Nematology, 2005, Vol. 7(4), 631-636

Corm rot of giant swamp taro (*Cyrtosperma merkusii*) caused by the burrowing nematode *Radopholus similis* (Nematoda: Pratylenchidae) in the Pacific

Vazhaveli K. MURUKESAN [1], Esther VAN DEN BERG [2], Laurens R. TIEDT [3], Puthiyaparambil C. JOSEKUTTY [4] and Dirk DE WAELE [5,*]

[1] *College of Micronesia, Yap State Campus, P.O. Box 1226 Colonia, YAP, FM 96943, Federated States of Micronesia*
[2] *National Collection of Nematodes, Biosystematics Division, Plant Protection Research Institute, Private Bag X134, Queenswood 0121, South Africa*
[3] *Laboratory for Electron Microscopy, North West University, Potchefstroom Campus, Potchefstroom 2520, South Africa*
[4] *Cellular and Molecular Biology Laboratory, School of Biological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand*
[5] *Laboratory of Tropical Crop Improvement, Catholic University Leuven (K.U.Leuven), Kasteelpark Arenberg 13, 3001 Leuven, Belgium*

Received: 28 February 2005; revised: 5 July 2005
Accepted for publication: 6 July 2005

Summary – The association between the burrowing nematode *Radopholus similis* and giant swamp taro is studied in detail for the first time in corms collected from swampy taro patches in Yap, one of the states of the Federated States of Micronesia. The *R. similis* population from Yap displays similar variation in morphometrics and morphology as reported in the literature. The rot caused by the nematodes is wet with a loose mass of brown dead tissues and a deep brown necrotic centre housing nematodes inside. Usually, the infected tissues spread a disgusting odour typical of this disease. The dead tissues progress into shallow to deep cavities that advance towards the edible, central portion of the corm giving a perforated appearance on the outside of the otherwise smooth corm. The disease becomes more severe as the age of the plant increases. Nematode-infected plants seldom show any above-ground symptoms. The market quality of the corm is greatly reduced by the nematode damage. The widespread occurrence of the disease and the type of damage *R. similis* causes to the corms pose a serious threat to giant swamp taro production, food security and the continuation of traditional customs on those islands where *R. similis* occurs.

Keywords – Federated States of Micronesia, plant-parasitic nematode, symptomatology, Yap.

Giant swamp taro, *Cyrtosperma merkusii* (Hassk.) Schott, is an important crop on many Pacific islands where it is grown in flooded swamp land for its large edible corms. It is an important source of starch, is rich in natural fibres and carbohydrates and is low in fat. In Yap, one of the states of the Federated States of Micronesia, an adult consumes about 800 g fresh weight of corm daily (Nakano, 1999). Some of the yellow cultivars are reported to be high in carotenoids, making them an ideal local resource to fight vitamin A deficiency among the people of the Pacific islands (Englberger *et al*., 2003). The crop is not seasonal and withstands strong winds, the corm having the potential to remain in the ground for 10 years or more and thereby provide food security. Moreover, giant swamp taro also plays a significant role in the traditional life of the islanders, especially in Yap where for many centuries it has been considered a cultivated plant of status and where a healthy corm has a significant value in funerals and traditional ceremonies. Corms from plants 10 or more years old are among the most highly prized gifts that a person can give to chiefs during these funerals and ceremonies. Also, a number of strong taboos and restrictions surround the cultivation of giant swamp taro and its preparation for food.

In 1987, a corm rot of *Cyrtosperma* caused by *Radopholus similis* (Cobb, 1893) Thorne, 1949 was reported from

