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# Plant-parasitic Nematodes in the Waimanalo, Hawaii Irrigation System from Watershed to Farm[1]

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*Abstract:* Nematode occurrence at specific locations throughout a water catchment-irrigation system was determined. Soil samples were collected from five water source locations on the slopes of Olomana Mountain and Maunawili Valley and from about 40 plant species on 18 farms (56 ha of 480 ha irrigated by the reservoir). Water was sampled from the catchment reservoir at 0.3 m, 9 m, and 18 m (bottom). A farm irrigated with potable water was sampled and compared to areas of the same farm irrigated from the reservoir. Nematodes present in soil from the mountain and farms were root-knot (*Meloidogyne* spp.), lesion (*Pratylenchus* spp.), reniform (*Rotylenchulus reniformis*), stunt (*Tylenchorhynchus* sp.), ring (*Criconema* spp.), dagger (*Xiphinema* sp.), spiral (*Helicotylenchus* sp.), *Tylenchus* sp., *Aphelenchus* sp., and pin (*Paratylenchus* sp.) nematodes. The economically important genera *Rotylenchulus, Meloidogyne,* and *Pratylenchus* occurred in very low numbers (10, 41, and 10/250 $cm^3$ soil, respectively) and in low frequency (10%, 25%, and 8% of the samples, respectively) in the mountain samples compared with high numbers (170–895/250 $cm^3$ soil) from farms. Frequency of occurrence over all farms was near 40% for *Meloidogyne* and 80% for *Rotylenchulus.* No nematodes were detected in water from the reservoir. One sample from the outlets contained two specimens of plant-parasitic nematodes. The population densities of nematodes were not different between the soil samples collected from crops irrigated by potable or reservoir water.
*Key words:* *Criconema,* dagger nematode, Hawaii, *Helicotylenchus,* irrigation, lesion nematode, *Meloidogyne,* nematode, *Paratylenchus,* pin nematode, *Pratylenchus,* reniform nematode, ring nematode, root-knot nematode, *Rotylenchulus,* spiral nematode, watershed, *Xiphinema.*

Plant-parasitic nematodes damage agricultural crops throughout the world, especially in the tropics where environmental factors favor survival and dispersal of nematodes (Luc et al., 1990; Noe and Sikora, 1990). Reniform (*Rotylenchulus reniformis*), root-knot (*Meloidogyne* spp.), and lesion (*Pratylenchus spp.*) nematodes are of significant economic importance in the tropics (Bridge, 1988; Caswell et al., 1990; Davide, 1988; Taylor, 1976). These nematodes have broad host ranges (Bridge, 1988; Davide, 1988) and are easily distributed by movement of soil and plant materials (Noe and Sikora, 1990). Soil and plant movement can be accomplished by animals, machinery, wind, water, and activities of human beings. Erosion is considered to be important in nematode dissemination (DuCharme, 1955; Faulkner and Bolander, 1966; Godfrey, 1923; Rostombekova, 1957; Thompson et al., 1949). High population densities of plant-parasitic nematodes can be present in the surface soil, which is easily eroded; therefore, irrigation water also can be a source of contamination. Faulkner and Bolander (1966), Godfrey (1923), Rostombekova (1957), and Thompson et al. (1949) found that the distribution of nematodes from reservoirs was somewhat different from the distribution of nematodes in rivers, canals, and other flowing water systems.

Two previous preliminary investigations have been made in Hawaii on nematode movement in small catchment-irrigation systems. In one system, water was recycled from a reservoir, through plant beds to a catchment, and then returned to the reservoir. Irrigation of fumigated beds in this system resulted in immediate reinfestation of the plant bed with *R. reniformis, M. javanica,* and *M. incognita* (Schmitt, unpubl.). In the second system, run-off water from the landscape was used to fill a small reservoir. A pipe from this reservoir led directly to a greenhouse. Water collected from the outlet in the greenhouse contained *Helicotylenchus* sp. (Schmitt, unpubl.). These data raise concerns about using reservoirs as sources of irrigation water because of the potential of dispersing plant-parasitic nematodes originating at the source (the mountain) to growers' fields. The objectives of this research were to: (i) determine the kinds and numbers of nematodes from the five catchment areas above Maunawili Valley, the reservoir, and the outlets from the reservoir; and (ii) characterize nematode populations on farms prior to using water from the reservoir for irrigation and then 5 to 6 months later after the farms were irrigated with water from the reservoir.

## Materials and Methods

A 230-million-liter reservoir, completed in 1994, provides irrigation water for 480 ha of farmland in Waimanalo, Oahu, Hawaii. The catchment-irrigation system consists of five water collection sites on the slopes of Olomana Mountain and Maunawili Valley, from which water is discharged into the reservoir some 2 km away. Water is released through four outlets to farms, the most distant user being 3 km from the reservoir.

