with 9359; older leaves with feathery mosaic; younger leaves rolled with shorter petioles	Produced 3 small shoots with small leaves, none malformed by 3 months; later died; no re-shooting	Dead
9361	L,S	Very large plant; death of oldest leaf blades but shortening of youngest rolled leaf only	Produced one small side shoot with two small leaves; later died; no re-shooting	Dead

* Particles determined immediately from field; L = Large bacilliform; S = Small bacilliform

+n.d. = not determined

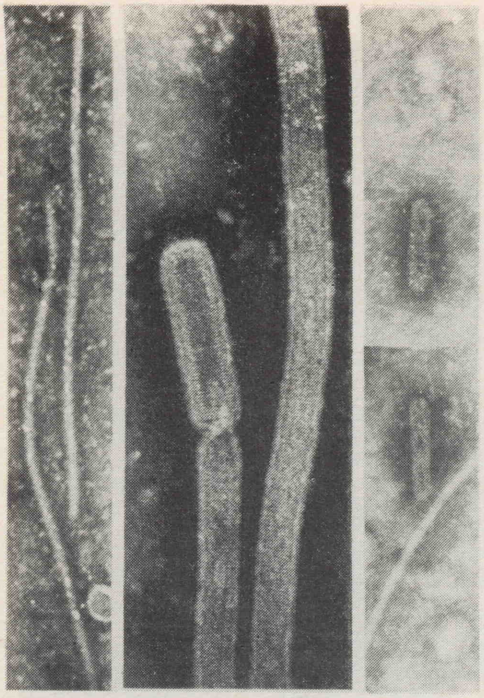

Plate XII. — Virus particles from C. *esculenta*, x approx. 100,000. L.H.: two flexuous rod-shaped particles. Centre: a large bacilliform-shaped particle apparently formed by constriction. R.H.: two small bacilliform-shaped particles.

small bacilliform particles were found in the first or third leaves of *Colocasia* Accession PNG 9360, although they were present in the second leaf *(Table 1)*. Also, in *Xanthosoma* Acc. PNG 9503 *(Table 1)* no symptoms were present in the next but one leaf produced after a leaf with mosaic that had been shown to contain flexuous rods. *Colocasia* Accs. PNG 9316, 9318 and 9458ii, all containing large bacilliform particles, were symptomless, although presumably still infected, seven months after transplanting into pots *(Table 4)*. On the other hand, no particles were confirmed in *Colocasia* Accs. PNG 8282, 8843 and 8852, all apparently healthy in the field *(Table 1)*.

DISTRIBUTION OF DISEASES AND PARTICLES

Taro plants with leaf patterns, rugosity and with rolled, malformed and stunted leaves have been recorded in many areas in P.N.G., and the presence of viruses in them was confirmed by electron microscopy. A lethal wilt of taro has mainly been recorded at sites in North Solomons and in the Gazelle Peninsula of New Britain in village gardens such as at Takuba, and at Keravat and Vudal, and the small particle was present at all sites except Vudal. A few small bacilliform particles were also detected in material from Hoskins (New Britain) and from Karkar Island about 274 km (170 miles) directly west from New Britain. Whether the small bacilliform particle was involved with the malformed condition, or with the "wilt" reported by O'Connor (unpublished report) in 1945 in New Britain is not known. Magee (1954), Oats and Rotscheid (both pers. comm.) made no mention of deaths in their surveys of taro in various parts of P.N.G.. New Britain and North Solomons, where the small particle has been confirmed, are adjacent to Solomon Islands, where the small particle (as well as the large) has been recorded.

The apparent absence of the lethal disease of taro from some areas of P.N.G. may indicate that the small particle is not present, the taro cultivars are resistant or that it is present in isolated villages not visited during surveys.

Large bacilliform particles were found in plants with rolled, malformed leaves, and large and small bacilliform particles in plants with lethal disease *(Tables 1* and *4)*. The exceptions were where small particles were not detected in two plants with obvious lethal disease in the field *(Table 1*, Accs. PNG 9322 and 9323) nor in Accs. PNG 9317 and 9358i, all of which died after being held in pots at the laboratory for some months *(Table 4)*. This may be because particles were few or could not be detected in material that was in poor condition.

