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CORRIGENDA

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The Aúthor of "Performance of ducks under semi-intensive management in Papua New Guinea" written as "R.A. Abdelsamie" *should read* "R.E. Abdelsamie"

Page 72, para. 1, line 7 "poty virus" *should read* "potyvirus"

Page 86, caption "petiols" *should read* "petioles"

ABSTRACTS

PERFORMANCE OF DUCKS UNDER SEMI-INTENSIVE MANAGEMENT IN PAPUA NEW GUINEA

R.A. Abdelsamie, *Papua New Guin. agric. J.*, 30 (4): 43-51

A management system for raising Muscovie ducks that is appropriate for subsistence farmers in Papua New Guinea has been developed and has been adopted with considerable success. Farmers received day old ducklings and six weeks supply of feed. After six weeks the ducklings had access to free range all day and were given one meal of the farmer's subsistence diet. Seventy percent of the ducks survived to the age of 36 weeks. Body weight was 1.7kg and 2.9kg for females and males respectively. Egg production, hatchability and survival of ducklings to six weeks, measured over a period of three months, were satisfactory.

EFFECTS OF PESTS AND DISEASES ON THE YIELD AND QUALITY OF TOMATOES IN THE PORT MORESBY AREA, PAPUA NEW GUINEA

J. Dodd, *Papua New Guin. agric. J.*, 30 (4): 53-59

Studies with tomato variety 'Red Cloud' at Port Moresby showed that the greatest cause of crop loss was fruit damage by the Tomato Caterpillar *Heliothis armigera* and, to a lesser extent, the Cluster Caterpillar *Spodoptera litura*. Weekly spraying with 2 g/litre of the insecticide 'Septene 80' (Carbaryl) reduced the numbers of caterpillars and, consequently, the proportion of fruit insect-damaged. Insecticide effectiveness was greater during the dry season when insect damage was reduced from 71.5% to 25.6% of all fruit. Application of 1.5g/litre of fungicide 'Dithane M-45' (Mancozeb) did not affect the proportion of fruit damaged by *Phytophthora nicotianae* and *Sclerotium rolfsii* rots, which together caused a crop loss of 1.6%. The physiological disorders Blossom End Rot and Growth Cracking occurred on a total of 5.2% of fruit. Flood irrigation during the dry season trial apparently reduced the incidence of Blossom End Rot. Under most favourable conditions a marketable fruit yield potential of 41 t/ha was realised.

(continued overleaf)

COMPARISON OF SINGLE AND PROGRESSIVE HARVESTING OF SWEET POTATO *(IPOMOEA BATATAS* (L) LAM.)

C.J. Rose, *Papua New Guin. agric. J.*, (4): 61-64

Components of sweet potato yield were compared under single harvest and progressive harvest systems using two varieties. The crop was harvested at six months under the single harvest system. With progressive harvesting, large tubers were lifted at six months and the crop was completely harvested at nine months after planting.

For one variety, total tuber yield was significantly greater from progressive harvesting, but bulking rate was not significantly different for either variety. Progressive harvesting significantly increased the yield of pig tubers (those less than 100 g in weight) and the proportion of pig tubers in the total harvest also appeared to increase, although this was not significant. Top growth production was not affected by the harvest system.

TOXICITY OF *LEUCAENA LEUCOCEPHALA* I. EQUAL TOXIC EFFECTS OF TWO *LEUCAENA* STRAINS ON TWO BREEDS OF TROPICAL CATTLE

J.H.G. Holmes, *Papua New Guin. agric. J.*, 30(4): 65-69

The toxic effects of Hawaii and Peru varieties of *Leucaena leucocephala* on Brahman crossbred and Javanese Zebu cattle were compared under grazing, using Buffel grass *(Cenchrus ciliaris)* as a non-thyrotoxic control. Incidence of hair loss, erosions of the mucosa of the tongue and goitre was the same for both varieties of *Leucaena* and both breeds of cattle. These effects were not found with Buffel grass. Toxicity was also observed with the indigenous Papua New Guinea variety of *Leucaena*. Animal production per hectare on *Leucaena* was similar to that on Buffel grass.

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

Dorothy E. Shaw, R.T. Plumb and G.V.H. Jackson, *Papua New Guin. agric. J.*, 30 (4): 71-97

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.

PERFORMANCE OF DUCKS UNDER SEMI-INTENSIVE MANAGEMENT IN PAPUA NEW GUINEA VILLAGES

R.A. Abdelsamie*

ABSTRACT

A management system for raising Muscovie ducks that is appropriate for subsistence farmers in Papua New Guinea has been developed and has been adopted with considerable success. Farmers received day old ducklings and six weeks supply of feed. After six weeks the ducklings had access to free range all day and were given one meal of the farmer's subsistence diet. Seventy percent of the ducks survived to the age of 36 weeks. Body weight was 1.7 kg and 2.9 kg for females and males respectively. Egg production, hatchability and survival of ducklings to six weeks of age, measured over a period of three months, were satisfactory.

INTRODUCTION

Ducks have been regarded in many countries as the birds most suited for subsistence level poultry production. However, no attempt has been made to investigate the feasibility of the raising of ducks by the subsistence farmer in Papua New Guinea.

In preliminary work carried out at the Poultry Research Centre in Lae (Abdelsamie, unpublished data), Muscovie ducks were raised semi-intensively from 6 to 30 weeks of age. The ducks were allowed access to free range all day, were housed only during the night, and were fed one meal of 16% crude protein commercial feed. They reached a body weight of 3.6 kg (males) and 2.3 kg (females) at 18 weeks of age. This method of management can be recommended in areas where commercial feeds are available.

In many parts of Papua New Guinea, commercial feeds are very expensive and difficult to obtain. In isolated areas of the country, people normally live by subsistence root crop culture supplemented with limited hunting and gathering. The kind of food produced will, therefore, determine their nutritional status (Abdelsamie 1976). Utilizing surplus local produce for raising ducks could help to correct the protein deficiency of people living in these areas.

The present study was conducted to investigate survival and productivity of ducks using a simple management system suitable for people living in isolated areas of the country.

MATERIALS AND METHODS

The experiment was conducted at Situm and Gobari in the Morobe Province. The areas are typical of coastal, mainland New Guinea with a temperature range of from 32°C to 36°C during the day, and from 22°C to 27°C during the night. Average annual rainfall is 2200 mm, of which about 1300 mm fall in two wet seasons (April and May, and July to September).

Six families were selected at random to represent the population living in these areas, the main activity of which is subsistence farming which produces a small surplus available for marketing. There are some coconut trees in poor condition, and some cattle projects financed by the P.N.G. Development

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Bank. Subsistence poultry production is very limited with an average of one bird per family. Knowledge of poultry management is almost non-existant, except in the case of one farmer who started a 500 layer project financed by the Development Bank. This project, however, was closed at the end of 1975 because of the high mortality rate.

Farmers built native material houses 3 m × 3 m. A total of 117 individually tagged day old ducklings (9 Pekin and 108 Muscovie, were selected from the Poultry Research Centre breeding stock, and randomly allocated to six projects (19 or 20 per project). Each group was provided with a 6 weeks supply of 21% crude protein broiler starter feed (2.6 kg/bird/6 weeks). During this period ducklings were housed intensively and fed only this feed. After this period, ducklings were allowed access to free range all day and were housed during the night. Farmers were asked to feed the ducklings once a day in the afternoon. In order that their feed supply would be as varied as possible it was suggested that an extra amount should be added to whatever the family was preparing for their evening meal and that this should be fed to the ducklings. When the ducks reached 18 weeks of age, farmers were encouraged to keep all the females plus one or two males, depending on the number of surviving females. The other males were to be eaten by the family or sold. The experiment continued until the second generation was six weeks of age.

DATA RECORDING

Projects were visited each week when body weight of ducks was recorded individually until 40 weeks of age. Mortality and losses, number of eggs incubated under mothers, number of ducklings hatched, and survival of ducklings to six weeks were also recorded. The physical data were converted to kina and toea and each project was rated as highly successful, successful, marginal or failure according to whether they earned an equivalent money value of 300%, 200%, 100% or less than 100% of the original cost of the day old ducklings and the starter feed (K10.00 per 20 ducklings and K12.00 per 55 kg starter feed). The value of labour input and locally produced feed was not taken into consideration as the work involved was considered to be part of the subsistence system.

RESULTS

SURVIVAL OF DUCKS

The number of surviving ducks at 6, 8, 12, 18 and 36 weeks of age is presented in *Table 1*. Less than 2% of the ducklings were lost during the first 8 weeks of life. Losses gradually increased with time and reached 30% when ducks were 36 weeks of age.

The various causes of losses are presented in *Table 2*. Disease seems to be the main cause, while stealing and predators are the second major cause.

PERFORMANCE

BODY WEIGHT

Table 3 shows body weight of ducks at different time intervals after distribution. Body weight at 6 weeks of age was about 700 g and 725 g for females and males, respectively. There was a step-wise increase in body weight as the ducks grew older. By the time the ducks reached 36 weeks of age, body weight had reached 1.7 kg and 2.9 kg for females and males, respectively. *Figure 1* shows the curve or line of best fit of body weight against time for both females and males.

REPRODUCTION

All females started laying at 30 to 32 weeks of age. The number of eggs set and the number hatched during 3 months of egg production are presented in *Table 4*. Total egg production was found to be difficult to record under village conditions.

ECONOMIC EVALUATION OF THE PROJECT

Table 5 shows the actual value of drakes sold after they reached 18 weeks of age, the market value of females and males remaining on the projects, and the value of the second generation ducklings. Profit or loss and success rating are also shown.

Table 1. — SURVIVAL OF DUCKS IN VILLAGES

Farmer	Number of Ducklings Supplied	Number Surviving at Weeks: 6	8	12	18	36	Number Sold	Total*
1	20	20	20	18	18	5	7	12
2	20	20	19	19	19	8	9	17
3	19	19	19	17	16	4	10	14
4	20	20	20	20	18	11	3	14
5	19	19	19	19	17	10	7	17
6	19	18	18	13	7	4	3	7
Total	117	116	115	106	95	42	39	81

* This column represents the number of ducks surviving at 36 weeks of age plus the number of males sold after they reached 18 weeks of age.

