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Nematodes Associated with Dieback Disease of Cranberries[1]

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Abstract: *Hemicycliophora ritteri* and *Paratrichodorus minor* were associated in high numbers with a previously unknown "dieback disease" of cranberry. Chemical treatment with nematicides and fungicides failed to control this disease. There were no correlations ($P \leq 0.05$) among nematode numbers and yields of good or rotten berries, and with disease ratings. Nematodes were apparently not involved in the etiology of this dieback disease.

Key words: cranberry, cranberry dieback, *Hemicycliophora ritteri*, nematode, *Paratrichodorus minor*, *Vaccinium macrocarpon*.

During the 1980s, a severe dieback of cranberry, *Vaccinium macrocarpon* Ait, was observed on several bogs in southern New Jersey. This previously undescribed "dieback disease" occurred in scattered patches, irregular in outline. Most diseased areas were from 2 to 190 m^2, although a few were considerably larger in size. The central zone contained bare ground and weeds but usually few or no cranberry vines. This central zone was surrounded by a fringe approximately 1 m wide of dying, often browning cranberry vines intermixed with weeds. Just beyond this fringe in a band ≥ 1 m wide, tops of vines appeared normal, but roots were blackened and rotting. Plants in this band could be lifted like a "rug" using al flat-bladed shovel. Because of accelerated senescence, cranberry vines in the diseased areas became reddish during early fall. Healthy plants surrounded these dieback areas.

High numbers of a sheath nematode, *Hemicycliophora ritteri* Brizuela, 1963, and a stubby root nematode, *Paratrichodorus minor* (Colbran, 1956) Siddiqi, 1974, were extracted from soil collected from the periphery of dieback disease areas and among declining, thinning cranberry vines. Other nematodes sporadically present in very low numbers were *Helicotylenchus* sp., *Tylenchorhynchus* sp., and *Criconemella* sp. Total nematode numbers in areas adjacent to cranberry dieback often exceeded 3,000/500 cm^3 soil.

Because high numbers of nematodes were associated with the dieback disease, it was suspected that nematodes might be responsible for or involved in its etiology. Experimental plots were therefore established in affected areas to investigate this possibility.

MATERIALS AND METHODS

Experimental protocol: Three experiments were conducted during a 3-year (1983–1985) period on plots placed in Lees's cranberry bogs (Chatsworth, NJ). Several bogs contained both normal, vigorously growing vines and also diseased areas. In semipermanent plots, steel surveyor tacks were used to delineate the corners before flooding the bogs over the winter. These pins were readily relocated with a metal detector the following spring when the water was drawn off (7).

A disease rating was used to estimate vine discoloration and amount of dieback (mortality). The rating scale ranged from 1 to 5, where 1 = normal, green-colored plants and no apparent brown, blackened, or reddish-colored vines; 2 = light dieback with some foliage discoloration (< 25%); 3 = moderate dieback, some thinning and discoloration of foliage (25 to < 50%); 4 = heavy dieback with dead, blacked foliage and missing plants (50 to < 75%); and 5 = severe dieback, bare soil, and foliage of residual plants mostly discolored or dead (≥ 75%). A second disease rating system utilized percentage of plots covered by healthy cranberry vines and foliage.

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At harvest, all fruits were removed from 0.28 m^2 sample areas, and good and rotten berries were separated before weighing. All plots were sampled to a depth of about 25 cm with 1.9-cm-d soil cores. Soil was mixed and 250 cm^3 was processed by the sugar flotation-centrifugation method using a 38-μm-pore sieve (6). Weeds were wipe-treated with 20% aqueous glyphosate to reduce weed competition to cranberry plants.

Experiment 1: An experimental field trial using nematicidal and fungicidal chemicals was established (1983) in Bog 8 overlapping and edge of a large diseased area. Plots (0.915 m × 1.83 m) were divided into two vegetation conditions. The fringe of dead and dying cranberry vines was designated Vegetation Condition 1. Vegetation Condition 2 referred to the outer belt of normal-appearing plants that had rotting roots. Half of a plot (0.84 m^2) overlapped each vegetation condition, and every half was sampled for nematodes and harvested for yields separately. Soil samples, made up of nine cores from each vegetation condition, were taken from every plot prior to applying treatments and again just prior to harvest, which occurred in mid- to late October. During the second year, no chemicals were applied, but all plots were again sampled for nematodes during mid-summer and just prior to harvest. Numbers and weights of both good and rotten fruit were determined over two growing seasons, because fruit buds set during one year produce berries the following year.