The corm type of most diseased plants was unknown as specimens received from the field usually consisted of the original planting piece only. Taro in the field generally consisted of a single large corm or a large corm with up to six laterals. Some diseased specimens produced multiple shoots after being potted for some months *(Plate IX)*, perhaps due to stimulation of lateral buds or abnormal growing conditions. Plants in the field with lethal disease showed the above range of corm types *(Plates VI, VII* and *VIII)*.

Although the introduction into P.N.G. of vegetative material of the agriculturally important genera, such as *Colocasia, Xanthosoma* and *Alocasia*, is prohibited, vegetative material of 10 genera of Araceae of ornamental interest has been imported, some of which may have been carrying DMV, even though remaining symptomless during the quarantine period.

At least 20 other genera of the Araceae are indigenous to P.N.G. but no virus-like symptoms have been reported in any of them, although no detailed survey has been carried out. Perhaps DMV has, or could still, infect these genera by aphid transmission from infected taro gardens near or in the rain forest. However, although these genera may persist locally by vegetative means, spread to new locations is mainly by seed (Henty, pers. comm.), so that even if DMV were present, the virus would not be distributed by vegetative propagation as it is in the cultivated aroids.

NAMES OF THE DISEASES

In Solomon Islands there are two names for lethal virus diseases of taro, namely, "alomae" on Malaita and "joa" on Santa Ysabel. The former has both large and small bacilliform particles (in taro with one large corm and leaves) and the latter has small particles only (corm type unspecified). "Bobone" is the name given on Malaita to the disease associated with large particle infection of the small corm/many cormels type of taro, from which the plant recovers. No common or local dialect names appear to have been given to taro, either with small particles in the large corm type, or with any combination of bacilliform particles in the small corm type, that recovers. Flexuous rods may also be present in any of the above.

In P.N.G. there are over 500 languages and some local names are given to the virus diseases. However, it seems inadvisable to promote the P.N.G. names which have restricted local significance or to adopt Solomon Islands names, especially as there are difficulties in predicting, from symptoms in the field or in specimens, the ultimate state of the plants, the corm type or which of the three virus particles, or combination of particles, may be present. Therefore it seems preferable to give verbal descriptions of the virus symptoms, rather than attempt to assign common names to the diseases.

NAMES OF THE VIRUSES

Zettler *et al.* (1970) and Abo El-Nil *et al.* (1977) described the flexuous rod virus of taro and other aroids as dasheen mosaic virus (DMV) and it would be convenient to have names for the bacilliform viruses. The names suggested are taro large bacilliform virus (TLBV) (*/*:*/*:U/*:S/Au, rhabdovirus group) and taro small bacilliform virus (TSBV) (*/*:*/*:U/*:S/Cc(Au)).

HOST IDENTIFICATION AND CHROMOSOME NUMBERS

In this paper taro has been referred to as *C. esculenta* (L.) Schott, following Hill (1939), who applied the

International Rules of Botanical Nomenclature to the taxonomy of Engler and Krause (1920), which recognized taro as one polymorphic species with varieties.

Other workers have retained *C. antiquorum* for the species, and this has resulted in some confusion. Purseglove (1972) recognized *C. esculenta*, with *C. esculenta* var. *esculenta* (syn. *C. esculenta* var. *typica* A.F. Hill) for species with (usually) one large corm and with a sterile appendage shorter than the male inflorescence and protuberant from the inrolled tip of the spathe, and *C. esculenta* var. *antiquorum* (Schott) Hubbard and Rehder (syn. *C. esculenta* var. *globulifera* Engl. and Krause) for taro with a smaller central corm with many cormels, and a sterile appendage longer than the male section of the spadix (three times or more that of *C. esculenta* var. *esculenta)* and which is retained within the inrolled tip of the spathe. This latter type is that which occurs, for example, in the West Indian "eddoes".

So-called "male" taro (Gollifer and Brown 1972; Jackson and Gollifer 1975; Gollifer *et al.* 1977; 1978) was described as usually having only one large corm, and the so-called "female" type, one small central corm and many cormels. However, as no description of the floral apparatus of taro in Solomon Islands has been published, the cultivars cannot be assigned with assurance to botanical varieties. The Mengen people of New Britain (P.N.G.) also distinguish between "avale" (so-called "female") taro, producing more than five cormlets and with other characteristics, from "apanung" (so-called "male") taro, with fewer than five cormlets and different characteristics; however, here again neither flowering nor floral characters have been reported (Panoff 1972).

