AN OVERVIEW OF THE PATHOLOGY OF GENUS COLOCASIA

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ABSTRACT

This paper reviews information available from various sources which relates to diseases of taro in Papua New Guinea. Taros are subject to infection by both aerial and soil-borne pathogens. The pathogens which exploit taro production include fungi, bacteria, nematodes, viruses and virus-like organisms and mycoplasmas, some of which are able to reduce yields quite substantially. Because of the nature of this crop, its traditional system of cultivation and the strong influence of ecosystem on both the host and the pathogens, it appears that taro pathogens do interact with their host and that the mechanism of resistance is relatively narrow. Thus, the integrated pest management (IPM) approach appears to be appropriate for taro disease control.

Key words: *Taro, diseases, fungi, bacteria, nematode, viruses, mycoplasmas.*

INTRODUCTION

Taro (*Colocasia esculenta* L.) is ranked second by McArthur (1972), after sweet potato followed by yam and bananas, in terms of annual production in PNG. This vegetatively propagated crop has been grown mainly under primitive mixed cropping system over a wide geographical area, from Highlands to dry and wet coastal lowlands and to coral atoll islands with varying climatic characteristics.

This crop is probably a host to many of the diseases infecting the Araceae family than its relatives including species of *Alocasia*, *Xanthosoma*, *Cyrtosperma* and *Amorphophallus* taros. Diseases described so far appear to indicate conspicuously that most or possibly all are diseases of taro, *C. esculenta*.

In Papua New Guinea (PNG) the most common recorded disease is the taro leaf blight (*Phytophthora colocasiae* Racib.) (Shaw 1963, Clarkson 1981, Bourke 1982 b, Bayliss-Smith 1982, Shaw 1984, Muthappa 1987, Tomlinson 1987). Surveys for pests and diseases of plants in provinces from 1989 to 1992 has revealed the same trend. Philemon and Hyde (1990, unpublished report) have noticed this similarity in the Western Province and the prevalence of favourable climatic conditions at that time was100% leaf defoliation (per. obs.). Other common diseases with varying significance are leaf spots caused by *Cladosporium colocasiae* Saw., *Phyllosticta* spp. and *Xanthomonas campestris* (Pammel) Dowson, infecting leaves and species of *Pythium*, *Rhizoctonia*, *Phytophthora*, *Fusarium*, *Sclerotium*, *Erwinia carotovora* (Jones) Bergy, Harrison, Breed, Hammer & Huntoon (Shaw 1963 & 1984, Muthappa 1987, Tomlinson 1987) and *Hirschmanniella miticausa* Bridge, Mortimer and Jackson causing rots of stem, root and corm (Mortimer *et al. 1981*, Bridge and Page 1982, Bridge *et al.1983).The* nematode *H. miticausa* has been recorded once at a site in the Southern Highlands Province (Bridge and Page 1982) and a more recent finding was at Karaisa, Tufi in the Northern Province. In both cases taro corms were rotten, pink to reddish in colour.This nematode has been found to be responsible for the severe losses of taro in the Solomon Islands (Mortimer *et al.*1981, Bridge *et al.* 1983) and its presence in PNG poses a serious threat to taro production.

The cultivation and yield of taro vary greatly and this variation is correlated to: (a) land selection and preparation; (b) nutrient levels in the soil; (c) varieties of taro available; (d) choice of planting material; (e) planting time; (f) planting techniques and (g) crop density (Bourke and Perry 1976, Bourke 1982 a & b, Anonymous 1982, Hombunaka 1985).The yield losses induced by diseases alone are variable and under

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conducive environment significant losses may occur. Jackson (1980) and Gollifer *et al.* (1978) have found that yield losses of between 30-50% and 25% were induced by *Phytophthora* leaf blight and Dasheen bobone rhabdovirus (DBRV), respectively.