A total of seven chemical treatments and a control were replicated four times for a total of 32 plots for each vegetative condition. Treatments using nematicides were carbofuran (3.56 kg a.i./ha), oxamyl (4.45 kg a.i./ha), fenamiphos (8.90 kg a.i./ha), and ethoprop (8.90 kg a.i./ha). Fungicidal treatments included metalaxyl (1.33 kg a.i./ha), benomyl (0.44 kg a.i./ha), and captafol + mancozeb (2.22 + 1.78 kg a.i./ha). The nematicides were applied just once (early July), metalaxyl was applied twice (once each during July and September), and the other fungicides were applied three times (early July, late July, and in early September). All chemicals were applied in water at 2,805 liters/ha.

Chemical treatments, numbers of nematodes, disease ratings, and yields consisting of the numbers and weights of good and rotten berries were analyzed by analysis of variance followed by Duncan's multiple range test at $P \leq 0.05$. Correlation coefficients (r) were calculated among numbers of the predominant species of plant-parasitic nematodes, percentage of ground covered by healthy cranberry vines, a dieback disease rating, and with the numbers and weights of good and rotten berries. Nematode numbers are reported in the text as mean ± standard deviation.

Experiment 2: A second set of experimental plots (Bog 6) was established in 1984 in an area of dieback, and correlation coefficients were calculated between nematode numbers, disease ratings, and yields as performed in Experiment 1. The predominant species was *P. minor,* with *H. ritteri* absent from most plots or occurring in very low numbers. Thirty 5-m^2 plots were established (1.58 × 3.16 m). Sixteen soil cores were taken from each plot prior to harvest (October 1984 and 1985) for estimating nematode numbers.

Experiment 3: The final experiment was set up in 1985 to determine if numbers of *H. ritteri* had an effect on cranberry yields in a normally growing, dieback-disease-free bog (Bog 11). Twenty 0.84-m^2 plots were placed at random throughout Bog 11, and after harvesting the berries, 16 soil cores/plot were taken. Correlation coefficients were calculated only between nematode numbers and yields.

RESULTS

Experiment 1: No phytotoxicity was noted after chemical applications to experimental plots in Bog 8. Nematicidal chemical treatments did not improve yields (Table 1) or modify dieback disease ratings. Some of the fungicidal treatments did have an effect ($P \leq 0.05$) on the number and weight of good and rotten berries. No differences ($P \leq 0.05$) in nematode numbers were not-

TABLE 1. The effects of chemical treatments on yield of usable, nonrotted cranberries.

Treatment	Mean yield (g/m^2)			
	Vegetative Condition 1		Vegetative Condition 2	
	1983	1984	1983	1984
Carbofuran	114 ab†	456 ab	543 a	1,463 a
Oxamyl	63 ab	203 ab	402 a	1,087 ab
Fenamiphos	100 ab	338 ab	384 a	1,349 a
Ethoprop	42 ab	99 b	242 a	631 ab
Metalaxyl	69 ab	182 ab	214 a	454 b
Benomyl	86 ab	199 ab	544 a	1,317 a
Captafol + mancozeb	174 a	619 a	520 a	1,444 a
None (control)	31 b	208 ab	411 a	778 ab

† Means in columns followed by the same letter are not different ($P \leq 0.05$), according to Duncan's multiple range test.

ed among treatments as compared with the controls.

Mean numbers of *H. ritteri* were not significantly different between spring (580 ± 705/500 cm^3 soil) and fall (412 ± 486/500 cm^3 soil) and remained at about the same level over the 2-year period. Because some female *H. ritteri* always had eggs *in utero*, it is believed that reproduction occurred continuously during the growing season. *Hemicycliophora ritteri* was detected in 92% of the plots during the first year and ranged from 0 to 3,750 nematodes/500 cm^3 soil. The following year, they were detected in only 80% of the plots, with a range of 0 to 2,617 nematodes/500 cm^3 soil.

Paratrichodorus minor increased, but not significantly, in overall numbers from 88 ± 120/500 cm^3 soil to 188 ± 264/500 cm^3 soil between October 1983 and October 1984. This nematode was detected in 75% and 85% of the plots, respectively, and ranged from 0 to 530 nematodes/500 cm^3 soil during the first year, but 0 to 1,400/500 cm^3 soil the following year. *Tylenchorhynchus* sp. and *Helicotylenchus* sp. were present in low numbers/500 cm^3 soil in less than 25% of the plots.