Gollifer and Brown (1972) suggested that differences in resistance to alomae in some taro cultivars grown in Solomon Islands are related to ploidy. They pointed out that the group referred to as "male" taro in Solomon Islands is similar to the 2n = 42 chromosome taro mentioned by Abraham (1970), or, in direct contrast, to the 2n = 28 chromosome taro described by Fukushima *et al.* (1962). Subsequently, Gollifer *et al.* (1977) stated that "evidence suggests that the cultivars of taro susceptible to alomae and known locally in Malaita as "male" are triploid (2n = 42), while the smaller ones known as "female" and susceptible to bobone are diploid (2n = 28)".

Various workers have studied chromosome numbers in *Colocasia*. Mookerjea (1955) found definite indication of polyploidy and gave seven chromosomes in the basic set. Marchant (1971) also reported *Colocasia* with x = 7, and gave *C. esculenta* with 2n = 28 and *C. antiquorum* as the hexaploid with 2n=42. Fukushima *et. al.* (1962) reported their findings under the species *C. antiquorum*, but they stated that *C. antiquorum* var. *esculenta*, (which some workers would give as *C. esculenta* var. *esculenta)*, has 2n = 28 (which they designated diploid) and *C. antiquorum* var. *globulifera* (which some would give as *C. esculenta* var. *antiquorum*) 2n = 42 (which they designated triploid). They further classified their taro varieties by their "parts of utilization": 19 out of 20 varieties grown for large stock tubers had 2n = 28 and only one 2n = 42, whereas 72 varieties grown for many small adherent tubers all had 2n = 42, as did six grown either for stock or small tubers; five varieties grown for their petioles had 2n = 28. No description of the floral apparatus was published for any of the 103 varieties studied by Fukushima *et al.*, but floral characters may have been used as the basis of the separation of the taros into "var. *esculenta*" and "var. *globulifera*" as given above.

Of 199 samples of taro from the Pacific region, 137 had 2n = 28 and 62 had 2n = 42 but morphology did not relate to chromosome number (Yen and Wheeler 1968). Sixteen lines from New Guinea and 22 lines from the Solomon Islands all had 2n = 28. Because no material from the lowland river basins of New Guinea was examined, the possibility that plants with 42 chromosomes occur in the area cannot be eliminated. Haynes and Sivan (1975) reported that all the taro examined by them in Fiji had 28 chromosomes, and showed a wide range of petiole colour and corm type. However, three varieties from Fiji, said to be introductions from India in recent times, all had 2n = 42 chromosomes (Yen and Wheeler 1968).

Engler and Krause (1920) assigned taro specimens from various areas in New Guinea to *C. antiquorum* var. *typica*, which became *C. esculenta* var. *typica* (Hill 1939), which would be *C. esculenta* var. *esculenta* according to modern rules (Mayo, pers. comm.). Shaw (1975) found that the sterile appendage of the spadix of all taro in bloom* in various areas in P.N.G. during her study was shorter than the fertile male inflorescence of the spadix. This conforms to the description given by Purseglove (1972) for *C. esculenta* var. *esculenta*. If this does prove to be the only type of floral apparatus of taro in P.N.G. and if the report of Yen and Wheeler (1968) that taro throughout P.N.G. has 2n = 28 is not amended after the study of further material, then the taro reported in *Tables 1-4* in this paper would probably all be 2n = 28. However, plants with lethal disease may prove to have 42 chromosomes, as suggested for plants susceptible to alomae in Solomon Islands by Gollifer *et al.* (1977). If so, this 42 chromosome taro may have limited distribution in P.N.G. and even less frequent flowering than the 28 chromosome taro.

* Except for three plants on North Solomons, where each spathe lacked the entire spadix (Shaw 1975).

Therefore, pending a revision of the taxonomy of *Colocasia*, it would seem desirable that when leaf specimens are taken for E.M. determination of virus particles, some root tips from *the same plant* should be fixed for cytological determination of chromosome number.

The cultivated *Xanthosoma* has been known agriculturally in P.N.G. as *X. sagittifolium* (L.) Schott, but, as Dr H. Nicolson (pers. comm.) has grave reservations about Engler's definition of species in this genus, the plant is given as *Xanthosoma* sp. in this paper.