People whose dietary demand includes taro and have moved and settled down either in urban cities and towns of the same country or foreign countries has raised high prospects for additional taro cultivation. The demand for taro in the latter for the Pacific Island communities in New Zealand alone in 1976 was estimated to be around 1,500 metric tonnes and this has gone up over the years (Anonymous 1982). Export of taro to New Zealand came mainly from Fiji, Tonga and Western Samoa. To meet such demands either for local consumption or export meant an increase in taro production through expansion in area and the adoption of monocropping farming system for taro cultivation. The cultivation of this crop under monocropping system is being expanded continuously, albeit such an increase in area planted to taro and the adoption of monocropping farming have led to increased pathological problems.

DISEASES

About forty taro diseases induced by fungi, bacteria, nematodes, viruses, virus-like causal agents and mycoplasmas have been recorded in PNG (Shaw 1963, 1984; Muthappa 1987). Diseases induced by virus like agents and mycoplasmas are, so far, absent. The information available on the etiology of all agents, as well as the epidemiology of diseases recorded in PNG is relatively limited and in many cases lacking. The only diseases that are being well researched and documented in the South Pacific region include the taro leaf blight (*Phytophthora colocasiae*) and the Dasheen viruses: Dasheen mosaic potyvirus (DMPVY), Dasheen bobone rhabdovirus (DBRV) and Dasheen badnavirus (DBV). The following is a brief account of diseases recorded on taro in PNG.

Fungal diseases

Approximately twenty species of fungal pathogen have been recorded in association with the taro crop, inducing either foliar, stem, root or corm rot diseases in PNG.

Foliar diseases

The most important diseases in this group are the taro leaf blight (*P. colocasiae*), (*Cladosporium* leaf spot) (*C. colocasia* Saw.) and *Phyllosticta* leaf spot (*Phyllosticta* spp.), each inducing varying effects (Clarkson 1981, Ooka and Trujillo 1982, Shaw 1984, Muthappa 1987, Tomlinson 1993). The *Phytophthora* leaf blight alone has induced losses that range from 30-50% (Jackson 1980). Others in this group are common but rarely of economic importance.

Other diseases whose incidence and severity are sporodically endemic and mild and thus considered of minor importance are blossom blight (*Choanephora cucurbitarum* Berk. and Rav.) Thaxter, leaf blight (*Thanatephorus cucumeris* (Frank) Donk and other leaf spot fungi including *Johnstonia colocasiae* M.B. Ellis, *Phoma* spp., *Leptosphaerulina triflii* (Rostrup) Petrak, *Cercospora* spp. and *Colletotrichum* spp. (Shaw 1963 & 1984, Muthappa 1987). No research has been done on these pathogens, as well as on the epidemiology of diseases induced by them and thus the extent of damage and yield reduction are still unknown in PNG.

Root and Corm rot diseases

The pathogens that are responsible for inducing diseases of roots and corms are basically soil-borne fungi. These fungi infect roots and corms either before or after harvesting and generally may cause soft or dry rot. Their presence is related to the conducive environment under which taro is grown and is attributed to either (a) poor drainage conditions in heavy clay soils (*Phytophthora* spp., *Pythium* spp. and *Rhizoctonia* spp.) and (b) the history of the land including the vegetation grown before taro is planted as plant debris harbour fungi likely to infect taro (*Botryodiplodia theobromae* Pat., *Sclerotium rolfsii* Sacc., *Chaetophoma* spp.,*Rhizoctonia* spp., *Periconia* spp., *Fusarium* spp. and *Epicoccum* spp.) (Shaw 1963, Ooka and Trujillo 1982, Shaw 1984, Muthappa 1987).

The intensity of damage induced by the rot-causing organisms on stored corms, cuttings and suckers is dependent on (a) the magnitude

and severity of the mechanical damage or injury caused during harvesting and transportation and (b) the fungal flora able to metabolise the damaged tissues. The latter includes most of the major rot-causing organisms including *Pythium* spp., *P. colocasiae*, *B. theobromae*, *Fusarium* spp. and *S. rolfsii* (Shaw 1963, Jackson 1980, Ooka and Trujillo 1982, Shaw 1984, Muthappa 1987).