Table 2. — CAUSE OF LOSSES IN DUCKS

Cause of Loss	Number	% of Total Supplied	% of Total Losses
Disease	19	16.23	52.78
Dogs	1	0.86	02.78
Pigs	4	3.42	11.11
Hawks	2	1.71	5.55
Stealing	4	3.42	11.11
Unaccounted for (Presumably Stolen)	6	5.13	16.67
Total	36	30.8	100.00

Table 3. — BODY WEIGHT PERFORMANCE

Average Body Weight in grams at weeks: *, **

	6		8		12		18		36	
Farmer	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1	743	681	1186	901	1837	1262	2134	1276	3110	1777
2	794	840	1067	1084	1609	1303	2011	1317	2945	1535
3	—	—	1183	1058	1539	1192	1787	1442	1995	1650
4	—	—	1440	1210	1524	1196	2230	1594	3365	1989
5	642	601	918	795	934	691	1510	993	—	1653
6 ***	462		480		914		1153		906	
Mean for 1st 5 Projects	726	707	1158	1110	1489	1129	1934	1324	2853	1721

* Averages for Muscovie and Pekin ducks combined to 18 weeks of age. No Pekin ducks remained after 18 weeks.

** Average body weight of Pekin ducks was 620 g and 780 g at 12 and 18 weeks, respectively.

*** Average weights of ducks in the last project were pooled for males and females due to error in recording sex.

Figure 1. — Body weight performance for both males and females

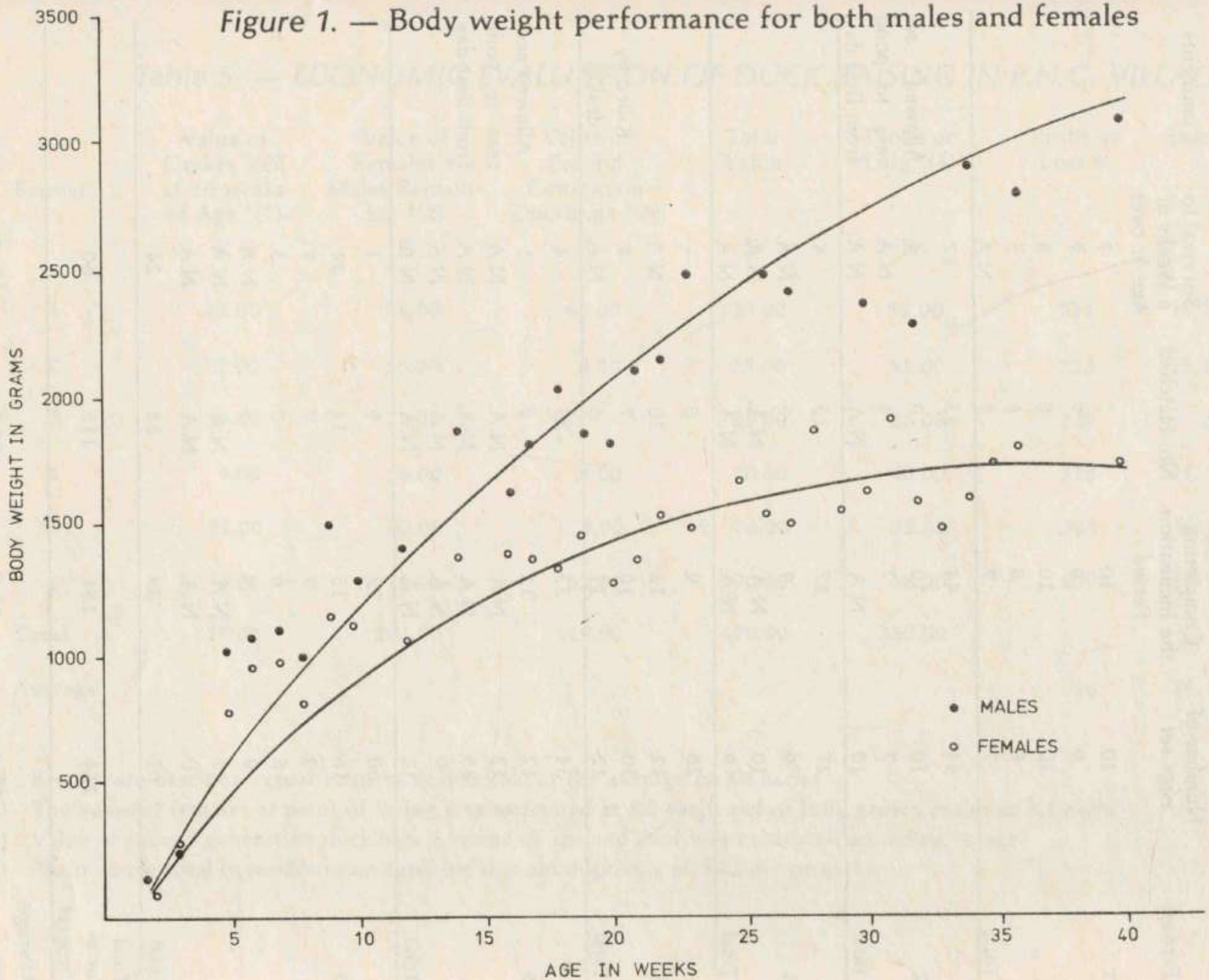

Table 4. — PRODUCTION
EGGS SET, HATCHABILITY, AND SURVIVAL OF DUCKLINGS TO SIX WEEKS OF AGE FOR 3 MONTHS

Farmer	Number of eggs set	No. of Eggs Completing the Incubation Period	No. Hatched	Survival to 6 Weeks of Age or over	Comments
1	10	10	7	7	
	9	9	7	7	
	10	10	8	8	
	8	8	6	5	
Total	7	7	5	N.A.	
	44	44	33	27	
2	10	10	9	4	Allowed ac-
	7	7	4	N.A.	cess to pond
Total	10	N.A.	N.A.	N.A.	from first day
	27	17	13	4	
3	9	9	5	N.A.	
	10	N.A.	N.A.	N.A.	
Total	9	N.A.	N.A.	N.A.	
	28	9	5	—	
4	12	12	10	N.A.	
	10	10	7	4	Killed by
Total	12	11	6	N.A.	drakes
	34	33	23	4	
5	12	12	9	1	Allowed ac-
	12	N.A.	N.A.	N.A.	cess to pond
	15	N.A.	N.A.	N.A.	from first day
	9	N.A.	N.A.	N.A.	
Total	12	N.A.	N.A.	N.A.	
	60	12	9	1	
6	16	15	14	14	
	9	9	7	7	
	6	6	3	3	
	9	9	8	N.A.	
	11	N.A.	N.A.	N.A.	
	10	N.A.	N.A.	N.A.	
Total	61	39	32	24	
Total for 6 Projects	254	154	115	60	
Average per Project	42.3	25.7	19.2	10.00	

N.A. = Not Available

Table 5. — ECONOMIC EVALUATION OF DUCK RAISING IN P.N.G. VILLAGES

Farmer	Value of Drakes sold at 18 weeks of Age *(1)	Value of Females + Males Remaining *(2)	Value of Second Generation Ducklings *(3)	Total Value	Profit or Loss *(4)	Profit or Loss %	Success Rating
	K	K	K	K	K		
1	21.00	24.00	68.00	113.00	91.00	514	H. Successful
2	27.00	38.00	8.00	73.00	51.00	332	H. Successful
3	30.00	20.00	—	50.00	28.00	227	Successful
4	9.00	53.00	8.00	70.00	40.00	318	H. Successful
5	21.00	50.00	3.00	74.00	52.00	336	H. Successful
6	9.00	19.00	62.00	90.00	68.00	409	H. Successful
Total	117.00	204.00	149.00	470.00	330.00		
Average						356	H. Successful

*(1) Results are based on actual value of drakes sold at the average of K3 each.
*(2) The value of females at point of laying was estimated at K5 each, and of fully grown males as K4 each.
*(3) Value of second generation ducklings 6 weeks of age and over was calculated according to age.
*(4) Profit above total expenditure on feed and day old ducklings of K22 per project.

DISCUSSION

The results of the present investigation indicate some of the benefits of introduing ducks into the subsistence agriculture system of coastal New Guinea. The management system adopted in raising ducks proved to be satisfactory.

Some problems were experienced and will need further investigation. The data presented in *Table 1* indicate that high losses were experienced. Disease accounted for more than 50% of these losses *(Table 2)*, but the main cause of death could not be established with certainty due to the difficulty of post mortem diagnosis, when death occured between visits and examination was made 2 or 3 days later. There were some indications, however, that one of the main causes of death was botulism. Stealing was the second major cause of losses (about 25% of the total) and predators accounted for the remaining losses. Stealing and predators could also have an indirect effect on duck performance in the villages. The fear of losses due to these two factors forced the farmers to confine the birds at times when no one was there to look after them. This could have resulted in reducing the advantage of free range. In the past, dogs were always blamed for the high losses of chickens distributed to the villages. In this experiment, village dogs did not seem to make a very significant contribution to the overall losses. In fact, native pigs accounted for far more losses than did dogs.

Average body weight of ducklings at six weeks of age was 700 g and 725 g for females and males, respectively. Research work conducted here (Bauer, unpublished data), and in Australia (Mc Ardle 1969), indicates that Muscovie ducklings can reach an average of 900 g and 1200 g for females and males, respectively, at the same age. This difference in performance is due partially to the higher level of feed consumption in the latter group (3 kg vs 2.6 kg), but differences in management cannot be excluded as one of the contributing factors. Subsequent body weights, as presented in *Table 3* were also below those of ducks raised semi-intensively and fed one meal a day of 16% crude protein formulated feed at the Poultry Research Centre. There was also about three weeks delay in maturity of females (when egg laying commenced) in the present experiment compared with those raised semi-intensively. These differences could be expected, because of the difference in the quality of feed between the two experiments (local feed vs formulated feed).

