Technical Report No. 42

PLANT-PARASITIC NEMATODES OF BANANA IN AMERICAN SAMOA

F. E. Brooks, Plant Pathologist

This article was published in *Nematropica* 34: 65-72 (2004) and is being included in these Technical Reports with permission of the editor.

ABSTRACT

Brooks, F. E. 2004. Plant-parasitic nematodes of banana in American Samoa. Nematropica 34: 65-72.

Sixteen commercial banana farms in American Samoa growing the cultivar Williams (*Musa* AAA, Cavendish subgroup) and eight non-commercial farms with mixed varieties were surveyed over a 10-month period. Fields were assessed for nematode species present, population densities, and root damage. In addition, two FHIA hybrids with putative resistance to the burrowing nematode, *Radopholus similis*, were evaluated. Population densities of *Helicotylenchus multicinctus* and *H. dihystera* were five times higher, on average, than population densities of *R. similis*. *Pratylenchus loosi* and *P. gibbicaudatus* are new records for American Samoa and this is only the second report of *P. gibbicaudatus* on *Musa* spp. The FHIA-01 hybrid had 60 times fewer burrowing nematodes than 'Williams' growing in the same field and FHIA-25 had the lowest nematode population densities (all species) of any variety surveyed. Average estimates of external and cortical root necrosis in the commercial fields were both 26%.

Key words: American Samoa, banana root damage assessments, FHIA hybrids, *Helicotylenchus*, *Musa*, *Pratylenchus gibbicaudatus*, *Pratylenchus loosi*, *Radopholus similis*.

INTRODUCTION

Five species of plant-parasitic nematodes have been listed on bananas (*Musa* spp.) in the US Territory of American Samoa (Firman, 1975; Grandison, 1996). These nematodes, especially burrowing (*Radopholus similis* (Cobb) Thorne) and spiral (*Helicotylenchus multicinctus* (Cobb) Golden) nematodes, were reportedly causing serious root damage and assumed to be suppressing yield. Burrowing and spiral nematodes are a worldwide problem in banana growing regions causing yield losses of 30-50% in Costa Rica and Panama, 40% in Africa, and 30-60% in India (Davide, 1995). Severe nematode damage to banana crops has also been reported in Southeast Asia and all other South Pacific Islands, including the neighboring independent nation of Samoa (Siddiqi, 1973; Bridge, 1988; Davide, 1995).

Banana ranks fourth of all agricultural crops produced worldwide and first among fruits, with annual sales of approximately US$2.5 billion (Ploetz, 2001). This figure represents only about 10% of the 78.2 million tonnes (86 million tons) cultivated. The remaining 90% is produced by subsistence farmers and consumed by their families. These growers are situated in the developing tropical regions of Africa, Asia, the Americas, and South Pacific. Banana and taro (*Colocasia esculenta* (L.) Schott) are the principle crops grown for market in American Samoa. In 1998, American Samoan growers produced 9.8 million kg (21.5 million pounds) of 'Williams' (*Musa* AAA, Cavendish subgroup) with an estimated value of US$12.5 million (National Agricultural Statistics Service, 1999). A similar amount of bananas from other cultivars were produced, such as 'Misi Luki' (*Musa* AAB, Mysore subgroup) and 'Pata Samoa' (*Musa* ABB, Bluggoe subgroup) (Daniells, 1995; Jones, 2000), and were valued at US$10.5 million. All of these locally produced bananas are sold and consumed on the islands where they were grown.

Banana is a perennial crop that is grown on the same site for many years. This practice provides conditions for nematode survival and population increase. Roots damaged by nematodes are inefficient in water and nutrient uptake. The consequences of this damage are a reduced rate of plant growth, lengthening of the vegetative cycle, suppression of bunch weights, and a reduction in the productive life of the farm (McSorley and Parrado, 1986; Bridge, 1988; Fogain and Gowen, 1997; Araya et al., 1999). Top-heavy banana plants may fall over (topple) at fruiting or during strong winds due to the loss of anchoring roots (Gowen, 1995; Whitehead, 1998), a common sight in American Samoa. Farmers may incorrectly attribute these problems to poor root development, lack of soil nutrients, shallow soil, or unsuitable soil moisture.