OCCURRENCE OF VECTORS

Vectors of the flexuous rod-shaped particle. Aphis gossypii was recorded at Port Moresby (Szent-Ivany 1956) and *A. gossypii* and *A. craccivora* at Keravat (Szent-Ivany 1959) but not on Araceae. Species recorded by Lamb (1972) trapped in Moericke trays, and records of previous workers, are summarized as follows:

A. (Pergandeida) craccivora Koch, 1954: trapped at Waigani (Papua mainland), Bulolo (N.G. mainland) and Keravat (New Britain), and specimens from Morobe and Aiyura (both N.G. mainland). Hosts given do not include Araceae.

A. (Cerosipha) gossypii Glover, 1877: trapped at Waigani (Papua mainland), Bulolo (N.G. mainland) and Keravat (New Britain), and specimens from Morobe and Chimbu (N.G. mainland). Hosts given include taro *(Colocasia)* but no other Araceae.

M. (Nectarosiphon) persicae (Sulzer) 1976: trapped at Bulolo and Goroka (both N.G. mainland). Hosts given do not include *Colocasia* or other Araceae.

In his host list records, the only genus of Araceae mentioned by Lamb (1972) was *Colocasia*, and the only aphids recorded on it are as follows: *Colocasia* sp.: *A. (Cerosipha) gossypii* and *Pentalonia nigronervosa* Coq.. However, Morales and Zettler (1977) and Gollifer *et al.* (1977) have reported that apparently this latter aphid cannot transmit DMV.

Vectors of the large bacilliform particle. Tarophagus proserpina (Kirk.) subsp. *proserpina**, was first determined in P.N.G. as *Megamelus proserpina* Kirk., by Evans from specimens that were feeding on taro foliage and that had been collected by O'Connor from Manus Island in 1945. In 1973 *T. proserpina* was identified on taro at Keravat, New Britain, in 1973 and 1974 at Vudal, also in New Britain and in 1977 in Morobe province on the New Guinea mainland (Fenner, pers. comm.).

Large numbers of *T. proserpina* on taro have only been reported by Putter (pers. comm.) and Shaw at Vudal and by Perry (pers. comm.) at Keravat. Taro varietal and other plantings on these Governmental institutions may not have been as widely separated in space and time as occurs in some village gardens, where fewer *T. proserpina* have been recorded.

Vectors of the small bacilliform particle. Planococcus citri (Risso) has been recorded many times on eleven plant species in many areas of P.N.G., including North Solomons and at Keravat in New Britain (Szent-Ivany 1956, 1959; Szent-Ivany and Catley 1960). It has not been recorded on taro (Fenner, pers. comm., 1978). *Pseudococcus longispinus* Targ. has not been recorded in P.N.G. (Fenner, pers. comm.). The only species of mealy bugs reported from taro in P.N.G. is *Dysmicoccus brevipes* (Cockerell) (Fenner, pers. comm.).

The paucity of records of mealy bugs on taro may not be a true indication of their occurrence. Shaw noted that every taro plant pulled up at random in one village garden had a heavy infestation of mealy bugs on the below-ground parts. Such occurrence, not visible above ground, could well be overlooked by collectors.

It is evident that known vectors of all three virus particles are widely distributed in P.N.G.

CONTROL

Many of the local growers in P.N.G. already discard malformed taro plants (Magee 1954; Oats (pers. comm.) and Shaw) and the opening of taro gardens in new areas is traditional practice. Roguing plants with symptoms would probably help to decrease the incidence of diseases by removing sources of infection, especially if done as soon as symptoms appear. Growers would probably be unwilling, however, to remove plants unless symptoms were marked, so that infected plants with slight symptoms would probably be left and act as sources of infection. Opening new gardens in new areas may decrease the numbers of infective and potentially infective vectors and manual removal and killing of insects on planting pieces may help to delay vector arrival but the removal of eggs which are laid in the petiole bases would be more difficult. Extension work should therefore try to encourage the use of the healthiest planting pieces from unaffected gardens, and to explain in simple terms the involvement of insects and the desirability of spacing plantings as far apart as possible.