The difference in performance between Muscovie and Pekin ducks is of some interest. Although survival of Pekin ducks was similar to that of Muscovie ducks, average body weight of Pekin ducks at 12 weeks of age was about half the average weight of Muscovie ducks. This difference in body weight was still in evidence when the ducks were sold at 18 weeks of age. Direct observation of the behaviour of Pekin ducks may offer an explanation for the difference in performance. The Pekin ducks tended to be dominated by the Muscovie during feeding. Also, the slightly curved beak of the Muscovie allowed a better grip on hard feed materials such as raw sweet potato, green banana and pawpaw, while the flat beak of the Pekin was not suitable for this function. A further comparison is that female Muscovie ducks are excellent mothers while Pekin ducks do not brood.

Figures presented in *Table 5* show that all projects made sufficient profit to cover the initial cost of day old ducklings and starter feed. Five projects were rated as highly successful, while the other one was rated as successful. The full extent of profitability cannot be determined because the original stock are still in their active reproductive life.

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EFFECTS OF PESTS AND DISEASES ON THE YIELD AND QUALITY OF TOMATOES IN THE PORT MORESBY AREA, PAPUA NEW GUINEA

J. Dodd*

ABSTRACT

Studies with tomato variety 'Red Cloud' at Port Moresby showed that the greatest cause of crop loss was fruit damage by the Tomato Caterpillar Heliothis armigera *and, to a lesser extent, the Cluster Caterpillar* Spodoptera litura. *Weekly spraying with 2 g/litre of the insecticide 'Septene 80' (Carbaryl) reduced the numbers of caterpillars and, consequently, the proportion of fruit insect-damaged. Insecticide effectiveness was greater during the dry season when insect damage was reduced from 71.5% to 25.6% of all fruit. Application of 1.5 g/litre of fungicide 'Dithane M-45' (Mancozeb) did not affect the proportion of fruit damaged by* Phytophthora nicotianae *and* Sclerotium rolfsii *rots, which together caused a crop loss of 1.6%. The physiological disorders Blossom End Rot and Growth Cracking occurred on a total of 5.2% of fruit. Flood irrigation during the dry season trial apparently reduced the incidence of Blossom End Rot. Under most favourable conditions a marketable fruit yield potential of 41 t/ha was realised.*

INTRODUCTION

In Papua New Guinea the tomato *Lycopersicon esculentum* Mill. is grown as a minor crop in subsistence gardens, while intensive market gardening techniques are being used increasingly in many areas, including Port Moresby. All stages in the development of tomato plants and fruit are susceptible to attack by a variety of pests and diseases. Successful commercial production is usually only possible if these are controlled.

In Papua New Guinea, some insect pests of tomato were reported by Dumbleton (1954), Barrett (1967) and Anon. (1970 and 1971) while Shaw (1963) listed several tomato diseases caused by fungi, bacteria, nematodes and, possibly, viruses.

Fruit losses averaging 45% of total yield have been reported for experiments in the Port Moresby area (Dodd 1976 and 1977; Kesavan 1977). This paper reports the impact of pests diseases and disorders on fruit yield and quality, and the effectiveness of a fungicide and an insecticide, separately and in combination.

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MATERIALS AND METHODS

A determinate variety 'Red Cloud' of proven merit in yield trials in the Port Moresby area (Dodd 1977; Kesavan 1977) was used in field trials involving four treatments: Fungicide (F), Insecticide (I), Fungicide with Insecticide (F + I) and Control. The experiment was replicated five times at each of the two planting dates, 7/4/76 (wet season) and 9/7/76 (dry season). The dry season experimental site was lightly infested with Root Knot Nematode, *Meloidogyne incognita* Chitwood: its effects on yield during that trial are reported separately (Dodd 1979). Insecticide 'Septene 80' (carbaryl) and fungicide 'Dithane M-45' (mancozeb) were used at the rates of 2 g/litre and 1.5 g/litre respectively, with Yates' 'Sprayfix' as wetting agent at 0.7 ml/litre. Spray was applied using a manually pumped knapsack sprayer.

Individual plots consisted of ridges 1 m apart along which unstaked plants were spaced at 50 cm intervals (20,000 plants per hectare). In the wet season trial there were five rows of seven plants in each plot (giving an inner plot of three rows of five) while in the dry season there were four rows of nine (giving an inner plot of two rows of seven). Plots were separated by 2 m wide pathways. Plants were mulched with dry grass and fertilized with a 50 g per plant basal dressing of B.A.S.F. 'Nitrophoska Special Blue' at transplanting with a side-dressing of the same quantity at the onset of flowering.

Spray application began 6 days after transplanting in the wet season trial and after 15 days in the dry season trial, and was repeated at weekly intervals. The final application was made two days after the first harvest in the wet season trial and one day after the third harvest of the dry season. Contamination by spray drift was countered by using guard rows and inter-plot pathways, and by spraying only in the relatively windless mornings.

Plants were regularly inspected for signs of fungal infection. Counts were made of the number of larvae of *Heliothis armigera* Hb. and *Spodoptera litura* F. on 3 plants of each plot before flowering had started.

Records were taken from ten experimental plants chosen at random from the inner plot bordered by the guard row. At each harvest all undamaged, ripe and green-mature fruit were removed, together with any that were damaged by fungi, insects, Blossom End Rot and Growth Cracks. Weights and numbers of fruit in each category were recorded. Three harvests were taken from the wet season trial. During the dry season trial six harvests were made although results of only the first three were subjected to statistical analysis. Results from the two trials were analysed together using combined analysis of variance as described in Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The most important factor affecting the quality and yield of marketable fruit was the damage caused by caterpillars of *H. armigera* and *S. litura*, especially the former. Application of 'Septene 80' had a marked effect on the number found on plants when counts of larvae were made. None was found on plots receiving insecticide (I and F + I) in the wet season, although small numbers were counted on those receiving the combined fungicide and insecticide (F + I) spray in the dry season *(Table 1)*.

Insecticide application significantly reduced the proportion of total fruit yield damaged by caterpillars and, conversely, resulted in a higher percentage of undamaged and thus marketable fruit *(Table 2)*.

The effects of insecticide were greater during the dry season when spray deposits persisted on plants. In the wet season, rain probably removed some of the applied spray despite the use of a sticking agent. In both seasons the level of insect damage to fruit in the +I treatments increased after spraying had ceased, and in the dry season reached the value for -I treatments *(Figure 1C and 1D)*. The increase was accelerated by heavy rainfall a few days after the final spraying in both seasons. The use of ditch irrigation during the dry season prevented spray removal which would have occurred with overhead sprinkling. Control in plots receiving insecticide (I and F + I) was, however, far from complete, as shown by the relatively high levels of fruit damage *(Table 2)* and the presence of caterpillars on (F + I) plots *(Table 1)*. This was due partly to incomplete penetration of insecticide into the dense foliage produced by 'Red Cloud', while a further cause was rapid crop growth producing unprotected shoots and fruit bunches which were vulnerable to caterpillar attack between spray applications. Improved spray coverage would result from staking although high costs of labour may render this uneconomical. In view of the significant reduction in caterpillar numbers and insect damage following application of 'Septene 80', it would be desirable to test a variety of spraying schedules and insecticides to find an effective minimum and economical application for intensive tomato production.

Fruit size, as indicated by the mean weight of individual undamaged fruit, responded in a complex manner. In

Table 1. — Effects of treatment on caterpillar numbers, fruit rot percentage and total weight and number of fruit per plant

Treatment	Mean number of *H. armigera* & *S. litura* larvae per plant — WET SEASON	DRY SEASON	Percentage of total fruit number affected by *P. nicotianae* and *S. rolfsii* rot	Total weight of fruit per plant (grams)	Total number of fruit per plant
Control	1.3 b*	2.3 b, c	0.8 a	759.7 a, b	12.4 a, b
Fungicide alone	2.4 c	1.4 b	0.3 a	688.3 a	10.8 a
Insecticide alone	0.0 a	0.0 a	2.8 b	881.6 b	13.0 b
Fungicide & Insecticide combined	0.0 a	0.5 a	2.5 b	1244.9 c	16.1 c
Mean	0.9	1.1	1.6	893.6	13.1

* Values indicated with the same letter within a column do not differ significantly at $P < 0.05$.

Table 2. — Effects of season and insecticide on percentages of total fruit number undamaged and insect damaged, and on mean size of undamaged fruit. Treatments receiving (+I) or lacking (−I) insecticide 'Septene 80'

Treatment and Season	Percentage of undamaged fruit	Percentage of insect-damaged fruit	Mean size of undamaged fruit (grams)
−I, Wet Season	19.8 a*	67.4 c	50.6 a
+I, Wet Season	45.2 b	39.8 b	57.5 b
−I, Dry Season	27.1 a	71.5 c	100.6 c
+I, Dry Season	69.5 c	25.6 a	96.3 c
Mean	40.4	51.1	76.3

* Values indicated with the same letter within a column do not differ significantly at $P < 0.05$.

general, fruit from +F plots (mean weight = 81.2 g) were significantly larger than those from -F plots (71.3 g), while those produced in the dry season trial were much larger than those of the wet season *(Table 2)*. In both trials, the largest fruit were those from the first two harvests *(Figure 1A)*. The greater fruit size in the dry season trial may have been a response to the improved nitrogen status of the soil of the planting site following winged bean cultivation there.

Fungicide and insecticide application affected other variables of fruit yield, quality and quantity in addition to those directly related to caterpillar damage. Total yield, as measured by both total weight and total number of fruit per plant, was significantly increased when the combined (F + I) spray was applied, although the application of fungicide and insecticide separately had no significant effect *(Figure 1B; Table 1)*. Considering results of the dry season trial alone, total yield of the (F + I) treatments after the final (6th) harvest was 3014 g/plant, equivalent to 60 t/ha, of which 68.3% was undamaged giving marketable yields of 2059 g/plant or 41 t/ha *(Figure 1B)*.