Most growers are unaware that nematodes are a cause of banana production problems and it is important to inform them of possible management options. Only a few nematode management practices are available to Pacific Island banana farmers in a sustainable system, however, and some may not be economically or environmentally acceptable (Speijer and Ssango, 1999).

The objectives of this study were to identify nematodes extracted from banana roots and soil and estimate their population densities, assess root health, evaluate banana cultivars with putative resistance to the burrowing nematode, and suggest methods of control.

MATERIALS AND METHODS

Survey method

Sixteen commercial banana farms and eight non-commercial plantings were surveyed for plant-parasitic nematodes between July 2002 and May 2003 on Tutuila, the main island of American Samoa. Tutuila is located at 14° 18' S latitude and 170° 41' W longitude. Most soils on these farms are well-drained clay loams of either the Iliili Series (Medial-skeletal, isohyperthermic Lithic Dystrandepts) or Oloava Series (Medial over cindery, isohyperthermic Typic Dystrandepts), with an average effective rooting depth of 90 cm (35-150 cm) (Soil Conservation Service, 1984). Average annual rainfall is 400 cm per year (300-625 cm) over these sites, with a mean annual temperature of 26°C.

Commercial farms selected for the survey grew only ‘Williams’. Ten plants in their first 14 days of flower emergence (Sarah, 1993; Speijer and Gold, 1995) were arbitrarily chosen for sampling. From each plant, all banana roots and approximately 100 g of soil were removed from holes measuring 25 cm on a side dug next to the base of the rhizome. The roots of each plant were kept separate and placed into individual plastic bags, but soil from the 10 plants was mixed into a bulk sample (Speijer and Gold, 1995; Fogain and Gowen, 1997; Araya et al., 1999). Sampling methods were the same in the non-commercial fields. In order to sample plants at the same growth stage on the same cultivar on these private farms, fewer than 10 plants were sampled. Two tetraploid hybrids resistant to black leaf streak disease (black Sigatoka) from the *Fundacion Hondurena de Investigacion Agricola* (FHIA) breeding program, were similarly assessed for putative resistance to burrowing nematode. These assessments included 10 FHIA-01 and 10 ‘Williams’ plants growing in the same field, and 10 of the recently introduced FHIA-25 hybrids growing in monoculture.

Root damage

After recording the fresh root weight of each sample, the percentage of necrotic roots, hereafter referred to as external necrosis, was estimated. Five primary roots were then selected from the sample, cut into

10-cm-long pieces and split lengthwise. The percentage of cortical necrosis was assessed using a modified scale for burrowing nematode damage (Bridge and Gowen, 1993; Speijer and Gold, 1995). This adjusted scale assumed that smaller lesions in the outer cortex were caused by spiral nematode and expressed them as coalesced lesions extending to the stele.

Nematode Extraction

The method of extraction was based on the procedures described by Hooper (1990) and Speijer and Ssango (1999). The 5 root pieces assessed for cortical necrosis were cut into 1-cm-long segments and mixed. A 5-g subsample was then added to 50 ml water and blended at medium speed for 10 seconds. The macerate was poured onto two 2-ply layers of paper toweling (Bounty, Procter and Gamble, Cincinnati, OH) suspended on a Baermann tray with the water level in the tray touching the roots (McSorley, 1987). Two days later the water was removed, replaced with fresh water, and the nematodes counted in two 2.5 ml aliquots of the suspension. Changing water during incubation increased extraction efficiency (Brooks, personal observation), possibly by increasing the oxygen content of the water (Gowen and Edmunds, 1973; Sarah, 1993). A final count was made at 5 days, added to the 2-day count, and the nematode population density adjusted to 100 g fresh root weight. Nematodes were extracted from the 100-g bulk soil sample using the Baermann tray method (McSorley, 1987).