It is most desirable that the vectors of the viruses be controlled biologically. Species of ladybird predaceous on mealy bugs are already present and widespread in P.N.G. with records of *Cryptolaemus affinis* Crotch and *C. montrouzieri* Muls. (Catley 1966) and *C. wallacei* Crotch (Fenner, pers. comm.). Gollifer *et al.* (1977) reported that in Hawaii direct damage by large populations of *T. proserpina* has been decreased by the introduction from the Philippines of the egg-sucking bug

* *T. proserpina* subsp. *proserpina*, as *T. proserpina* subsp. *australis* was described by Fennah (1965).

Cyrtorhinus fulvus Knight. *C. lividipennis* Reut. has been recorded in P.N.G. on rice in Morobe Province and an unidentified species of *Cyrtorhinus* has been collected from taro at Keravat, and may be a predator (Perry, pers. comm.).

If varieties are maintained on experimental stations as collections for agronomic and other research, or as a germplasm collection, it is essential that they be kept free from viruses. As adequate insect proofing would probably not be available pesticides may be needed to achieve this. Treatment of the area and the planting pieces with a systemic insecticide before planting and at regular intervals during the growth of the crop, will decrease numbers of resident breeding vectors but would not afford full control of adult migrants. Therefore, regular inspections and roguing and selection for propagating material may need to be combined with comprehensive chemical treatment.

It would be highly desirable for growers to have varieties resistant to the bacilliform viruses. Gollifer *et al.* (1978) found that 13 cultivars of the type with a small central corm and many cormels were not susceptible to the lethal disease when field grown on Malaita. However, these varieties are less acceptable in taste and yield than the varieties with one large corm. All 284 cultivars of the latter (preferred) type from Solomon Islands, Hawaii, New Hebrides and New Zealand field tested on Malaita proved susceptible to the lethal disease. Varieties in the field at Keravat certainly showed differences in susceptibility. Some lines were nearly wiped out while others survived (Bourke and Rangai, pers. comm.) *(Plate VI).*

Each of the separate taro-growing peoples of P.N.G. have between 40 to 70 different cultivars (Bourke, pers. comm.), although in exceptional cases this can be much higher; for example, the coastal group of the 5000 Mengen people of New Britain has at least 130 different cultivars whereas the bush Mengen has over 200 (Panoff 1972). The reaction of the wide range of P.N.G. cultivars to the viruses has not been studied.

Although some taro varieties set seed (Shaw 1975) and seed is not known to transmit DMV (Zettler *et al.* 1978) or the bacilliform viruses (Gollifer *et al.* 1977), little is known of the normal mechanism of fertilization, or of segregation of characters in progeny, of this crop. However, if the disease reaction and chromosome number relationship suggested by Gollifer *et al.* (1977) for Solomon Islands material proves correct, crossings may be needed between 28 and 42 chromosome taros to yield progeny with both resistance and acceptable taste and yield. If $x = 7$ in *Colocasia* (Mookerjea 1955; Marchant 1971), these taros would be tetraploids and hexaploids, so that fertile crossings and selection of desired types in progeny may be possible. Gross chromosome morphology for $2n = 14$ and $2n = 42$ lines is already available (Mookerjea 1955) and for $2n = 28$ (Marchant 1971) so that genome identification and chromosome charting may also eventually be possible.

ACKNOWLEDGEMENTS

Grateful thanks are extended to all collectors, especially members of the Department of Primary Industry (D.P.I.) in P.N.G., who provided specimens or information, or who gave assistance during field visits; to Mr R.M. Bourke of D.P.I., P.N.G., for discussions on taro cultivars; to Mr E. Henty, Division of Botany, Department of Forests, P.N.G., Dr S.J. Mayo, Royal Botanic Gardens, Kew and Dr D.H. Nicolson, Smithsonian Institution, Washington, for advice on botanical aspects including nomenclature and taxonomy; to Mr T.L. Fenner, D.P.I., P.N.G., and to officers of the Entomology Branch, D.P.I., Queensland, for entomological advice, and to Mr G.S. Purss, Director, Plant Pathology Branch, D.P.I., Indooroopilly, Queensland, for facilities made available to D.E.S. during the later stages of this study.