There is no obvious explanation for the greatly increased yield of the (F + I) treatments *(Table 1; Figure 1B)*. There may have been a synergistic effect between fungicide and insecticide, in addition to which 'Dithane M-45'* may have been a source of the nutrients Zn, Mn and S, which could have raised yield, as in the case of certain Zn-containing fungicides which increased potato yields by improving crop nutrition as well as by reducing disease (Callbeck 1954; Hoyman 1949). Nutrients derived this way may also have resulted in the larger fruit of the +F treatments.

The only fungus diseases encountered were the fruit rots caused by *Phytophthora nicotianae* B. de Haan var. *nicotianae* (D.P.I. accession numbers PNG 9237a and IMI 183052a) and *Sclerotium rolfsii* Sacc.. Since it was not possible to differentiate between the two pathogens at harvest, all fruit showing fruit rot symptoms were pooled when the number affected were counted. Fungicide application did not affect the frequency of fruit rot, due possibly to the low incidence of the pathogens, although rot was significantly greater amongst +I treatments *(Table 1)*. Overall, 1.6% of the total fruit number was affected, although the wet season mean of 2.4%, which was significantly higher than the dry season value of 0.7%, was probably related to continual high levels of soil moisture during most of that season and this would have favoured activity of the pathogens. Staking plants to prevent soil contact by fruit would control these diseases but would probably not be economically worthwhile in view of the low level of crop loss caused by fruit rot.

* 'Dithane M-45' = A combination of the Zinc and Manganese radicals of ethylene -1, 2- bisdithiocarbamate.

Figure 1. — Fruit and rainfall measurements for trials in 1976 wet season (left) and dry season (right).

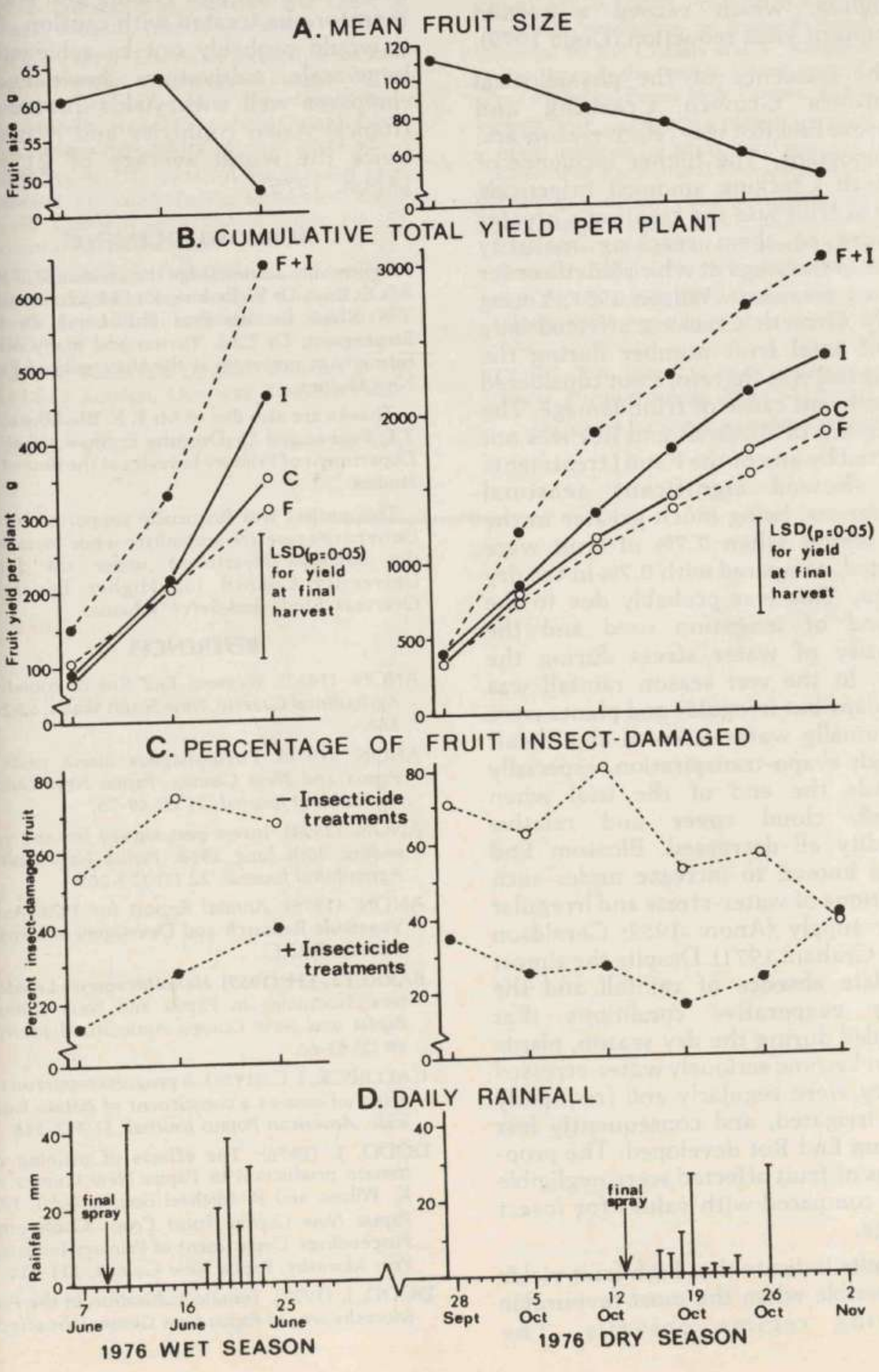
A. Mean size of undamaged fruit, measured as fruit weight; average of all treatments.

B. Cumulative total yield of fruit per plant for different spraying treatments: C = unsprayed control; F = fungicide ('Dithane M-45') alone; I = insecticide ('Septene 80') alone; F + I = fungicide and insecticide together.

C. Percentage of insect-damaged fruit from treatments receiving insecticide (I & F + I) and receiving none (C & F).

D. Date of final spray application, and daily rainfall at experimental site during harvest period.

Figure 1: —See opposite page for caption



None of the dry season spraying treatments affected the level of infestation by Root Knot Nematode, *M. incognita,* which caused a certain amount of yield reduction (Dodd 1979).

The incidence of the physiological disorders Growth Cracking and Blossom End Rot was relatively low and unimportant. The higher incidence of Growth Cracking amongst insecticide treated fruit was the result of a greater number of them reaching maturity which is the stage at which this disorder is most prevalent (Wilson 1957; Young 1947). Growth Cracking affected only 1% of total fruit number during the trials, and was therefore not considered a significant cause of fruit damage. The frequency of Blossom End Rot was not affected by any of the F and I treatments but showed significant seasonal differences, being much greater in the wet season when 7.7% of fruit were affected, compared with 0.7% in the dry season. This was probably due to the method of irrigation used and the intensity of water stress during the trials. In the wet season rainfall was abundant but irregular and plants were occasionally water-stressed as a result of high evapo-transpiration, especially towards the end of the trial when rainfall, cloud cover and relative humidity all decreased. Blossom End Rot is known to increase under such conditions of water-stress and irregular water supply (Anon. 1952; Geraldson 1957; Graham 1971). Despite the almost complete absence of rainfall and the highly evaporative conditions that prevailed during the dry season, plants did not become seriously water-stressed as they were regularly and frequently flood irrigated, and consequently less Blossom End Rot developed. The proportions of fruit affected were negligible when compared with values for insect damage.

Results indicate that high fruit yields are possible when the most favourable spraying regime prevails. The marketable yield of about 40 t/ha for the (F + I) treatments in the dry season was based on small plot results and should therefore be treated with caution since it would probably not be achieved in large-scale cultivation; however, it compares well with yields quoted for tropical Asian countries and is nearly twice the world average of 21 t/ha (Anon. 1975).

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COMPARISON OF SINGLE AND PROGRESSIVE HARVESTING OF SWEET POTATO (*IPOMOEA BATATAS* (L) LAM.)

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ABSTRACT

Components of sweet potato yield were compared under single harvest and progressive harvest systems using two varieties. The crop was harvested at six months under the single harvest system. With progressive harvesting, large tubers were lifted at six months and the crop was completely harvested at nine months after planting.

For one variety, total tuber yield was significantly greater from progessive harvesting, but bulking rate was not significantly different for either variety. Progressive harvesting significantly increased the yield of pig tubers (those less than 100 g in weight), and the proportion of pig tubers in the total harvest also appeared to increase, although this was not significant. Top growth production was not affected by the harvest system.

INTRODUCTION

The practice of progressively harvesting the sweet potato crop is common among subsistence farmers (Mac Donald 1963). This technique of *mumutim* as it is termed in Neo-Melanesian, is widespread throughout the Highlands of Papua New Guinea. Mature tubers are hand dug for human consumption leaving smaller tubers undisturbed. When these later maturing tubers are big enough, they will be harvested in the same manner. Small tubers that are not so acceptable for human consumption are fed to pigs after the larger tubers have been taken and when top growth is becoming more mature. Subsequently, any remaining tubers will be eaten by foraging pigs when the land is prepared for the next crop. This small-size tuber component is important in the diet of village pigs.

Once harvested, the sweet potato tuber deteriorates very quickly (Gooding .and Campbell 1964) and therefore progressive harvesting is a useful storage method and ensures a supply of fresh tubers (Kimber 1972).

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Some crops have been reported as being harvested over three years (Jamieson 1968), but in the Tari area where this experiment was carried out crops are harvested three or four times over a period of only eight months to a year. After nine months, the tubers are more liable to rot; this being influenced by variety, soil drainage and rainfall.

Since the sweet potato crop is the staple of both the human and pig populations in the Highlands, this trial was designed to assess by tuber size the amount of crop available for human and pig consumption under single and progressive harvest systems. A sweet potato crop was completely harvested at six months after planting and compared with another where only tubers over 100 g weight were harvested at six months and a complete harvest followed at nine months.