Data analysis

Nematode population densities and fresh root weights were $\log_{10}(x + 1)$ transformed for analysis. Root damage ratings, expressed as percentage of necrotic tissue, were normalized with a square root transformation (Marin et al., 1999; Fogain, 2001). All observations were compared with transformed data using Kruskal-Wallis ANOVA on ranks, the Tukey test for pairwise comparison of means, and Pearson's product moment correlation (SigmaStat, SPSS Inc., Chicago, IL). Nematode population densities on farm #10, containing only spiral nematodes and farm #14, containing only burrowing nematodes, were evaluated separately for their correlation to root weight and root necrosis.

RESULTS

Nematode population densities

Nematode population densities in roots varied widely between commercial farms and among plants within the same farm (Figure 1). Farms 3, 8, and 13 had significantly more plant-parasitic nematodes than farm 9, and farm 3 had more than farm 10 ($P < 0.05$). The average population density of all nematode species for the 16 farms was 28,500 per 100 g of roots. *Helicotylenchus multicinctus*, a spiral nematode, was the most prevalent species. It was found in 15 of the 16 commercial farms and together with a small number of *H. dihystera* (Cobb) Sher , averaged more than 23,000 nematodes per 100 g of roots. *Radopholus similis* was also isolated from 15 of 16 farms and averaged 4,680 nematodes per 100 g of roots. Root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, was recovered from one plant on each of three commercial farms; galled roots accounted for <5% of each sample.

Nematodes collected from non-commercial farms included the lesion nematodes, *Pratylenchus loosi* Loof, extracted from roots of ‘Pata Samoa’, and *P.*

gibbicaudatus Minagawa, from an isolated planting of 'Ducasse' (*Musa* ABB, Pisang Awak subgroup). Nematode population densities were 5,400 and 8,800 per 100 g roots, respectively. Meloidogyne *incognita* caused mild root galling (<5%) on various cultivars including 'Soa'a' (Fe'i-type), an unusual banana with an upright bunch.

The average population densities of burrowing nematode on FHIA-01 and 'Williams' growing in the same field were 107 and 6,353 per 100 g of roots, respectively. The population density of spiral nematodes was 31,492 per 100 g of roots on FHIA-01 and 32,130 per 100 g of roots on 'Williams'. From ten plants of FHIA-25 on previously fallowed land, 177 spiral nematodes and 76 burrowing nematodes were recovered per 100 g of roots. Nematode populations in the soil averaged 270 per 100 g of soil and were positively correlated ($r = 0.67$, $P < 0.005$) with root population densities in the commercial fields.

Root damage

Average fresh root weight per sample for the 16 farms was 133 g (57-268 g). There was no correlation between root weight and nematode population density, but there was a negative correlation between root weight and external root necrosis ($r = -0.43$, $P < 0.001$), and a weak negative correlation between root weight and cortical necrosis ($r = -0.22$, $P < 0.01$).

Root necrosis ratings for all nematode species averaged 26% (6-62%) for the commercial fields, but nematode population density was correlated only with cortical necrosis ($r = 0.36$, $P < 0.0001$). On farm #10, with just spiral nematodes present, there was no correlation between population density and root weight or external necrosis ratings. Conversely, on farm #14, consisting of burrowing nematodes, population density was strongly correlated with cortical necrosis ratings ($r = 0.71$, $P < 0.02$), but not with external necrosis.

DISCUSSION

The presence of spiral and burrowing nematodes in most commercial banana farms in American Samoa agreed with Grandison's (1996) preliminary survey. Bridge (1988) reported that *H. multicinctus* was the most common banana root-parasitic nematode in the Pacific Islands, especially in the absence of the burrowing nematode. When both are present in an area, it is common to find them together (McSorley and Parrado, 1986), as in this study. The lesion nematode, *Pratylenchus* spp., was absent from all commercial plantings of the Cavendish-type 'Williams'. Both *P. loosi* and *P. gibbicaudatus*, recovered from roots of AAB and ABB *Musa* genotypes, respectively, are new identifications for American Samoa. *Pratylenchus loosi*, commonly associated with damage to tea and coffee (Campos et al., 1990), was extracted from roots of 'Paka Samoa'. This is the second account of *P. gibbicaudatus* in the South Pacific and only the second confirmed isolation from *Musa* spp. worldwide. *Pratylenchus gibbicaudatus* causes a reddish-black cortical necrosis typical of lesion nematodes and was first reported in this area from the Cook Islands on banana, coffee, and eggplant (*Solanum melongena*) (Grandison, 1990).