Bacterial diseases

Two bacterial diseases have been reported on taro (Shaw 1984: Muthappa 1987; Tomlinson 1987), and these include *Erwinia carotovora* (Jones) Bergy, Harrison, Breed, Hammar and Huntoon sub. sp. *carotvora* causing stem and corm rot and *Xanthomonas campestris* (Pammel) Dowson pv. *aracearum* (Berniac) Dye inducing leaf blight. Tomlinson (1987) has established that *X. campestris* pv. *aracearum* as being pathogenic to taro. Besides these two species, no other bacterial pathogens have yet been reported in association with taro diseases in PNG. Jackson (1980) has reported *E. chrysanthemi* as being one of the rot-causing organisms of the stored taro corms in the Solomon Islands and it is possible that this species may also be found in the stored taro corms elsewhere where taro is grown including PNG.

The bacterial pathogens of taro can be differentiated on the basis of symptomatology in addition to their cultural characteristics (Table 1). The stem and corm rot caused by *E. carotovora*

Table 1. **Different characteristics of presently identified bacterial diseases of taro.**

CHARACTERISTICS	TBR	TBLB
Symptoms	Small water-soaked lesions on tissues which enlarge rapidly becoming smelly, creamy-white, watery, decayed mass (Agrios 1978, Jackson 1980).	Leaf spotting and blight (Muthappa 1987, Tomlinson 1987).
Species	*Erwinia carotovora* sub. sp. *carotovra* (Dye 1969, Skerman *et al.* 1980, Ooka and Trujillo 1982).	*Xanthomonas campestris* pv. aracearum (Tomlinson 1987).
Cultural features	Fast growth, mucoid and hydrolyses Casein and cotton oil (Krieg 1984).	Fast growth, highly mucoid, yellow and round colonies (Tomlinson 1987)
Dissemination	Infected organs and plants, in soil and in pupae of maggots eg. seed corn maggot *Hylemyia cilicrura* (Agrios 1978)	Rain splash onto wounded leaf surface (Tomlinson 1987).
Control	Resistant varieties, avoid corm injury, do not scrape roots and small suckers from corms to be stored, dip corms in suspension of 1% sodium hypochlorite and leaflined pits for corm storage (Jackson 1980, Ooka and Trujillo 1982, Anonymous 1993).	Avoid leaf injury and allow thorough decomposition of plant debris before taro is planted (Anonymous 1978, Tomlinson 1987).

TBR = Taro bacterial rot; TBLB = Taro bacterial leaf blight.

sub sp. *carotovora* is probably the most important bacterial disease and the disease that has been most commonly recorded in PNG (Shaw 1963 & 1984, Muthappa, 1987).

Nematode Diseases

Among the known plant parasitic nematodes, Bridge and Page (1982) have found about fifteen different genera of plant parasitic nematodes associated with taro plants in PNG. (Table 2). Some of these are known pathogens of other crops in different parts of the world (Bridge 1978, Orton Williams 1980). Four are listed in Table 3 as the most common nematodes of taro (Jackson 1980, Bridge and Page 1982) though Mortimer *et al.* (1981) and Bridge and Page (1982) considered *Hirschmanniella miticausa* as the most potent and important nematode pathogen infecting taro crop.

Table 2. **Plant nematodes genera and species found in association with taro in PNG. (Adapted from Bridge and Page 1982).**

COMMON NAME	SCIENTIFIC NAME	SPECIES
Foliar nematode	*Aphelenchoides*	*besseyi*
Foliar nematode	*Aphelenchoides*	spp.
–	*Aphelenchus*	*avenae*
Ring nematode	*Criconemella*	spp.
–	*Gracilacus*	*aonli.*
Spiral nematode	*Helicotylenchus*	*dihystera*
Spiral nematode	*Helicotylenchus*	*mucronatus*
–	*Hirschamnniella*	*miticausa.*
Lance nematode	*Hoplolaimus*	*indicus.*
Lance nematode	*Hoplolaimus*	*seinhorsti*
Cyst nematode	*Heterodera*	spp.
Root knot nematode	*Meloidogyne*	*arenaria*
Root knot nematode	*Meloidogyne*	*incognita*
Root knot nematode	*Meloidogyne*	spp.
Root lesion nematode	*Pratylenchus*	*coffeae.*
Root lesion nematode	*Pratylenchus*	spp.
Burrowing nematode	*Radopholus*	spp.
Reniform nematode	*Rotylenchulus*	reniformis
–	*Scutellonema*	spp.
–	*Tylenchus*	spp.
Dagger nematode	*Xiphinema*	*elongatum*
Dagger nematode	*Xiphinema*	spp.