EXPERIMENTAL METHODS

The trial was carried out at Piwa Agricultural Station near Tari in the Southern Highlands Province (1,620 m a.s.l.; 2,693 mm mean annual rainfall). The soil was free-draining, re-worked volcanic ash and had been left fallow for three months following two years of

Table 1. — Tuber and top growth yield from single and progressive harvests of two varieties of sweet potato

VARIETY	HABARE		MAME	
TREATMENT	Single Harvest	Progressive Harvest	Single Harvest	Progressive Harvest
TOTAL TUBERS				
Yield (t/ha)	10.7	16.2*	12.0	15.9
BULKING RATE (g/week/m²)	40.9	40.6	45.5	40.0
MARKETABLE TUBERS				
Yield (t/ha) 1st harvest	9.9	8.3	10.8	8.8
Yield (t/ha) 2nd harvest	—	5.0	—	4.0
Bulking rate (g/week/m²)	37.9	33.6	40.9	32.2
PIG TUBERS				
Yield (t/ha)	0.8	2.8**	1.2	3.1**
Bulking rate (g/week/m²)	3.2	6.9**	4.5	7.7**
% pig tubers of total weight	9.8	15.6	10.9	16.0
LEAF AND VINES (t/ha)	20.6	20.1	11.0	9.4

** and * indicate a significant difference between treatments for each parameter within a variety at $P < 0.01$ and 0.05 respectively.

Table 2. — Mean tuber number per 25 m² and individual tuber weight (g) from single and progressive harvests of two varieties of sweet potato

VARIETIES	HABARE				MAME			
TREATMENT	Single		Progressive		Single		Progressive	
No. and Wt.	No.	Wt. g	No.	Wt. g	No.	Wt. g	No.	Wt. g
MARKETABLE TUBERS	115	213	140	235	170	152	178	199*
PIG TUBERS	74	28	100	71***	107	27	158*	49*

*, **, and *** indiciate a significant difference between treatments of number and weight of tubers within each variety where $P < 0.05$, 0.01 and 0.001 respectively.

continuous cropping with sweet potato. It was rotary cultivated and spade mounded in preparation for planting.

Sixteen mounds each utilizing soil from 6.25 m^2 of ground were incorporated into a 100 m^2 block. Four mounds were randomly allocated to each of the four treatments. The treatments were a single harvest at six months and a twice harvested crop at six and nine months for each of two varieties. The two varieties used were Habare and Mame. Blocks were replicated seven times.

Disease-free planting material was collected from other plots on the station and used immediately. Apical cuttings of 40 cm in length with an average number of four nodes were planted in bunches of three at ten locations on each mound (equivalent to 48,000 cuttings per ha). The practices of the Huli people of Tari of planting the sweet potato cuttings at about thirty degrees to the horizontal and of bending (Kimber 1972) were used in this experiment.

The crop was weeded on the 46th, 99th and 153rd days after planting. Mounds that had been marked for a single harvesting were dug on the 184th day after planting. The tubers were separated into marketable (over 100 g weight) or pig (under 100 g weight) tubers, counted and weighed. Other mounds that had been marked for a second harvest were dug into at the base and then lifted up so that most of the tubers over 100 g weight were collected without disturbing the rest of the plant. The second harvest was taken 279 days after planting. Tuber classes were again separated, counted and weighed. Weight of leaf and vine was recorded at both harvests.

RESULTS

Total tuber yield was significantly greater from progressive harvesting than from the single harvest for variety Habare, but there was little difference in growth rate (expressed as bulking rate), *(Table 1)*. An apparent trend, although not significant, was that marketable tubers harvested in the progressive treatment actually yielded less than those from the single harvest and this was the same for the bulking rate of marketable tubers. Pig tuber yield and bulking rate increased significantly in both varieties from progressive harvesting. Pig tubers appeared to constitute a greater proportion of total tubers in the progressive harvest, although this was not significant. Yield of leaf and vine was not affected by the treatments.

Mean tuber weight of marketable tubers of variety Mame, but not of variety Habare, was significantly greater in the progressively harvested treatment *(Table 2)*. However, the mean tuber weight of the pig tubers of both varieties was significantly greater in the progressively harvested treatment. The number of pig tubers of variety Mame increased significantly in the progressively harvested treatment.

DISCUSSION

The removal of the larger tubers by progressively harvesting effectively removes a carbohydrate 'sink', so that although small tubers get bigger and have a higher bulking rate than in a once-harvested crop, they don't attain the larger marketable size. The method of progressive harvesting is however an important practice for increasing the yield of that portion of the crop suitable for feeding to pigs.

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TOXICITY OF *LEUCAENA LEUCOCEPHALA* I. EQUAL TOXIC EFFECTS OF TWO *LEUCAENA* STRAINS ON TWO BREEDS OF TROPICAL CATTLE

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ABSTRACT

The toxic effects of Hawaii and Peru varieties of Leucaena leucocephala *on Brahman crossbred and Javanese Zebu cattle were compared under grazing, using Buffel grass* (Cenchrus ciliaris) *as a non-thyrotoxic control. Incidence of hair loss, erosions of the mucosa of the tongue and goitre was the same for both varieties of* Leucaena *and both breeds of cattle. These effects were not found with Buffel grass. Toxicity was also observed with the indigenous Papua New Guinea variety of* Leucaena. *Animal production per hectare on* Leucaena *was similar to that on Buffel grass.*

INTRODUCTION

Toxic effects of *Leucaena leucocephala* (Cv. Peru) on ruminants include depilation (Hegarty, Schinkel and Court 1964), goitre (Bindon and Lamond 1966) and infertility (Holmes 1976). These effects have been related to the content of mimosine or to that of its fermentation product 3, 4, dihydroxy pyridine (DHP) (Hegarty, Court, Christie and Lee 1976). However, the Hawaii variety of *Leucaena* is used extensively as forage for ruminants in Hawaii and a similar variety is used in S.E. Asia, with few reported ill-effects, despite the mimosine content which is higher than that of the Peru variety (Hutton and Gray 1959).

The toxic effects of *Leucaena*, cited above, have been demonstrated with *Leucaena* making up most or all of the diet. While *Leucaena* is sometimes grazed in mixed pastures in Hawaii and S.E. Asia, it is often hand fed in limited quantities as hot-air dried (in Hawaii) or wilted or sun-dried material (e.g. in the Philippines). The small quantities fed or the drying treatments may ensure that the quantity of mimosine ingested is below a toxic limit and Hawaii *Leucaena* may be as toxic as Peru *Leucaena* if grazed as a pure stand.

Alternatively, Hawaii *Leucaena* may be less toxic than Peru *Leucaena*, or indigenous S.E. Asian cattle (Javanese Zebu) may have metabolic or digestive differences from *Bos taurus* and *Bos taurus* x *Bos indicus* hybrids rendering them less susceptible to the toxic factors. This trial was designed to compare the toxicity of Peru and Hawaii *Leucaena* for *Bos indicus* (Brahman) × *Bos taurus* and *Bos indicus* (Javanese Zebu).

MATERIALS AND METHODS

The Beef Cattle Research Centre, Erap, is situated at 100 m elevation in the Markham Valley, latitude 7° 30′ S. Rainfall is 1250 mm per annum, in two distinct wet seasons. Temperatures range from 18° to 35°C with little variation throughout the year.

The experiment was a 3 × 2 factorial, with three pastures, two breeds of cattle and three steers per group. The

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pastures available were 4.1 ha of Nunbank Buffel grass, 2.35 ha of Hawaii *Leucaena* and 3.7 ha of Peru *Leucaena*. Both *Leucaena* pastures were planted in rows 2-3 m apart, with only inedible weeds between the rows. The Hawaii *Leucaena* grew on slightly better soil, a sandy loam, while the other pastures were on more gravelly soil.

The Brahams crossbred steers, about ⅝ to ¾ Brahman, were 14-17 months old and weighed 215 + 8 kg. The "Javanese Zebu" (Holmes 1977), a smaller breed from South East Asia, were 12-18 months old, and weighed 177 ± 10 kg. Three steers of each breed were allocated to each pasture on the basis of liveweight, in November, 1976. They were set stocked and weighed every 4 weeks after an overnight fast. In October, 1977, the steers were slaughtered. Hair loss from the tail switch and erosions in the mouth were assessed on an arbitrary scale from 0 to 3. Carcass weight, back fat thickness and weight of thyroid were measured.

Statistical analysis was by the method of Snedecor and Cochran (1967).

RESULTS

HAIR LOSS

Nine of the 12 animals on *Leucaena* pastures lost hair from the tail switch, but only one lost all the hair. There was no difference in score between breeds of cattle or between varieties of *Leucaena* (*Table 1*) however results from both varieties of *Leucaena* differed significantly from those from Buffel grass ($P< .05$) where hair loss did not occur.

EROSIONS

Erosions on the side of the tongue, just anterior to the torus, occured in 5 of 12 steers grazing *Leucaena* but were smaller than previously seen, and no drooling of saliva was noted in any of these animals. There was no difference between breeds of cattle or varieties of *Leucaena* (*Table 1*). No tongue erosions were found in cattle grazed on Buffel grass.

THYROID GLAND WEIGHT

Steers grazing *Leucaena* had significantly ($P< .05$) larger thyroids than steers on Buffel grass (*Table 1*). There was no difference between *Leucaena* varieties or breeds of cattle. The heaviest thyroid from a steer fed Buffel grass weighed 25 g while thyroids from animals fed *Leucaena* ranged from 67 g to 245 g.

LIVEWEIGHT GAINS

Animals grazing Buffel grass and Peru *Leucaena* grew at similar rates (*Table 2*). Animals grazing Hawaii *Leucaena* at a heavier stocking rate grew more slowly ($P< 0.01$) but on a per hectare basis, Hawaii *Leucaena* was as productive as the other pastures. "Javanese Zebu" steers grew 0.3 kg/day, significantly ($P< 0.05$) more slowly than Brahman cross steers (0.4 kg/day).

CARCASS WEIGHTS AND BACK FAT

The carcasses of steers grazed on Hawaii *Leucaena* were smaller ($P< .01$) than those of steers fed Buffel grass or Peru *Leucaena* (*Table 3*). Steers grazing Peru *Leucaena* had slightly smaller carcasses than steers fed Buffel grass. The dressing percentage for steers grazing *Leucaena* was significantly ($P< 0.01$) greater than for steers grazing Buffel grass. The "Javanese Zebu" produced smaller ($P<.01$), fatter ($P<.01$) carcasses with a similar dressing percentage ($P< .10$).