Population densities of spiral nematode were five times greater on average than population densities of burrowing nematode (Figure 1). The superficial cortical lesions caused by spiral nematodes are considered less severe than burrowing nematode lesions, but they are potential entry points for other soilborne pathogens or saprophytes that can increase root damage.

Few studies have presented data on both burrowing and spiral nematode population densities and differing methods make comparisons with this study difficult. For example, Speijer and Gold (1995) extracted 6,037 spiral nematodes and 2,968 burrowing nematodes per 100 g of roots after 16-20 hours incubation, and Speijer and Ssango (1999) reported an average of 8,935 spiral nematodes and 10,317 burrowing nematodes per 100 g of roots following a 24-hour extraction. Marin et al. (2000) recorded only burrowing nematodes and after 7 days estimated 24,745 per 100 g of roots.

Variability in nematode population densities among and within farms on Tutuila agreed with a report by Fogain (2001). His estimated numbers in Cameroon ranged from 5,000 and 150,000 burrowing nematodes per 100 g of roots on farms located in the center of the country, and from 800 to 172,000 lesion nematodes (*Pratylenchus goodeyi*) per 100 g of roots in the highlands. Such variation in population densities is common under field conditions. This variation is due to an aggregated (contagious) nematode distribution and the influence of factors such as soil heterogeneity, root status, interactions with other organisms, and intra- and interspecific nematode competition (Barker et al., 1985; McSorley and Parrado, 1986; Gowen and Queneherve, 1990; Queneherve, 1993; Bridge and Gowen, 1993; Price and McLaren, 1995; Marin et al., 1998). Seasonal variations in temperature and precipitation (McSorley and Parrado, 1986) probably had a minimal effect on nematode population density. In this climate soil temperatures are relatively constant and soils drain rapidly (Soil Conservation Service, 1984). However, shallow soil, poor drainage, or high water tables may have affected the nematode populations in small areas of some fields. Differences in cultivar susceptibility (Speijer and Gold, 1995) were not a factor in our survey of commercial farms, but variability in aggressiveness among nematode isolates needs to be considered (Fallas et al., 1995; Marin et al., 1999, 2000).

Positive correlations between nematode population densities and root necrosis were lower than expected. This may have been due in part to inclusion of necrotic roots in sample estimates and extractions (Price and McLaren, 1995). Since the nematodes recovered in this survey are all obligate parasites requiring living tissue, roots with a higher percentage of necrosis should have fewer nematodes than roots with less necrosis (Mateille, 1992; Bridge and Gowen, 1993). To avoid "false-positives", Price and McLaren (1995) suggest discarding severely damaged roots from samples before nematode extraction. For example, Speijer and Ssango (1999) estimated the number of dead and functional roots in samples of seven *Musa* cultivars, but estimated cortical necrosis and extracted nematodes only from functional roots. In their study, the percentage of dead roots (= external necrosis) and necrotic roots (= cortical necrosis) vs. population densities of spiral and burrowing nematodes were strongly correlated ($r = 0.84$ to 0.94, $P < 0.001$).

Marin et al. (1998) tested FHIA-01 and FHIA-21 hybrids, both derived from the burrowing nematode resistant parent SH-3142 (Rowe and Rosales, 2000), against a susceptible control ('Grande Naine', *Musa* AAA, Cavendish subgroup) and found no statistical difference. In this study, FHIA-01 had 60 times fewer burrowing nematodes than 'Williams' growing in the same field; the spiral nematode population densities were similar. The newly introduced FHIA-25, however, had the lowest nematode population densities of any variety tested. Based on results from this study, FHIA-25 is a promising source of germplasm for resistance to the burrowing nematode in American Samoa.