* Corresponding author, e-mail: Dirk.DeWaele@biw.kuleuven.be

the Pacific islands of Yap, Palau and Guam (Jackson, 1987). Infected corms had small shallow holes as if they had been bored by insects, the holes being 0.5-2 cm in diam. and 1-2 cm deep. Beneath this tissue was a brown rot, mostly superficial, but occasionally extending as narrow channels deep into the centre of the corm. Because of the rot a considerable amount of decayed tissue had to be pared away before corms became fit for human consumption. Infected plants showed little above-ground symptoms. Large numbers of *R. similis* were found in the corms, but relatively few in the roots (Jackson, 1987). As *R. similis* had not previously been reported from *Cyrtosperma* and an anaerobic flooded swamp was thought an unlikely habitat for this nematode species, specimens were sent to the Institute of Parasitology in St Albans, England, where the identification was confirmed by taxonomists. Grandison (1990) reported that in Yap and Palau the incidence of corm rot of giant swamp taro caused by *R. similis* was at least 80% and that there were indications that the disease had become more important in recent years. In a recent study in Yap (Onjo *et al*., 2001) the validity of *R. similis* being the causal agent of dry corm rot of giant swamp taro was questioned as the authors failed to extract *R. similis* from diseased corms. As no detailed study of this interesting and important plant-nematode interaction had ever been made, samples were once again collected in Yap for further study.

In the present study, the identity and the role of *R. similis* in corm rot of giant swamp taro is confirmed. Information is given on the morphology of *R. similis* isolated from *Cyrtosperma* and the symptoms caused by this nematode species documented. Implications for the practical management of *R. similis* on giant swamp taro are discussed.

Materials and methods

Infected corms were collected from a knee-deep swampy taro patch at Gagil Municipality, Yap, and brought to the laboratory in an ice chest. Main and feeder roots were cut off and the corms gently washed to remove the mud and soil particles. Small pieces of infected corms together with encircling healthy portions were wrapped in tissue paper and sent to the Plant Protection Research Institute in Pretoria, South Africa, for isolation of the nematodes and identification.

For mounting, the nematodes were transferred to formalin-propionic acid-glycerin (FPG) and mounted in anhydrous glycerin (Netscher & Seinhorst, 1969; Hooper & Evans, 1993). For scanning electron microscopy, specimens were killed and fixed in TAF after which they were dehydrated in increasing concentrations of amyl acetate in pure alcohol and finally in pure amyl acetate. Following conventional critical point drying and gold/palladium coating (15 nm), specimens were viewed with a Philips XL30 DX41 stereoscan microscope at 10Kv. For *in situ* studies, corm tissue was placed in a concentration of 30% acetone overnight and then for 30 min each in concentrations of 75%, 95%, and then left in 100% acetone. The corm tissue was then critical point dried and coated and viewed as described above for the nematode specimens.

Results and discussion

Measurements

See Table 1 for morphometrics of female and male nematodes.

Morphological observations

The *R. similis* specimens from Yap compare very well with various descriptions of this species (Koshy *et al*., 1991; Ryss & Wouts, 1997; Valette *et al*., 1998; Elbadri *et al*., 1999a, b) (Fig. 1). These authors made detailed studies of the morphology and morphometrics of *R. similis* populations from many different countries and host plants. They found a substantial variation in all cuticular and morphometrical characters of both females and males. The population from Yap displays similar variation as recorded by these authors.

Disease symptoms

The nematode-infected plants seldom show any above-ground symptoms. Giant swamp taro is a perennial crop and the disease becomes more severe as the age of the plant increases. The disease has in the past been named 'dry corm rot' to distinguish it from soft rots caused by bacteria and fungi and in analogy with dry rots caused by *Radopholus* and *Pratylenchus* spp. in other root and tuber crops, such as yam. Our observations, however, show that the infected necrotic tissues are not dry as the original name of the disease suggests. On the corms from Yap examined in the present study, the rot is wet with a loose mass of brown dead tissues and a deep brown necrotic centre housing nematodes inside (Fig. 2A, B). Usually, the infected tissues produce a disgusting odour which is so typical of this disease. Corms are ready for harvest

Table 1. *Morphometrics of adult* Radopholus similis *from Yap Island. All measurements are in µm and in the form: mean ± standard deviation (range).*