REFERENCES

ABO EL-NIL, M.M. and ZETTLER, F.W. (1976). Natural occurrence of dasheen mosaic virus in Egyptian taro, *Colocasia antiquorum*. *Plant Disease Reporter*, 60:281-285.

ABO EL-NIL, M.M., ZETTLER, F.W. and HIEBERT, E. (1977) Purification, serology and some physical properties of dasheen mosaic virus. *Phytopathology*, 67:1445-1450.

ANON. (1973). A dictionary of the generic and family names of flowering plants and ferns of the New Guinea and South-West Pacific Region. *Department of Forests, Port Moresby, Botany Bulletin* No. 2, 134 pp..

CATLEY, A. (1966). Parasites and predators of some insects recorded from the Territory of Papua and New Guinea. *Department of Agriculture, Stock and Fisheries, Port Moresby, Research Bulletin* No. 2, (Page 6).

ENGLER, A. and KRAUSE, K. (1920). Araceae-Colocasioideae. *Das Pflanzenreich* IV, 23E:1-139. Leipzig.

FENNAH, R.G. (1965). Delphacidae from Australia and New Zealand. *Bulletin of the British Museum (Natural History)*. Entomology 17:3-59.

FENNER, F. (1976). Classification and nomenclature of viruses. Second Report of the International Committee on Taxonomy of Viruses. *Intervirology*, 7:1-115.

FUKUSHIMA, E., ISAWA, S., TOKUMASU, S. and ISAMASA, M. (1962). Chromosome number of the taro varieties cultivated in Japan. *Chromosome Information Service* No. 3:38-39.

GANGULY, B. and RAYCHAUDHURI, S.P. (1971). Purification of wheat streak mosaic virus. *Phytopathologische Zeitschrift*, 70:11-14.

GOLLIFER, D.E. and BROWN, J.F. (1972). Virus diseases of *Colocasia esculenta* in the British Solomon Islands. *Plant Disease Reporter*, 56: 597-599.

GOLLIFER, D.E., JACKSON, G.V.H., DABEK, A.J. and PLUMB, R.T. (1978). Incidence, and effects on yield, of virus deseases of taro (Colocasia esculenta) in the Solomon Islands. *Annals of Applied Biology, 88:131 - 135.*

GOLLIFER, D.E., JACKSON, G.V.H., DABEK, A.J., PLUMB, R.T. and MAY, Y.Y. (1977). The occurrence and transmission of viruses of edible aroids in the Solomon Islands and the South-west Pacific. *PANS*, 23:171-177.

HARTMAN, R.D. (1974). *Dasheen mosaic virus of cultivated aroids and its control by seed propogation and culture of shoot tips.* Ph.D. Dissertation, University of Florida, Gainesville. 80pp.. (Abstract)

HARTMAN, R.D. and ZETTLER, F.W. (1972). Dasheen mosaic virus infections in commercial plantings of aroids in Florida. *Phytopathology*, 62:804. (Abstract)

HAYNES, P.H., and SIVAN, P. (1975). A root crop research and development project in Fiji. *Tropical Root and Tuber Crops Newsletter*, 8:24-26.

HEROLD, F. (1967). Investigations of a virus disease of *Anthurium andraeanum*. *Phytopathology*, 57:8. (Abstract)

HILL, A.F. (1939). The nomenclature of the taro and its varieties. *Harvard University Botanical Museum Leaflets*, 7:113-118.

JACKSON, G.V.H. and GOLLIFER, D.E. (1975). Disease and pest problems of taro *(Colocasia esculenta* (L.) Schott) in the British Solomon Islands. *PANS*, 21:45-53.

JAMES, M., KENTEN, R.H. and WOODS, R.D. (1973). Virus-like particles associated with two diseases of *Colocasia esculenta* (L.) Schott in the Solomon Islands. *Journal of General Virology*, 21:145-153.

JOHNSTON, A. (1960). A preliminary plant disease survey in the British Solomon Islands Protectorate. *Food and Agriculture Organisation of the United Nations, Rome*. Page 23.

KENTEN, R.H. and WOODS, R.D. (1973). Viruses of *Colocasia esculenta* and *Xanthosoma sagittifolium*. *PANS*, 19:38-41.

KOLBASINA, N.E. and PROTSENKO, A.E. (1973). Mosaic virus of arum lily *(Zantedeschia aethiopica). Byulleten' Glavnogo Botanicheskogo Sada*, No. 88:98-101.