Damage thresholds are difficult to apply to bananas because of the numerous factors affecting nematode populations on a perennial crop (Gowen, 1995). Reported thresholds vary from 1,000 burrowing nematodes per 100 g of roots in W. Africa, to 20,000 per 100 g of roots in Costa Rica (Gowen and Queneherve, 1990). Taking this disparity into consideration, Gowen and Queneherve (1990) proposed that crop losses will occur at nematode population densities greater than 2,000 per 100 g of roots. This level was surpassed on all banana farms in American Samoa. Considering the amount of root damage that was associated with these populations, the need for nematode management is clearly indicated. Management options for American Samoa include propping of fruiting plants to prevent toppling, and ratoon management, mulches, and fertilization to increase plant vigor and root production (Gowen, 1995; Whitehead, 1998). Exclusion is the best means of nematode control and disease-free tissue culture plantlets are the first choice for establishing new plantings.

This study confirmed the presence of spiral and burrowing nematodes at levels high enough to affect yield. The identification of two lesion nematodes not commonly reported on banana and causing considerable root damage suggests future problems for local growers. This information illustrates the need for continued management and scouting efforts. It also provides a baseline for further studies on the relationship between nematode population densities and yield.

ACKNOWLEDGMENTS

I am grateful to D. Schmitt, G. Grandison, and B. Sipes for manuscript review, and to G. Grandison for his support throughout the study. This work was funded by USDA CSREES, Project No. SAM-026.

LITERATURE CITED

ARAYA, M., A. VARGAS, and A. CHEVES. 1999. Nematode distribution in roots of banana (*Musa* AAA cv. Valery) in relation to plant height, distance from the pseudostem and soil depth. Nematology 1:711-716.

BARKER, K. R., D. P. SCHMITT, and J. P. NOE. 1985. Role of sampling for crop-loss assessment and nematode management. Agriculture, Ecosystems and Environment 12:355-369.

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

BRIDGE, J., and R. GOWEN. 1993. Visual assessment of plant parasitic nematode and weevil damage on bananas and plantain. Pp. 147-154 *in* C. S. Gold, and B. Gemmill, eds. Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases, Cotonou, Benin, Africa.

CAMPOS, V. P., P. SIVAPALAN, and N. C. GNANAPRAGASAM. 1990. Nematode parasites of coffee, cocoa and tea. Pp. 387-430 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CAB International, Wallingford, UK.

DANIELLS, J. 1995. Illustrated guide to the identification of banana varieties in the South Pacific, Monograph No. 33. Australian Centre for International Agricultural Research, Canberra, Australia.

DAVIDE, R. G. 1995. Overview of nematodes as a limiting factor in *Musa* production. Pp. 27-31 *in* E. A. Frison, J-

P. Horry, and D. DeWaele, eds. New Frontiers in Resistance Breeding for Nematode, *Fusarium* and Sigatoka. International Network for the Improvement of Banana and Plantain, Montpellier, France.

FALLAS, G. A., J. L. SARAH, and M. FARGETTE. 1995. Reproductive fitness and pathogenicity of eight *Radopholus similis* isolates on banana plants (*Musa* AAA cv. Poyo). Nematropica 25:135-141.

FIRMAN, I. D. 1975. Plant diseases in the area of the South Pacific Commission, 2. American Samoa. South Pacific Commission, Noumea, New Caledonia.

FOGAIN, R. 2001. Nematodes and weevil of bananas and plantains in Cameroon: occurrence, importance and host susceptibility. International Journal of Pest Management 47:201-205.

FOGAIN, R., and S. R. GOWEN. 1997. Damage to roots of *Musa* cultivars by *Radopholus similis* with and without protection of nematicides. Nematropica 27:27-32.

GOWEN, S. R. 1995. Pests. Pp. 382-402 *in* S. R. Gowen, ed. Bananas and Plantains. Chapman and Hall, London, UK.

GOWEN, S. R., and J. E. EDMUNDS. 1973. An evaluation of some simple extraction techniques and the use of hydrogen peroxide for estimating nematode populations in banana roots. Plant Disease Reporter 57:678-681.

GOWEN, S., and P. QUENEHERVE. 1990. Nematode parasites of bananas, plantains and abaca. Pp. 431-460 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CAB International, Wallingford, UK.