	Female	Male
n	23	11
L	604 ± 54 (503-726)	586 ± 54.2 (454-646)
a	26 ± 3.4 (21-31.1)	32.8 ± 4.6 (23.5-40)
b	7.4 ± 0.7 (5.9-8.8)	7.3 ± 0.7 (6.1-8.4)
b^1	4.5 ± 0.3 (3.8-5)	5.4 ± 0.3 (4.9-5.9)
c	8.7 ± 0.7 (7.8-10.8)	8 ± 0.6 (6.5-8.4)
c^1	4.1 ± 0.4 (3.4-4.6)	5.2 ± 0.2 (4.9-5.7)
o	20.1 ± 3.6 (13-26.7)	–
V	57 ± 1.6 (53-59.5)	–
DGO	3 ± 0.5 (2-4)	–
OV_1	23 ± 5.1 (19-43)	–
OV_2	21 ± 2.9 (17-29)	–
Stylet length	16.5 ± 0.5 (15-17)	–
Metenchium length	8 ± 0.4 (8-8.5)	–
Telenchium length	8.5 ± 0.5 (8-9)	–
Stylet knob height	2 ± 0.3 (1.5-2.5)	–
Stylet knob width	3.5 ± 0.3 (3-4.5)	–
Median bulb length	12.5 ± 1.1 (11-14)	11 ± 1.4 (8-13)
Median bulb diam.	9.5 ± 1.1 (8-12.5)	5 ± 0.5 (4.5-6)
Lip region diam.	9.5 ± 0.6 (8-10)	7.5 ± 0.6 (6.5-9)
Lip region height	3.5 ± 0.4 (2.5-4)	5.5 ± 0.4 (5-6)
Pharynx length	135 ± 8.8 (119-156)	109.5 ± 11.6 (94-128.5)
Pharynx gland length	53 ± 9 (37-66)	30.5 ± 8.3 (16.5-42)
Excretory pore from anterior end	87.5 ± 6.5 (69-99)	92 ± 8.4 (80-120)
Diam. at midbody	23.5 ± 4.9 (16-33)	18 ± 2 (15.5-20.5)
Diam. at excretory pore	21 ± 2.2 (17.5-26)	16 ± 0.6 (5.5-17)
Diam. at anus	16.5 ± 2.2 (13-22)	14 ± 0.3 (13.5-15)
Diam. at start of hyaline part	6 ± 0.5 (5-7.5)	5 ± 0.8 (4.5-6.5)
Annulus width	1.5 ± 0.2 (1-2)	1.3 ± 0.2 (1-1.5)
Lateral field width	6.5 ± 1 (5.5-9)	5 ± 0.7 (4-6)
Tail length	68 ± 6 (53-77)	73 ± 3 (69.5-79)
Number of tail annuli	52 ± 4.5 (44-60)	–
h	10 ± 1.8 (7-14)	9 ± 1.7 (6.5-11.5)
Spiculum length	–	21.5 ± 0.9 (20-23)
Gubernaculum length	–	11 ± 0.4 (10-12)

from 3 years after planting, thus giving ample time for the nematodes to become established in large population densities inside the corms. The end result of nematode infection is the formation of shallow to deep cavities of dead tissues that advance towards the edible, central portion of the corm (Fig. 2C). Infection is visible on the external surface of the corm as a perforated appearance of the otherwise smooth corm (Fig. 2D). This damage highly reduces the market quality of the corm.

The widespread occurrence of the disease and the type of damage *R. similis* causes to the corms pose a serious threat to giant swamp taro production, food security and the continuation of traditional customs on those islands where *R. similis* occurs.

Up to 50 000 *R. similis* juveniles, females and males were extracted from 10 g of fresh corm. A stereoscan microscopy study revealed the high population densities of *R. similis* inside the corm tissues. Interestingly, in addition to *R. similis*, several specimens of a large, unidentified, dorylaimid were also observed. It is possible that this nematode species is a predator feeding on the numerous juvenile and adult *R. similis*. The occurrence