Table 3. **Economically important plant nematodes of taro in PNG. (Adapted from Bridge and Page 1982).**

NEMATODE	ASSOCIATED SYMPTOMS OF DAMAGE	DISTRIBUTION
H. miticausa	Red necrosis of corm corm rot (= mitimiti disease)	Tagura (SHP)* Tufi (NP)*
Meloidogyne spp.	Root swellings (= root knots or galls)	SHP* , Markham valley, MP*
Pratylenchus coffeae	Necrosis of corm	SHP* , ENBP*
Radopholus spp.	Red necrosis of corm tissue and rot	ESP*

* SHP = Southern Highlands Province; NP = Northen Province; MP = Morobe Province; ENBP = East New Britain Province; ESP = East Sepik Province.

The disease induced by *H. miticausa* is known in the Solomon Islands as "mitimiti" disease (Jackson 1980, Motimer *et al.* 1981, Bridge *et al.* 1983) and has been recorded in PNG (Bridge and Page 1982). In PNG, *H. miticausa* has been found infecting taro corms at a single site in Tagura, Pangia in the Southern Highlands Province (Bridge and Page 1982). A more recent finding of this nematode was in 1990 at Karaisa, Tufi in the Northern Province.

Viruses, virus-like organisms and mycoplasmas

Three viruses with different particle morphology have been recorded infecting taro by Gollifer *et al.* (1977), Shaw *et al.* (1979), Zettler and Jackson (1979), Jackson (1980) and Brunt *et al.* (1990); all three are reported to be present in PNG (Jackson 1978, Jackson 1980, Perason 1981, Shaw 1984, Muthappa 1987).The two viruses: Dasheen bobone rhabdovirus (DBRV) (taro large) and Dasheen badnavirus (DBV) (taro small) are both bacilliform in shapes albeit, differ in particle size of about 330 nm x 50 nm and 125 nm x 30 nm, respectively (James *et al.* 1973, Kenten and Woods 1973, Jackson 1980, Brunt *et al.* 1990). Both are found mainly within the South Pacific region (James *et al.* 1973, Jackson 1980).The third: Dasheen mosaic potyvirus (DMPVY) however, appears to be cosmopolitan in distribution and has been reported worldwide both in the tropic and subtropic regions (Brunt *et al.* 1990). In the Australasian and the Pacific regions, DMPVY has been recorded by Brunt *et al.* (1990) from PNG, French Polynesia, Gilbert Islands, Fiji, Vanuatu, Solomon Islands, Guam and Australia and it is possible that this virus may be present in other Pacific countries where taro is cultivated.

In addition to their sharp geographical distribution there are several differential characteristics for each virus (Table 4). Considering distribution, incidence and host range, DMPVY is by far the most common viral disease of taro because it has both more motile vectors, mainly aphid species including *Myzus persicae* (Sulzer) (Hem: Aphididae), *Aphis craccivora* Koch. (Hem: Aphididae), *A. gossypii* Glover (Hem: Aphididae) and *Pentalonia nigronervosa* van-der Goot (Hem: Aphididae) (Jackson 1980, Pearson 1981, Ooka and Trujillo 1982, Rodoni 1986) and wide host range (Gollifer *et al. 1981,* Shaw *et al.* 1979, Shanmuganathan 1980, Chase and Zettler 1982, Zettler and Hartman 1986). Pearson (1981) listed two species of Aphids responsible for the transmission of this virus in PNG and they are *A. gossypii* and *P. nigronervosa.* The host range is wide and Brunt *et al.* (1990) listed a total of 59 species of plants which 40 are dicotyledons and 19 monocotyledons known to have been in-