GRANDISON, G. S. 1990. Report on a survey of plant parasitic nematodes in the Cook Islands (Southern Group). South Pacific Commission, Noumea, New Caledonia.

GRANDISON, G. S. 1996. Plant-parasitic nematodes of American Samoa, Technical Paper No. 205. South Pacific Commission, Noumea, New Caledonia.

HOOPER, D. J. 1990. Extraction and processing of plant and soil nematodes. Pp. 45-68 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CAB International, Wallingford, UK.

JONES, D. R. 2000. Introduction to banana, abaca and enset. Pp. 1-36 *in* D. R. Jones, ed. Diseases of Banana, Abaca and Enset. CAB International, Wallingford, UK.

MARIN, D. H., T. B. SUTTON, K. R. BARKER, D. T. KAPLAN, and C. H. OPPERMAN. 1998. Burrowing nematode resistance of black Sigatoka resistant banana hybrids. Nematropica 28:241-247.

MARIN, D. H., K. R. BARKER, D. T. KAPLAN, T. B. SUTTON, and C. H. OPPERMAN. 1999. Aggressiveness and damage potential of Central American and Caribbean populations of *Radopholus* spp. in banana. Journal of Nematology 31:377-385.

MARIN, D. H., K. R. BARKER, D. T. KAPLAN, T. B. SUTTON, and C. H. OPPERMAN. 2000. Development and evaluation of a standard method for screening for resistance to *Radopholus similis* in bananas. Plant Disease 84:689-693.

MATEILLE, T. 1992. Comparative development of three banana-parasitic nematodes on *Musa acuminata* (AAA group) cvs. Poyo and Gros Michele vitro-plants. Nematologica 38:203-214.

MCSORLEY, R. 1987. Extraction of nematodes and sampling methods. Pp. 13-47 *in* R. H. Brown, and B. R. Kerry, eds. Principles and Practices of

Nematode Control in Crops. Academic Press, Marrickville, NSW, Australia.

MCSORLEY, R., and J. L. PARRADO. 1986. *Helicotylenchus multicinctus* on bananas: An international problem. Nematropica 16:73-91.

NATIONAL AGRICULTURAL STATISTICS SERVICE (USDA). 1999. Census of Agriculture—American Samoa. <http://www.nass.usda.gov/census97/amsamoa.htm> Accessed 7 September 2002.

PLOETZ, R. C. 2001. Black Sigatoka of banana. The Plant Health Instructor. On-line doi: 10.1094/PHI-I-2001-0126-01. Accessed 28 January 2004.

PRICE, N. S, and C. G. MCLAREN. 1995. Techniques for field screening of *Musa* germplasm. Pp. 87-107 *in* E. A. Frison, J-P. Horry, and D. DeWaele, eds. New Frontiers in Resistance Breeding for Nematode, *Fusarium* and Sigatoka. International Network for the Improvement of Banana and Plantain, Montpellier, France.

QUENEHERVE, P. 1993. Banana phenology in relation to phytophagous nematodes. Pp. 218-230 *in* C. S. Gold, and B. Gemmill, eds. Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases, Cotonou, Benin, Africa.

ROWE, P. R., and F. E. ROSALES. 2000. Conventional banana breeding in Honduras. Pp. 435-449 *in* D. R. Jones, ed. Diseases of Banana, Abaca and Enset. CAB International, Wallingford, UK.

SARAH, J. L. 1993. Estimation of nematode infestation in banana. Pp. 209-217 *in* C. S. Gold, and B. Gemmill, eds. Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases, Cotonou, Benin, Africa.

SIDDIQI, M. R. 1973. *Helicotylenchus multicinctus*, C.I.H. Descriptions of plant-parasitic nematodes, Set 2, No. 23. Commonwealth Institute of Helminthology, St. Alban's, UK.

SOIL CONSERVATION SERVICE (USDA). 1984. Soil survey of American Samoa. US Government Printing Office, Washington, DC, USA.