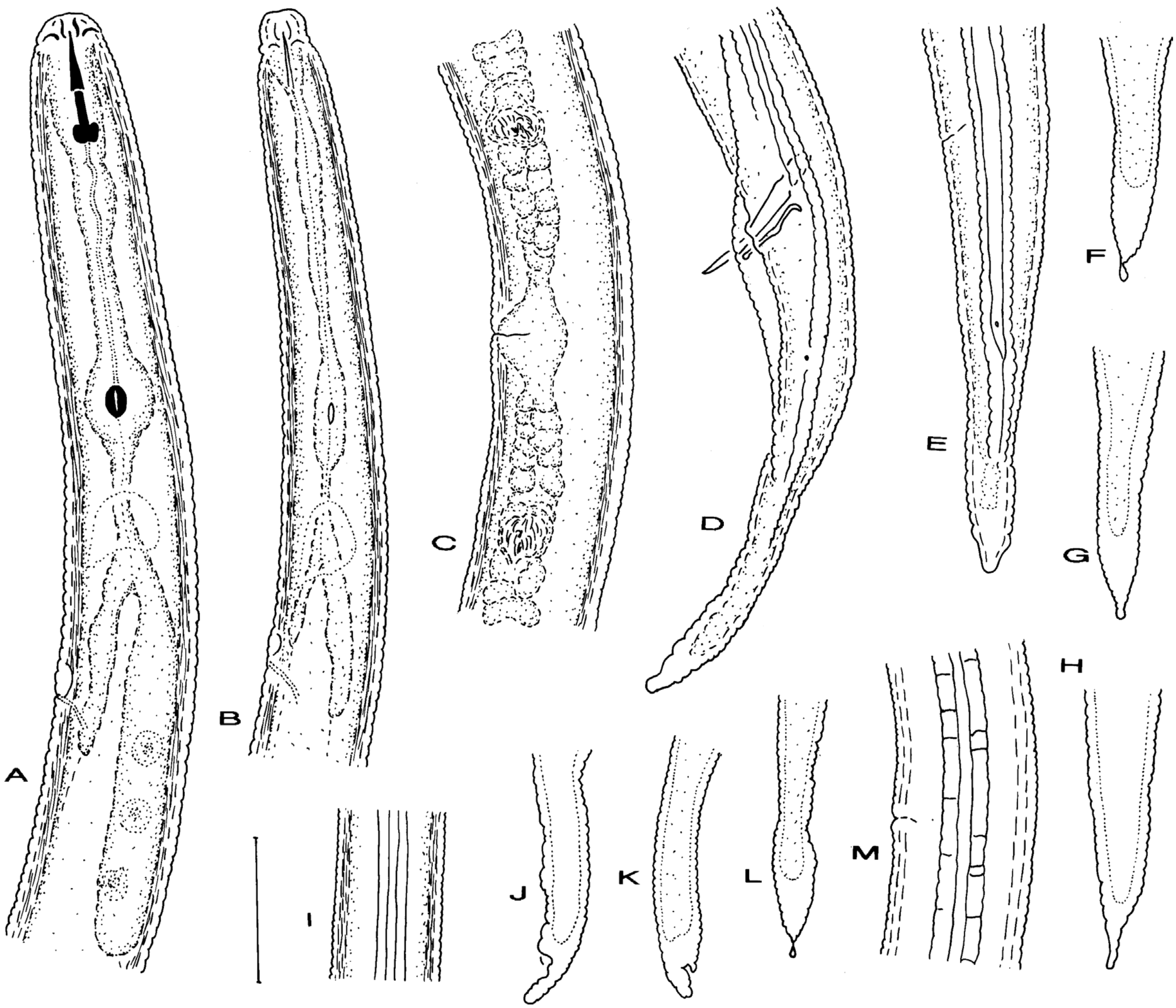

Fig. 1. Radopholus similis. *A: Anterior part of female body; B: Anterior part of male body; C: Female vulval area with two spermathecae of equal size; D: Male tail; E: Female tail; F-H: Tail tip variations in female; I: Male lateral field at midbody; J-L: Tail tip variations in male; M: Female lateral field at midbody. (Scale bar: A-M = 20 μm.)*

of concentrations of *R. similis* eggs indicates that this nematode species can reproduce inside the corm and may suggest that *R. similis* spends its entire life cycle inside the giant swamp taro plant tissue, thereby avoiding the anaerobic conditions of the flooded swamp. Although *R. similis* has a been reported from many islands in the Pacific and from many host plants, including taro (*Colocasia esculenta* (L.) Schott) and yam (*Dioscorea* spp.; *i.e.*, see Bridge, 1988), the occurrence of this nematode species in a swamp environment is uncommon and has not been reported previously. If our hypothesis that *R. similis* does not occur in the rhizosphere of the plants is correct, planting nematode-free cormlets could prevent the spread of the disease. In giant swamp taro, new cormlets develop from the outer surface of the mother corms as side shoots approximately 1-2 years after planting. At harvest, the cormlets are cut off close to the point of attachment with the mother corms. Currently, excised cormlets are the only type of planting material used in Yap. Nematode-free cormlets could be produced *via in vitro* micropropagation and nematode-infected cormlets could be disinfected *via* heat treatment. Thermotherapy has proven effective in eliminating *R. similis* from infected palms and *Anthurium* (Tsang *et al*., 2003; Arcinas *et al*., 2004).