Soil samples were collected from the catchment areas

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of the mountain and from the farms. Eight to 10 samples were arbitrarily obtained from each of the five water collection sites (mountain slopes and valleys) at the mountain. Each sample consisted of six to eight trenching shovels of soil (200–300 $cm^3$), which were composited. Soil samples were collected from 12% of the commercial fields and the University of Hawaii's Waimanalo Experiment Station, representing 56 ha of 480 ha serviced by the system. The average farm size was 3 ha. Two sets of samples were collected from the selected farms—one before water from the new reservoir was used (October to December 1994) and another set 5 to 6 months after reservoir water was used (May to June 1995). About 40 different plant species were represented in the sampling. The dominant crops were banana, sweet corn, ginger, heliconia, and papaya. Most other crops planted on farms using water from the Waimanalo irrigation system are grown in small plots of land. Examples of these limited production crops are: cucumber, chrysanthemum, croton, guava, a variety of herbs, longbean, neem, several varieties of palms, plumeria, vegetable soybean, tuberose, and ti. Samples were collected in a systematic zigzag pattern from the farms. Three to five samples (depending on the field size), each consisting of a composite of 8 to 10 shovels (800–1000 $cm^3$) of soil, were collected from each plant species. As a control for water source, a field of corn and papaya on the Experiment Station was irrigated from the reservoir and another field with these crops was irrigated with potable water. Nematodes were extracted from 250-$cm^3$ subsamples (one subsample/composite sample) by a combination of elutriation (Byrd et al., 1976) and centrifugal flotation (Jenkins, 1964). Nematodes were identified to genus using morphological characteristics, and the numbers were determined.

Water samples were collected once from the reservoir and four times from the outlets. The reservoir is 300 m × 200 m × 18 m deep with 30° slopes on the sides. Transects were established at 50-m intervals across the reservoir. Three locations were selected on each transect: the middle of the transect and at the point on each side of the reservoir where the side met the bottom. Four liters of water was collected with a 1-liter water sampler at 0.3, 9, and 18-m depths from each site on the transects. Additional water samples were collected from the four outlets servicing the farms and from one designed for releasing overflow water. The outlets were opened to allow a flow of 2.5 liters/minute. The water was collected for 4 (first sampling) or 8 minutes (all subsequent samples) per replicate sample. Three replicate samples were collected at weekly intervals for 4 weeks. The samples were passed through a 20-μm-pore screen to collect nematodes. Nematodes were classified as either microbivorous or plant-parasitic using morphological characteristics, and the plant-parasitic specimens were identified to genus.

## Results and Discussion

Nine genera of plant-parasitic nematodes were recovered from the slopes of Olomana Mountain and Maunawili Valley (Table 1). The economically important genera *Rotylenchulus, Meloidogyne,* and *Pratylenchus* occurred in very low numbers (10, 41, and 10 specimens/250 $cm^3$ soil, respectively) and in relatively low frequency (10%, 25%, and 8%, respectively). *Criconema* spp. occurred in the highest numbers from the mountain samples (145/250 $cm^3$ soil). *Tylenchorhynchus spp.* occurred in the highest frequency (55%) of these nine genera.

Plant-parasitic nematodes were not detected in water from the reservoir. Very low numbers of microbivorous nematodes were found from the 0.3 and 9-m depths of the reservoir; none were recovered at 18-m deep. The total of the replications produced 4 liters of water. Because the reservoir holds 230 million liters, considerably more water per sample may be needed to detect the presence of plant-parasitic nematodes.

Microbivorous nematodes were extracted from all outlets at all sampling times. However, only one specimen of *Meloidogyne* and one of *Tylenchorhynchus* were collected from one outlet after a heavy rain. These two specimens may have washed into the outlet through runoff water. In a preliminary evaluation of another reservoir, which was filled only with run-off water, *Helicotylenchus* sp. was readily detected at the outlet in a greenhouse (Schmitt, unpubl.).

Ten genera of plant-parasitic nematodes were found in soil from the farms (Table 2). Pin nematode (*Paratylenchus* sp.) and reniform nematode (*Rotylenchulus reniformis*) occurred in greatest abundance (1,023 and 895 nematodes/250 $cm^3$ soil in the initial sampling and 708 and 913 nematodes/250 $cm^3$ soil in the second sampling, respectively). *Rotylenchulus, Meloidogyne,* and *Helicotylenchus* occurred in the highest frequency among the plant species sampled, probably because these three genera have wide host ranges.

Irrigation water from the Waimanalo irrigation system is not a likely source of nematodes for the farms.

Table 1. Nematodes detected in soil samples ($n = 43$) from the slopes of Olomana Mountain and Maunawili Valley near Waimanalo, Oahu, Hawaii.

| Genus | Frequency of detection (%) | Average number of nematodes/250 $cm^3$ |
|---|---|---|
| *Paratylenchus* | 3 | 15[a] |
| *Tylenchus* | 5 | 15 |
| *Pratylenchus* | 8 | 10 |
| *Xiphinema* | 8 | 17 |
| *Rotylenchulus* | 10 | 10 |
| *Criconema* | 23 | 145 |
| *Helicotylenchus* | 23 | 54 |
| *Meloidogyne* | 25 | 41 |
| *Tylenchorhynchus* | 55 | 41 |

[a] Values are means of the samples for each genus.