SPEIJER, P. R., and C. S. GOLD. 1995. *Musa* root health assessment: A technique for the evaluation of *Musa* germplasm for nematode resistance. Pp. 62-78 *in* E. A. Frison, J-P. Horry, and D. DeWaele, eds. New Frontiers in Resistance Breeding for Nematode, *Fusarium* and Sigatoka. International Network for the Improvement of Banana and Plantain, Montpellier, France.

SPEIJER, P. R., and F. SSANGO. 1999. Evaluation of *Musa* host plant response using nematode densities and damage indices. Nematropica 29:185-192.

WHITEHEAD, A. G. 1998. Semi-endoparasitic nematodes of roots (*Helicotylenchus*, *Rotylenchulus* and *Tylenchulus*). Pp. 90-137 *in* Plant Nematode Control. CAB International, Wallingford, UK.

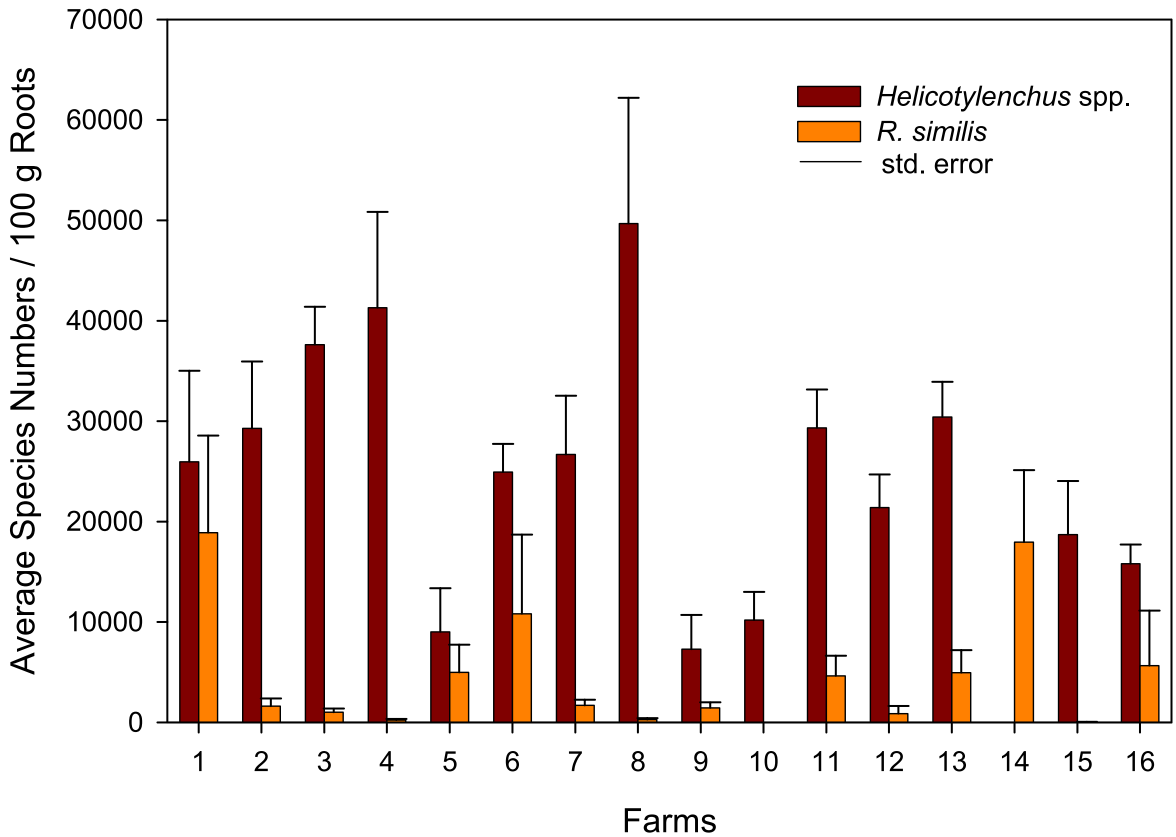

Figure 1. Average population densities of spiral (*Helicotylenchus* spp.) and burrowing (*Radopholus similis*) nematodes from16 banana farms on Tutuila, American Samoa. Only spiral nematodes were extracted from farm #10 and burrowing nematodes from farm #14.