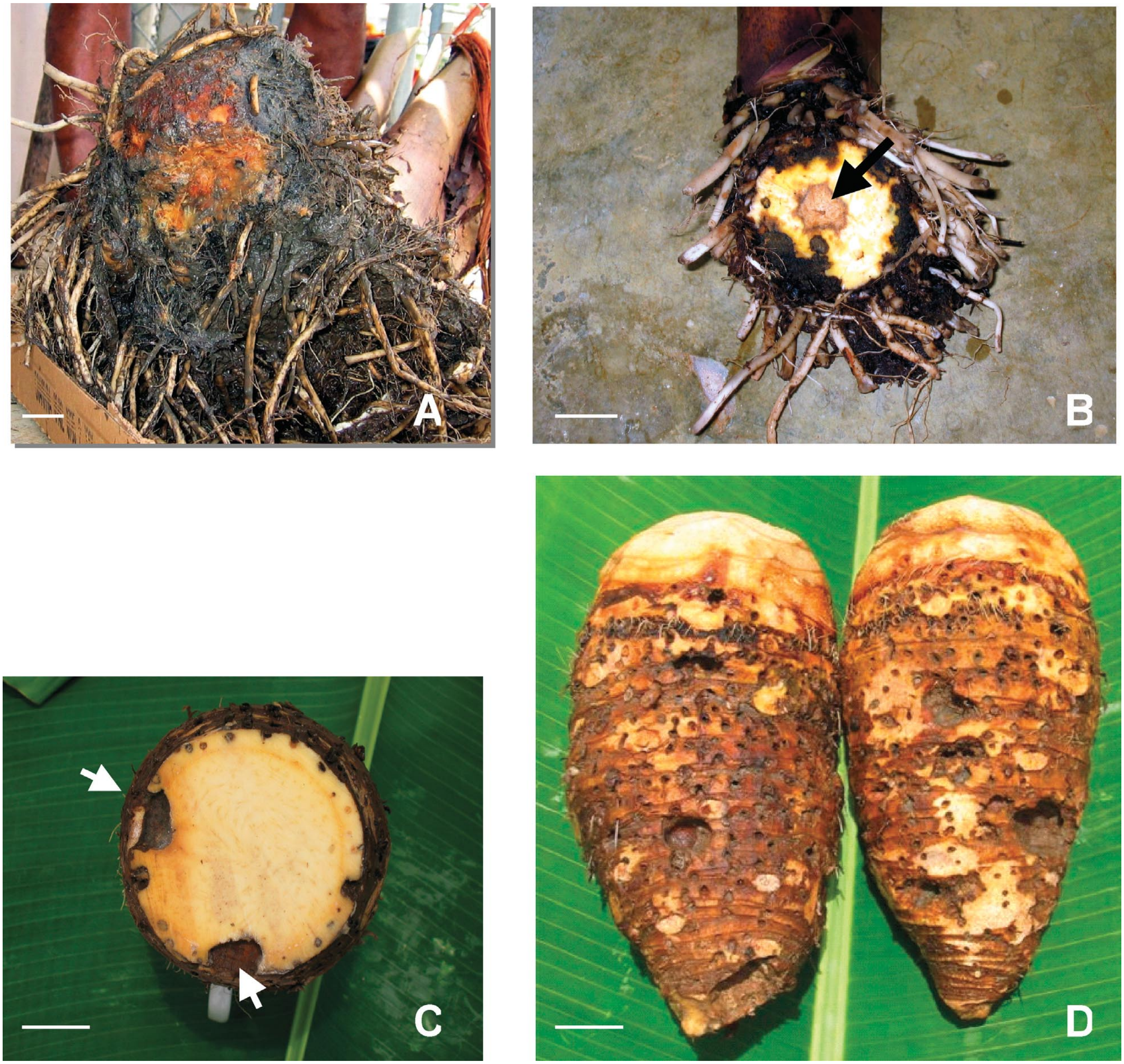

Fig. 2. *A: 9-year-old infected corm with wet, loose mass of brown dead tissue (scale bar = 3 cm); B: 2-year-old infected corm cut superficial diagonally showing the deep brown necrotic centre (arrow) (scale bar = 1 cm); C: 8-year-old infected corm cut in half showing cavities of dead tissues that advance towards the edible, central portion of the corm (arrows) (scale bar = 2 cm); D: Entire infected corms showing the perforated appearance of the otherwise smooth corm (scale bar = 2 cm).*