Table 4. **Charaterisation of taro virus.**

Charateristics	Dasheen mosaic potyvirus (DMPVY)	Dasheen bobobe rhabdovirus (DBRV) (Taro large)	Dasheen badnavirus (DBV) (Taro small)
Symptoms	Mosaic, leaf distortion and chlorotic feathering (Pearson 1981)	Stunting, thichering, pickering and distortion of leaves (Gollifer & Brown 1972, James *et al.* 1973, Pearson 1981).	Vein clearing and slight leaf distortion (Jackson 1980, Pearson 1981).
Distribution	UK, Italy, Denmark, Belgium, Netherlands, S. Africa, Nigeria, Cameroon, Taiwan, China, Japan, India, Florida, Brazil, California, Costa Rica, USSR, Dominica, Puerto Rico, PNG, Venezuela, French Polynesia, Egypt, Glibert Islands, Guam, Fiji, Vanuatu, Solomon Is. and Australia (Brunt *et al.* 1990).	Solomon Islands, PNG (Shaw *et al.* 1979, Jackson 1980, Pearson 1981).	Solomon Islands, Fiji, Vanuatu, W. Samoa, PNG, Cook Islands (James *et al.* 1973, Jackson 1980, Pearson 1981).
Particle morphology	Filament flexous rods 750 nm long (Kenten and Woods 1973 , Chase & Zettler 1982, Brunt *et al.* 1990).	Rhabdo or bullet-shaped; 335 nm long and 55 nm wide (Gollifer & Brown 1972, Brunt *et al.* 1990).	Bacilliform; 125 nm long and 28 nm wide (Gollifer & Brown 1972, Brunt *et al.* 1990)
Transmission	Aphids, mechanical (Morales & Zettler 1977, Gollifer *et al.* 1977 Hartman 1972, Zettler & Abo El-Nil 1978, Pearson 1981).	Leafhopper *Tarophagus proserpina* (Gollifer *et al.* 1977, Jackson 1980).	Mealy bug *Planococcus citri* (Kenten & Woods 1973, Jackson 1980).
Hosts	*Agloanema, Alocasia, Amorphophallus, Arisaema, Caladium, Crytosperma, Cryptocoryne, Dieffenbachia, Philodendron, Richardia, Zantedeschia, Colocasia and Xanthosoma* (Chase & Zettler 1982, Rana *et al.* 1983, Zettler & Hartman 1986).	*Tetragonia expansa, Colocasia esculenta* (Gollifer *et al.* 1977, Shaw *et al* 1979).	*Colocasia esculenta, Alocasia macrorrhiza, Xanthosoma spp.* (James *et al.* 1973, Gollifer *et al* 1977).
Control	Use resistant cultivars, strict quarantine to prevent its introduction, apply insecticide, (Jackson 1980, Pearson 1981, Ooka & Trujillo 1982).	Use resistant cultivars, destroy diseased plants, apply insecticide (Jackson 1980, Pearson 1981, Ooka & Trujillo 1982).	Use resistant cultivars, destroy diseased plants, apply insecticide (Jackson 1980, Pearson 1981, Ooka & Trujillo 1982).

fected by this virus. The virus is common albeit, its effect on yield is still undetermined.

The former two viruses are also transmitted by motile insect vectors by leafhopper *Tarophagus proserpina* Kirkaldy (Hem: Delphacidae) and the mealy bug *Planococcus citri*, respectively though, host range is narrow mainly species of *Colocasia, Alocasia* and *Xanthosoma* (Gollifer *et al.* 1977: Shaw *et al.* 1979). Infection of taro by DBRV has been shown to have reduced yield by 25% (Jackson 1980).

Unfortunately virus-like and mycoplasma induced diseases of taro have not yet been reported infecting taros in PNG. It is most probable that diseases induced by these two groups of pathogens is absent worldwide.

RECOMMENDED MEASURES FOR CONTROL OF DISEASE

It is not essentially necessary to adopt a single control measure or method such as chemicals for the control of diseases, as one may prove ineffective, costly and unsafe. Several control methods should be considered and options drawn to determine which control measure or combinations of control measures can be applied with great benefit. But preferably, integrated control measures of exclusion, eradication, protection and host resistance be applied and Agrios' (1978) system should be considered and used as a guide for disease control in taro cultivation and production.