DISCUSSION

Specific toxic effects, i.e. hair loss, erosions on the tongue and goitre did not differ significantly between *Leucaena* varieties or cattle breeds in incidence or severity. In a larger trial, or one using more sensitive techniques of assessing toxicity, such as measurements of circulating thyroid hormone concentrations, some difference

Table 3. — Carcass data for Brahman cross and "Javanese Zebu" steers grazed on Buffel grass or varieties of *Leucaena leucocephala* (dressing percentage and back fat corrected for carcass weight, within breeds)

	Carcass weight	Dressing	Backfat thickness
	kg	%	mm
Buffel grass	208 a	57.2 a	4.6
Hawaiian *Leucaena*	172 b	61.5 b	not recorded
Peruvian *Leucaena*	194 a	60.5 b	5.4
Brahman cross	212 a	59.2	3.8 a
Javanese Zebu	170 b	60.3	6.4 b

a, b: Means with different letters are significantly different (P< 0.05) by Newman Keul's test.

between varieties or cattle breeds may be detectable. However, the lack of reports of toxic effects of *Leucaena* in Hawaii and S.E. Asia does not seem to be due to a lower toxicity of Hawaii *Leucaena* or to a greater tolerance in S.E. Asian cattle. It is probably due to the feeding of small amounts of *Leucaena* which have often been subjected to drying processes which reduce the amount of mimosine (Matsumoto, Smith and Sherman 1951), or to restriction of feeding of *Leucaena* to the dry season when less active growth results in lower concentrations of mimosine (Hegarty and Court 1972).

No areas of the indigenous variety of *Leucaena* are available at Erap. On an area of 100 ha on an adjacent plantation, the indigenous variety of *Leucaena* was planted in rows and the intended underplanting with coffee did not take place. Cattle were grazed on this *Leucaena* and adjacent grassland at a stocking rate which compelled consumption of a large amount of *Leucaena*. Birth of dead hairless calves occurred, and some calves were born very weak and died soon after birth. Ten out of 20 live calves up to one month old showed visible goitre. This experience suggests that the indigenous P.N.G. variety of *Leucaena* is also strongly goitrogenic.

The higher dressing percentage of steers grazed on *Leucaena* was associated with a more extensive fat cover on the carcasses, although fat thickness did not show as significantly greater, partly due to unskilled skinning. Thyroid deficient animals normally show somewhat slower growth rates and more subcutaneous fat.

Accurate comparisons of animal production on the different pastures cannot be made, due to lack of replication. However, *Leucaena* did not exhibit the great advantage in cattle

Table 1. — Scores for hair loss and erosions of the epithelium of the tongue, and weight of thyroid glands from Brahman and "Javanese Zebu" steers grazing Buffel grass or *Leucaena leucocephala*

	Hair loss score	Erosions score	Thyroid weight (g)
Buffel grass	0 a	0	22 a
Hawaiian *Leucaena*	2.0 b	1.0	135 b
Peruvian *Leucaena*	1.8 b	1.0	133 b
Brahman cross	1.1	0.4	94
Javanese Zebu	1.4	0.9	100

a, b: Means with different letters are significantly different ($P < 0.05$) by Newman-Keul's test.

Table 2. — Growth rates of Brahman cross and "Javanese Zebu" steers grazing Buffel grass or varieties of *Leucaena leucocehala* in almost pure stands

	Growth rate kg/day	Stocking rate steers/ha	Growth rate kg/ha/day
Buffel grass	0.44 a	1.46	0.62
Hawaiian *Leucaena*	0.24 b	2.55	0.61
Peruvian *Leucaena*	0.38 a	1.63	0.62
Brahman cross	0.40 a		
Javanese Zebu	0.30 b		

a, b: Means with different letters are significantly different ($P < 0.05$) by Newman Keul's test.

growth rate it would need to compensate for the difficulty of management of browse pasture.

Blunt (1976) found that growth of steers on *Leucaena* planted in rows 2-3 m apart, interplanted with *Digitaria decumbens* was poor and toxic signs were seen. When grazed free-choice in blocks of up to 20% of the pasture area (Partridge and Ranacou 1974) *Leucaena* was an effective supplement to *Dichanthium caricosum* in the drier zones of Fiji, but the best growth rates achieved were only about 0.5 kg/day. In the present experiment, growth rates of animals grazing pure stands of *Leucaena* were even lower, 0.38 lbs/day. Thus animal performance on *Leucaena* in several trials has been below what would be expected from such a high protein, high energy forage, and presumably the limiting factors are mimosine and its metabolites. This suggests that the maximum amount of *Leucaena* in the diet of grazing cattle ought to be kept quite low to avoid toxicity. Under rapid growth conditions in the humid tropics or under irrigation during the dry season the method of utilizing *Leucaena* by grazing must be re-examined.

Current work in CSIRO's Division of Tropical Crops and Pastures (Hutton 1976) is directed to the production of a "Low-Mimosine" variety of *Leucaena*. This could be a big advantage for cattle-raisers who are contemplating planting *Leucaena*. Such new varieties however, will not solve the problems of areas where the older, toxic varieties already grow. *Leucaena* is widespread throughout Papua New Guinea up to 1500 m elevation. It grows in dense thickets along streams, where water-dispersal of seeds aids further spread, and it is in common use as a shade tree in plantations. Eradication and replacement by less toxic varieties does not appear feasible. Further studies are under way to find methods of using this legume in Papua New Guinea.

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

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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

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* 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

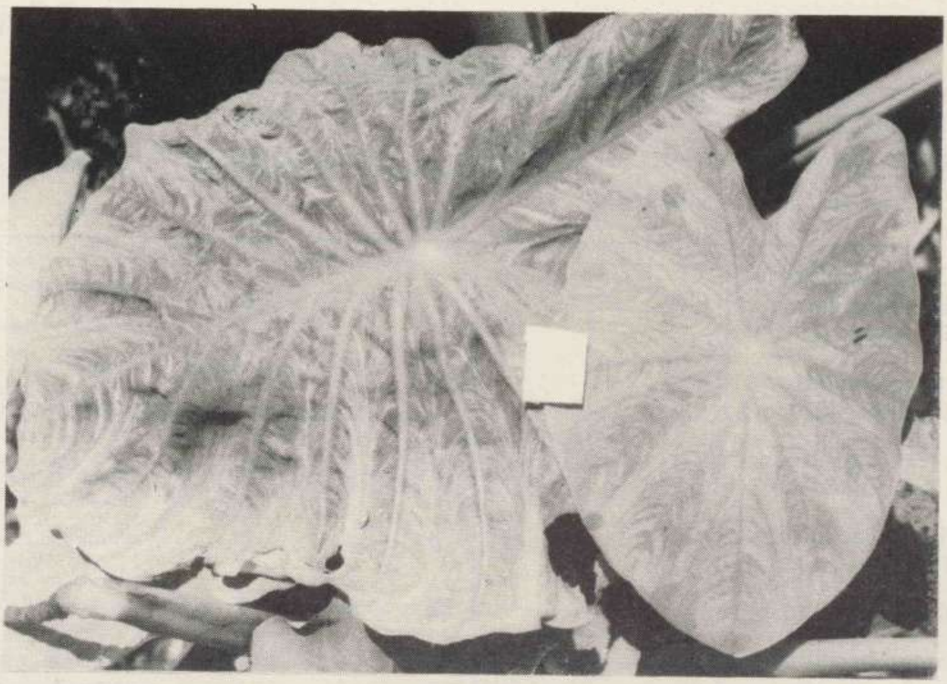


Plate I. — *C. esculenta* (PNG 10535); two leaves with feathering pattern and some puckering of the older leaf. Large and a few small bacilliform particles present. (No determination for flexuous rods.)

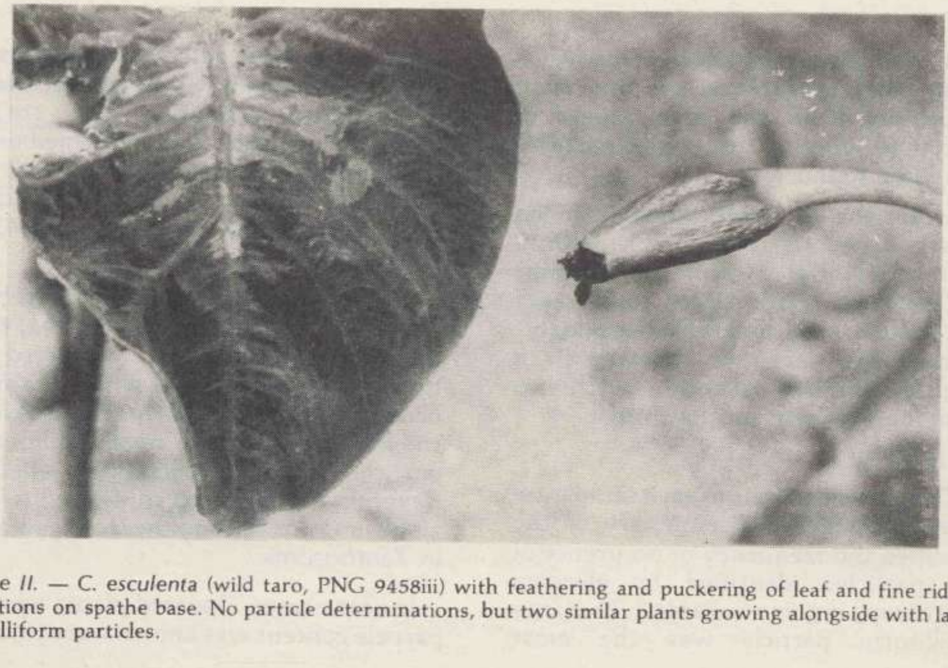


Plate II. — *C. esculenta* (wild taro, PNG 9458iii) with feathering and puckering of leaf and fine ridged enations on spathe base. No particle determinations, but two similar plants growing alongside with large bacilliform particles.