KUMURO, Y. and ASUYAMA, Y. (1955). Studies on cucumber mosaic virus. II. The isolation of the virus from various plants showing mosaic in the vicinity of Tokyo, Japan. *Annals of the Phytopathological Society of Japan*, 20:77-82.

LAMB, K.P. (1972). Aphids of Papua and New Guinea: an annotated Check List. *Proceedings of the Linnean Society of New South Wales*, 96: 186-192.

LOVISOLO, O. and CONTI, M.A.C. (1969). Biological characterization of some isolates of cucumber mosaic virus. *Annales de Phytopathologie*, 1:367-373.

MAGEE, C.J. (1954). Report on survey of virus diseases of food crops in the Territory of Papua and New Guinea with special reference to plant quarantine — Part II. *Papua New Guinea Agricultural Journal*, 9:17-26.

MARCHANT, C.J. (1971). Chromosome variation in Araceae: I. Pothoeae to Stylochitoneae. *Kew Bulletin*, 24:315-322.

MOOKERJEA, A. (1955). Cytology of different species of aroids with a view to trace the basis of their evolutions. *Caryologia*, 7:221-291.

MORALES, F.J. and ZETTLER, F.W. (1977). Aphid transmission characteristics of dasheen mosaic virus. *Fitopathologia Colombiana,* 6: 133. (Abstract)

PANOFF, F. (1972). Maenge taro and cordyline: elements of a Melanesian key. *Journal of the Polynesian Society,* 81:375-390.

PURSEGLOVE, J.W. (1972). *Tropical crops: Monocotyledons* 1. Longman Group Ltd. London. 607 pp..

SHAW, D.E. (1963). Plant pathogens and other micro-organisms in Papua and New Guinea. *Department of Agriculture, Stock and Fisheries, Port Moresby, Research Bulletin No.*1:1-78.

SHAW, D.E. (1975). Illustrated notes on flowering, flowers, seeds and germination in taro *(Colocasia esculenta). Department of Agriculture, Stock and Fisheries, Port Moresby, Research Bulletin No.* 13:39-59.

SZENT-IVANY, J.J.H. (1956). New insect pest and host plant records in the Territory of Papua and New Guinea. *Papua New Guinea Agricultural Journal,* 11:82-87.

SZENT-IVANY, J.J.H. (1959). Host plant and distribution records of some insects in New Guinea. *Pacific Insects,* 1:423-429.

SZENT-IVANY, J.J.H. and CATLEY, A. (1960). Host plant and distribution records of some insects in New Guinea and adjacent islands. *Pacific Insects,* 2:256-261.

TOMPKINS, C.M. and SEVERIN, H.H.P. (1950). Spotted wilt of white, yellow and pink calla. *Hilgardia,* 20:207-218.

TOOYAMA, A. (1975a). Indicator plants for dasheen mosaic virus. *Annals of the Phytopathological Society of Japan,* 41:504-506.

TOOYAMA, A. (1975b). Expression of mosaic symptoms on taro plants from dasheen mosaic virus infected corms. *Annals of the Phytopathological Society of Japan,* 41:506-507.

VERPLANCKE, G. (1930). Une maladie "a virus filtrant" des *Anthurium. Compte Rendu de la Societe de Biologie (Paris),* 103:524-526.

YEN, D.E. and WHEELER, J.M. (1968). Introduction of taro into the Pacific: the indications of the chromosome numbers. *Ethnology,* 7: 259-267.

ZETTLER, F.W., ABO EL-NIL, M.M. and HARTMAN, R.D. (1978). Dasheen mosaic virus. *CMI/AAB Descriptions of plant viruses.* No. 191.

ZETTLER, F.W., FOXE, M.J., HARTMAN, R.D., EDWARDSON, J.R. and CHRISTIE, R.G. (1970). Filamentous viruses infecting dasheen and other araceous plants. *Phytopathology,* 60: 983-987.

ZETTLER, F.W., RIDINGS, W.H. and HARTMAN, R.D. (1974). Dasheen mosaic virus of foliage aroids. *Florida Department of Agriculture Consumer Service, Division of Plant Industry, Plant Pathology Circular* No. 140. 2 pp..

(accepted for publication December, 1979)