Acknowledgements

Dr Singeru Singeo, Executive Director, College of Micronesia-Land Grant Program, and Mrs Kenye Killin, CES Assistant Director, College of Micronesia-FSM, Kosrae Campus, are gratefully acknowledged for the financial assistance provided from ADAP and USDA-IPM grants, respectively. Mrs N.H. Buckley of the Plant Protection Research Institute is thanked for technical assistance.

References

ARCINAS, A.C., SIPES, B.S., HARA, A.H. & TSANG, M.M.C. (2004). Hot water drench treatments for the control of *Radopholus similis* in *Rhapis* and fishtail palms. *HortScience* 39, 578-579.

BRIDGE, J. (1988). Plant-parasitic nematode problems in the Pacific Islands. *Journal of Nematology* 20, 173-183.

ELBADRI, G.A.A., GERAERT, E. & MOENS, M. (1999a). Morphological differences among *Radopholus* populations (Nematoda: Tylenchida) from banana in Africa. *Journal of Nematode Morphology and Systematics* 2, 7-16.

ELBADRI, G.A.A., GERAERT, E. & MOENS, M. (1999b). Morphological differences among *Radopholus similis* (Cobb, 1893) Thorne, 1949 populations. *Russian Journal of Nematology* 7, 139-153.

ENGLBERGER, L., SCHIERLE, J., MARKS, J.C. & FITZGERALD, M.H. (2003). Micronesian banana, taro and other foods: newly recognized sources of provitamin A and other carotenoids. *Journal of Food Composition and Analysis* 16, 3-19.

GRANDISON, G.S. (1990). Investigation of a nematode disorder of giant swamp taro (*Cyrtosperma chamissonis*). *Report on a visit to State of Yap (Federated States of Micronesia) and Republic of Palau, 3-8 June, 1990. Department of Scientific and Industrial Research, Auckland, New Zealand*, 14 pp.

HOOPER, D.J. & EVANS, K. (1993). Extraction, identification and control of plant nematodes. In: Evans, K., Trudgill, D.L. & Webster, J.M. (Eds). *Plant parasitic nematodes in temperate agriculture.* Wallingford, UK, CABI Publishing, pp. 31-59.

JACKSON, G.V.H. (1987). Corm rot of *Cyrtosperma* in Guam. *Report to Federated States of Micronesia and Palau.*

KOSHY, P.K., JASY, T., MATHEW, J. & NAMPOOTHIRI, C.K. (1991). Morphometric variability in *Radopholus similis*. *Indian Journal of Nematology* 21, 24-38.

NAKANO, K. (1999). *The supply of energy-source foodstuffs in the Yap Islands: a preliminary report*. Kagoshima University Research Center for the Pacific Islands, 13 pp.

NETSCHER, C. & SEINHORST, J.W. (1969). Propionic acid better than acetic acid for killing nematodes. *Nematologica* 15, 286.

ONJO, M., TAURA, S. & SAKAMAKI, Y. (2001). The present situation of agriculture in Yap. In: Aoyama, T. (Ed.). *Progress report of the 1999 survey of the research project 'Social homeostasis of small islands in an island-zone'.* Kagoshima University Center for the Pacific Islands, Occasional Papers No. 34, pp. 91-93.

RYSS, A.Y. & WOUTS, W.M. (1997). The genus *Radopholus* (Nematoda: Pratylenchidae) from native vegetation in New Zealand, with descriptions of two new species. *International Journal of Nematology* 7, 1-17.

TSANG, M.M.C., HARA, A.H. & SIPES, B.S. (2003). Hot-water treatments of potted palms to control the burrowing nematode, *Radopholus similis*. *Crop Protection* 22, 589-593.

VALETTE, C., MOUNPORT, D., NICOLE, M., SARAH, J.-L. & BAUJARD, P. (1998). Scanning electron microscope study of two African populations of *Radopholus similis* (Nematoda: Pratylenchidae) and proposal of *R. citrophilus* as a junior synonym of *R. similis. Fundamental and Applied Nematology* 21, 139-146.