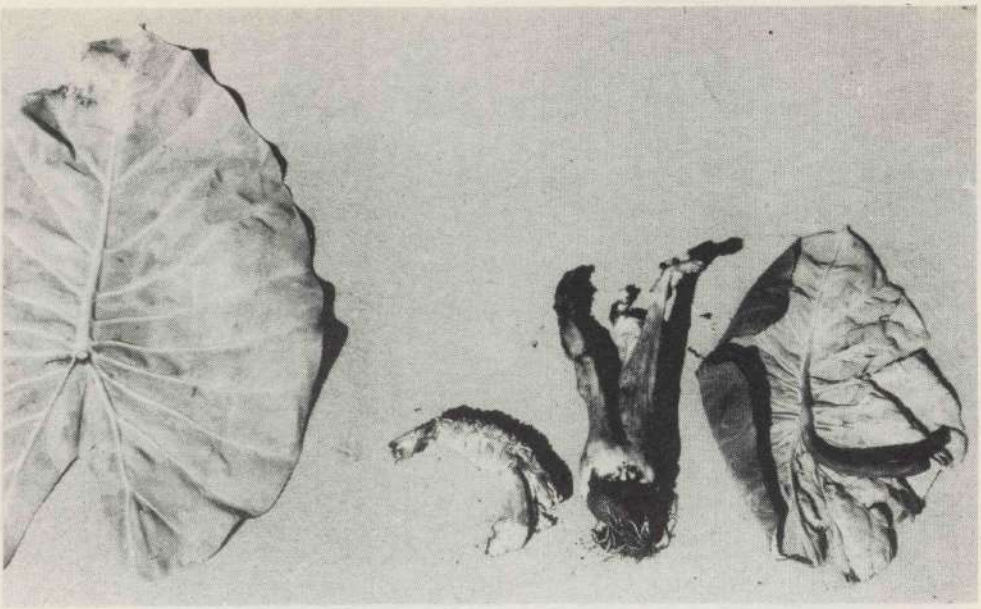


Plate III. — *C. esculenta* (PNG 5869); plant showing sequence of stunting of leaves, with youngest leaf and plant base in centre (prior to electron microscope facilities).

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.

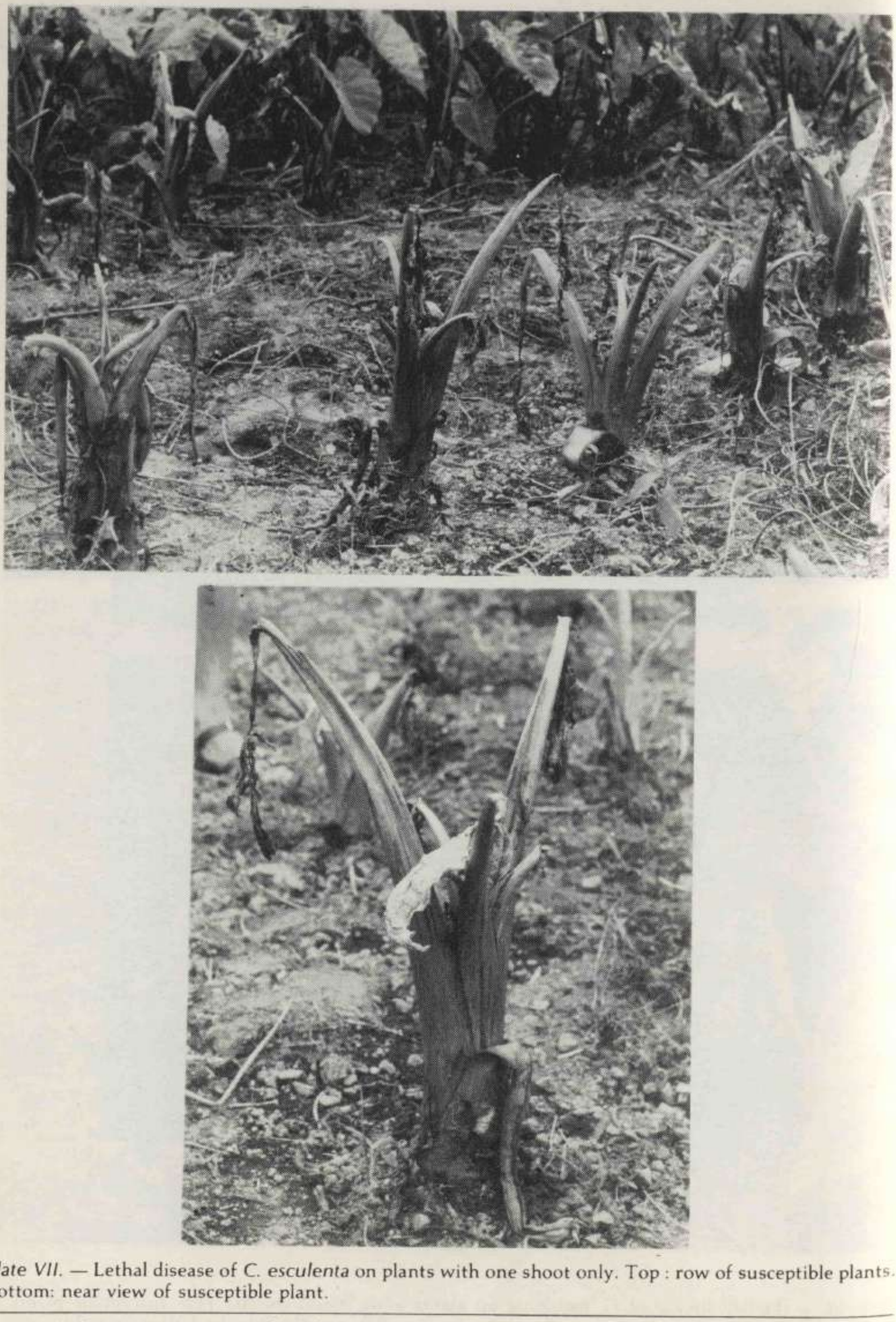


Plate VII. — Lethal disease of *C. esculenta* on plants with one shoot only. Top : row of susceptible plants. Bottom: near view of susceptible plant.

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).

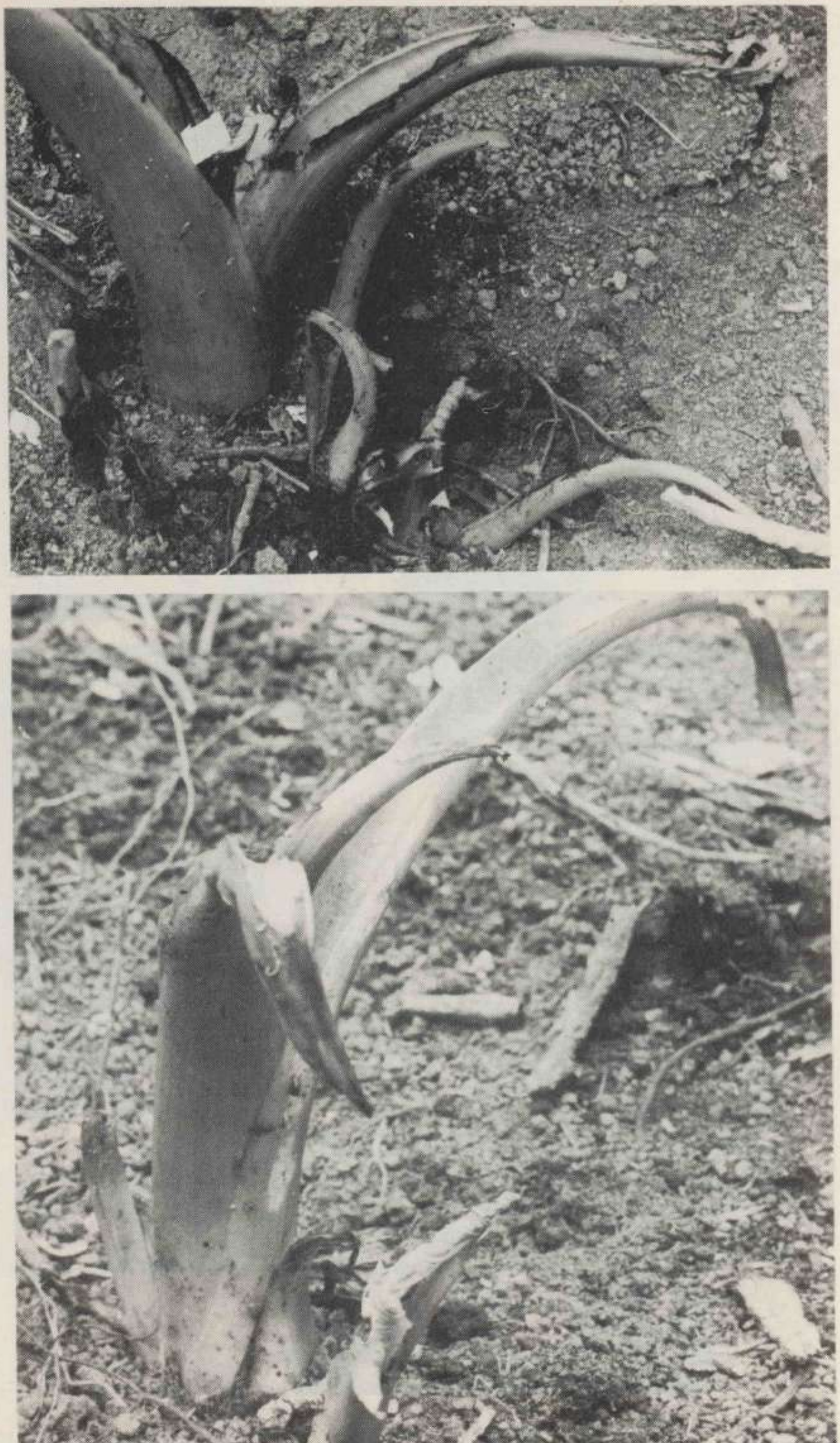
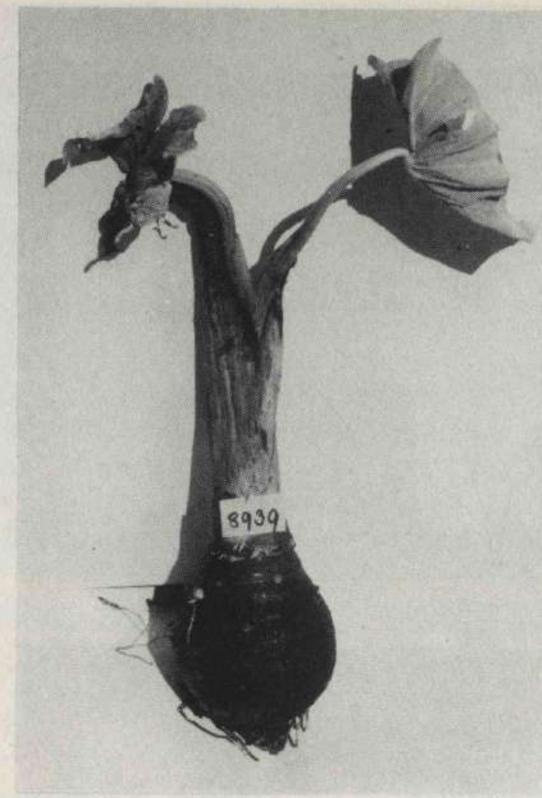