Regulatory methods

In order to prevent the introduction of alien and exotic strains and even the spread of taro diseases to other disease-free areas, countries must have strict quarantine regulations. These regulations must govern both the importation from abroad and movement internally of planting materials. The plant quarantine officers (incl. quarantine officers and plant inspectors) must be consulted prior to importing or moving plant and plant parts to new sites. Where such officers are not available, liaison with the nearest agriculture office for further information should be established. The movement of planting materials from areas known to have diseases of significance should be discouraged to ensure that diseases are restricted locally (Bridge and Page 1982).

Cultural methods

The cultural method of control is geared towards diseases already established and is aimed at reducing the level of infection and eradicating the diseases.The following cultural methods should be considered and applied to control some diseases infecting taro.

Host eradication

Taro relatives and other plant species that are known hosts to some of the taro diseases must be removed and burned or buried deeply in the soil. Removing affected parts (Jackson 1980) and whole diseased plants (Jackson 1978 & 1980, Pearson 1981) give good control of *Phytophthora colocasiae*, the causal agent of taro leaf blight and DBRV (Taro large) and DBV (Taro small), respectively.

Crop rotation

Soil-borne pathogens including fungi and nematodes can be sometimes reduced or eliminated through the absence of host plants (Agrios 1978) thus, replanting taro and its relatives on the same site should be discouraged and avoided (Jackson 1980, Bridge and Page 1982) to ensure that inocula levels left from the previous cropping are reduced.To further enhance the reduction of the inocula levels plant debris including small corms should be removed after harvest as these could harbour the pathogens.

Sanitary measures

There are several simple sanitary measures that have proved effective in disease control. Roguing infected plants (Gollifer and Brown, 1972, Jackson 1978, Pearson 1981) and removing affected parts (Jackson 1980, Ooka and Trujillo 1982) has given effective control of leaf diseases. Paring away diseased tissue (Bridge and Page 1982: Bridge *et al.*1983) and using disease-free planting materials are effective means of reducing the spread of diseases.

Improving growing conditions

To attain the expected potential of taro, in terms of production or yield even in the absence of diseases depends on several factors. For a start, select big (about 5.0 cm) healthy, high quality propagating material (Bourke and Perry 1976, Bourke 1982 a) and if small sucker setts are used (less than 2.5 cm) close spacing gives best result (de la Pena 1977, Anonymous 1982). Where diseases are present the same practices must be applied. Other practices that can sustain taro production include proper drainage of field (Anonymous 1982, Bourke 1982 a & b), mulching, timing of planting and proper spacing will significantly improve plant growth. Such improved practices and others can directly or indirectly control soil-borne diseases.

Tissue culture

Propagating materials derived from tissue culture method has proved a break through and a great success in that it (a) allows for rapid propagation of taro as planting material (Jackson *et al.* 1977) and (b) propagating materials derived from tissue culture techniques are often disease-free (Anonymous 1984, George and Sherington 1984).

Biological methods

Where possible biological agents can be used to control taro diseases.The eggs and the first instar nymphs of the planthopper *Tarophagus proserpina* was found being attacked by a mirid predator *Cyrtorhinus fuvlus* Knight (Hem: Miridae) (Jackson 1980).The presence of the predator has proved effective in controlling the planthopper population, albeit the level of control of virus spread is still not known.

Physical methods

Heat treatments have been used quite widely in eradicating soil-borne pathogens.The nematode *H. miticausa* can be eradicated from taro corms by immersion in hot water at a temperature of 50 degrees Celsius for 15 minutes (Bridge and Page 1982).

Chemical methods

It is not possible to recommend chemical control of diseases in the rural or small farm situation due largely to the costs of the chemicals and equipment and the risks chemicals pose to both humans and the environment. Where both costs and know how are not problem areas, chemicals can be applied but with great care. Several chemicals mainly copper and dithiocarbamate fungicides have been proved effective in fungal disease control including Tribasic copper sulphate, Mancozeb, Metiram, Captafol, Bordeaux, Copper oxychloride, Ridomil, Aliette and Captan (Jackson 1980). Nematicides (Bridge and Page, 1982) have been recommended for the control of nematodes. It is worth mentioning that the rate of chemicals recommended and methods of application depends on the environment (rainfall and temperature) under which taro is grown.

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