TABLE 2. Nematodes recovered from agricultural land ($n$ = 228) before and after land was irrigated with water from the Waimanalo irrigation system in Waimanalo, Oahu, Hawaii.

| Genus | Nematode/250 $cm^3$ | | % of samples | | % of hosts ($n$ = 40) | |
|---|---|---|---|---|---|---|
| | Before[a] (1994) | After[b] (1995) | Before (1994) | After (1995) | Before (1994) | After (1995) |
| *Aphelenchus* | 21 | 29 | 6 | 10 | 15 | 23 |
| *Tylenchorhynchus* | 32 | 51 | 6 | 6 | 13 | 9 |
| *Xiphinema* | 90 | 0 | 2 | 0 | 5 | 0 |
| *Tylenchus* | 108 | 10 | 7 | 1 | 23 | 3 |
| *Helicotylenchus* | 140 | 128 | 83 | 49 | 90 | 60 |
| *Criconema* | 170 | 388 | 7 | 5 | 15 | 14 |
| *Pratylenchus* | 170 | 53 | 15 | 5 | 20 | 9 |
| *Meloidogyne* | 284 | 187 | 37 | 41 | 78 | 46 |
| *Rotylenchulus* | 895 | 913 | 72 | 87 | 88 | 97 |
| *Paratylenchus* | 1,023 | 708 | 16 | 15 | 25 | 26 |

[a] Before = samples were collected before use of the reservoir for irrigation.
[b] After = samples were collected about 5 to 6 months after irrigation with reservoir water.

The reniform nematode was found in very low numbers and frequency from the mountain but occurred in large numbers and high frequency on the farms. This conclusion is strengthened by the fact that high numbers of several plant-parasitic species existed on the farms before they were irrigated from the reservoir. In addition, no differences occurred in numbers of *R. reniformis* collected from fields irrigated with potable water and those irrigated with water from the reservoir. For example, on papaya, 1,470 reniform nematodes were collected from the reservoir irrigated fields and 1,728 from fields irrigated with potable water from October to December 1994. The numbers of this nematode were 530 in May 1994 and 943 in June 1995 from fields irrigated with reservoir water and potable water, respectively. In the comparison of nematode populations on corn, numbers were low in all fields regardless of the water source.

The design of the Waimanalo irrigation system seems to minimize the potential introduction of plant-parasitic nematodes onto the land it will irrigate. The water in the reservoir is relatively clear. In addition, the filtration system appears to prevent or slow movement of nematodes to the user. Thus, from a practical point of view, nematode introduction from the Waimanalo irrigation system usually will not be an issue, allowing growers to focus their management of nematodes to those already present on each farm.

## Literature Cited

Bridge, J. 1988. Plant-parasitic nematode problems in the Pacific islands. Journal of Nematology 20:173–183.

Byrd, D. W., Jr., K. R. Baker, H. Ferris, C. J. Nusbaum, W. E. Griffin, R. H. Small, and C. A. Stone. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8:206–212.

Caswell, E. P., J. L. Sarah, and W. J. Apt. 1990. Nematode parasites of pineapple. Pp. 519–538 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant parasitic nematodes in subtropical and tropical agriculture. United Kingdom: C.A.B. International Institute of Parasitology.

Davide, R. G. 1988. Nematode problems affecting agriculture in the Philippines. Journal of Nematology 20:214–218.

DuCharme, E. P. 1955. Sub-soil drainage as a factor in the spread of the burrowing nematode. Proceedings of the Florida State Horticulture Society 68:29–31.

Faulkner, L. R., and W. J. Bolander. 1966. Occurrence of large nematode populations in irrigation canals of South Central Washington. Nematologica 12:591–600.

Godfrey, G. H. 192. The eelworm diseases: A menace to alfalfa in America. Washington DC: U.S. Department of Agriculture.

Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

Luc, M., J. Bridge, and R. A. Sikora. 1990. Reflections on Nematology in subtropical and tropical agriculture. Pp. xi-xvii *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant parasitic nematodes in subtropical and tropical agriculture. United Kingdom: C.A.B. International Institute of Parasitology.

Noe, J. P., and R. C. Sikora. 1990. Effects of tropical climates on the distribution and host-parasite relationship of plant-parasitic nematodes. Pp. 583–597 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant parasitic nematodes in subtropical and tropical agriculture. United Kingdom: C.A.B. International Institute of Parasitology.

Rostombekova, N. V. 1957. The significance of water and vegetables in the distribution of helminthiasis. Soobsbcbeniya Akademic Nauk Gruzinskoi SSR 18:467–472.

Taylor, D. P. 1976. Plant nematode problems in tropical Africa. Helminthological Abstracts Series B, Plant Nematology 45:269–284.

Thompson, H. W., A. Roebuck, and B. A. Cooper. 1949. Floods and the spread of potato root eelworm. Journal of the Ministry of Agriculture 56:109–114.