Plate VIII: —See opposite page for caption



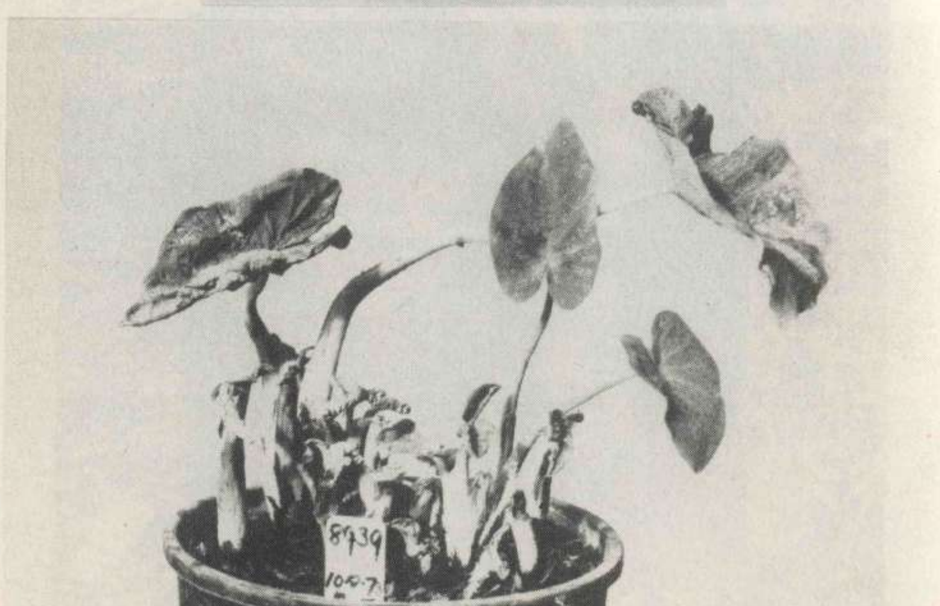


Plate IX. — *C. esculenta* (PNG 8939). Top: plant with thickened, stunted petiols; flexuous rods present and large bacilliform particles doubtfully present. Bottom: same plant as above after being potted for six months. Note prolific production of secondary shoots.

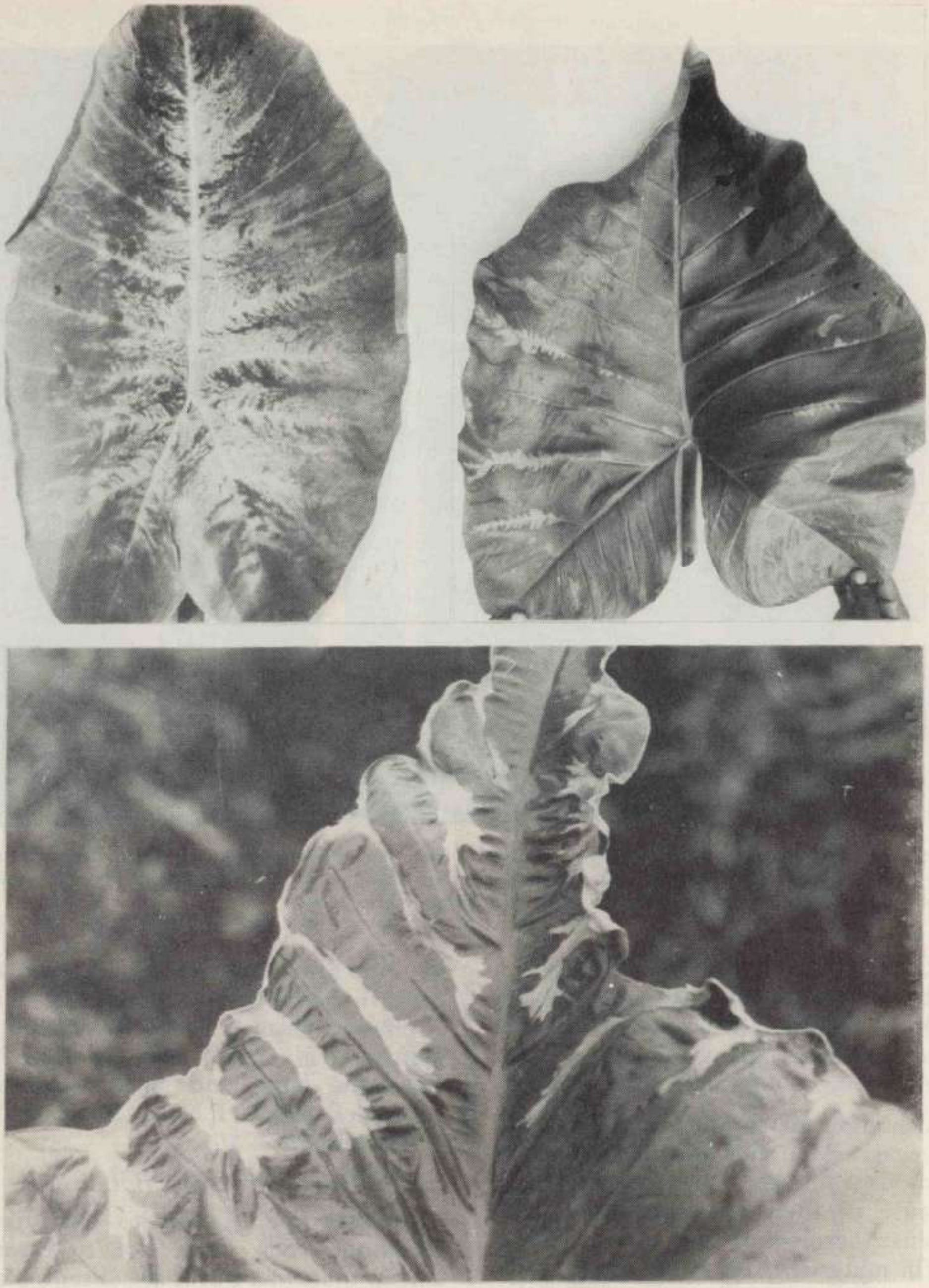


Plate X. — *Xanthosoma* sp. Top: L.H., pronounced pattern, flexuous rods present (PNG 9503). Top: R.H., definite yellow "Vs" along veins. Bottom: definite yellow "Vs" along veins, flexuous rods present (PNG 10402).

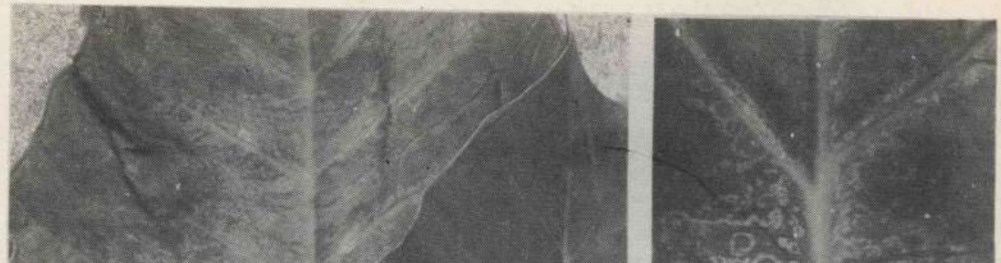


Plate XI. —*Xanthosoma sp.* (PNG 10554). L.H.: first (oldest) leaf showing extensive ring pattern, flexuous rods doubtfully present, and third (youngest) uppermost leaf free from symptoms. R.H.: near view of second leaf with some ring spotting only, on each side of main vein.

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

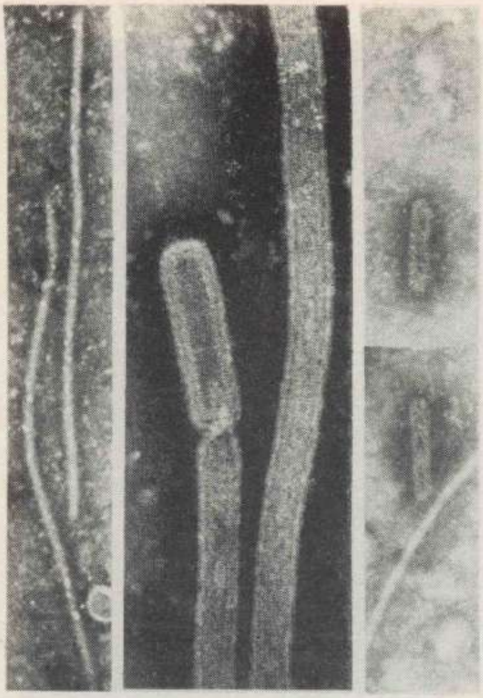


Plate XII. — Virus particles from *C. esculenta*, x approx. 100,000. L.H.: two flexuous rod-shaped particles. Centre: a large bacilliform-shaped particle apparently formed by constriction. R.H.: two small bacilliform-shaped particles.

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.

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