There was no significant correlation ($P \leq 0.05$) between disease rating and numbers of *H. ritteri* ($r = -0.18$), *P. minor* ($r = 0.29$), or total numbers of plant-parasitic nematodes ($r = 0.01$) in Vegetation Condition 2. Dieback disease rating correlated ($P \leq 0.05$) with numbers and weights of rotten berries in both Vegetation Conditions 1 and 2. In Vegetation Condition 1 plots, where far fewer cranberry vines were found, dieback disease rating correlated ($P \leq 0.05$) with the total number of nematodes and with the number of *P. minor*, as well as with the numbers and weights of rotting berries. In Vegetation Condition 2, the number of *H. ritteri* correlated ($P \leq 0.05$) with the number ($r = 0.37$) and weight ($r = 0.37$) of good berries and number ($r = 0.38$) and weight ($r = 0.41$) of rotten berries. Similar positive correlations ($P \leq 0.05$) occurred between the total number of nematodes or the number of *H. ritteri* with berry yield in Vegetation Condition 1. Mean weight and the number of good berries harvested during the second year were 1,064 ± 596 g/m^2 and 1,181 ± 649 berries/m^2, respectively (Vegetation Condition 2), whereas Vegetation Condition 1 areas produced only 288 ± 315 g/m^2 and 326 ± 319 berries/m^2. Data from Vegetative Condition 1 plots were of little value because mean plot coverage was only 45%, whereas Vegetation Condition 2 plots averaged 77% cranberry vine coverage. Across all plots, a negative correlation ($r = -0.45, P < 0.01$). existed between numbers of *H. ritteri* and *P. minor.*

Experiment 2: Numbers of *P. minor* in Bog 6 ranged from 6 to 1,106 nematodes/500 cm^3 of soil, with a mean of 296 ± 51/500 cm^3. Only an occasional *H. ritteri* was present. Contrary to what is normally observed for *P. minor*, only juveniles were present during the summer; males were first observed during September, and females appeared in October. Although juveniles were also present during late fall, spring populations consisted predominately of juveniles, along with relatively few females. Eggs and/or juveniles apparently represented the main overwintering stages in flooded bogs. Numbers of *P. minor* were correlated neither ($P \leq 0.05$) with disease rating nor with yields of good or rotten berries (23% rotten berries). Mean yield of good berries was 787 ± 595 g/m². Disease rating was highly correlated ($P < 0.0001$) with yield ($r = -0.71$). At Disease Rating 1 or no dieback, yield was 1,645 g/m², but when dieback was greater than 75% (Disease Rating 5), yield was only 200 g/m².

Experiment 3: The final experiment was set up to correlate the relationship of *H. ritteri* to growth parameters in Bog 11, which was producing excellent yields. *Hemicycliophora ritteri* ranged from 2 to 3,160 nematodes/500 cm³ soil, with a mean number of 1,002 ± 1,038/500 cm³ soil. Very few *P. minor* were present in the plots. The mean weight of total yield was 3,373 ± 540 g/m², with 49 ± 29 g/m² of rotten fruit. Mean number of good berries was 2,870 ± 559/m², and mean number of rotten berries, 43 ± 29/m². There were no significant correlations ($P \leq 0.05$) between nematode numbers and any yield parameter.

Discussion

Relatively little is known about nematode parasites of cranberries (8). *Hemicycliophora ritteri* predominates, but *H. similis* Thorne, 1955, also occurs in New Jersey (3), *H. similis* was identified from Massachusetts (11), and *H. typica* de Man, 1921, was recorded in Wisconsin (1). Several other genera of plant-parasitic nematodes have also been reported, but none have been shown to reduce yields in cranberries. These include *Merlinius joctus* (Thorne, 1949) Sher, 1973, *Atylenchus decalineatus* Cobb, 1913, and species from the following genera: *Aphelenchoides, Ditylenchus, Hoplolaimus, Meloidogyne, Paratylenchus, Pratylenchus, Psilenchus, Tylenchus,* and *Xiphinema* (1,2,9).

Relationships among nematodes and yield parameters on cranberry present some unique problems. Fruit bud set for the current year's crop takes place during the previous year's growth, generally on upright stems, so nematode numbers for the current year may be more important to next year's yields. Runners and upright stems from plants are interwoven into a mat of vegetation, and the main plant roots may be more than a meter distant from where fruit and nematode samples are taken. In addition, cranberry runners in contact with soil often produce adventitious roots, resulting in young plants that remain connected to a mother plant. The problem of associating nematode numbers with parameters separated by time and distance results in a high degree of variability (e.g., the high standard deviations associated with nematode numbers), which obscures trends in statistical analyses. This is why data in some plots were taken over a 2-year period, but results still remained unchanged. No evidence was developed during 3 years of research to connect nematodes to the dieback disease. In addition, no reductions of berry yields in normal cranberry plants were shown to be caused by the relatively high numbers of nematodes present in the bogs.

Nematode control was not very successful. The dieback disease remained unaffected, and yields were not increased by the chemical tests (Table 1). Bird and Jenkins (2) reported, however, the DBCP (dibromochloropropane) and thionazin, both of which are no longer labeled for use, significantly controlled nematodes and that treated plants produced a greater number of uprights and fruit buds (7–44%). Zuckerman (10) also indicated that yield increases resulted from field application of thionazin to cranberries. My data indicated that the presence of relatively high numbers of nematodes had no correlation with cranberry yield. Thus, it seems doubtful that nematodes cause a measurable effect on yield, except possibly during periods of stress. Such stress might be produced by diseases or prolonged drought when irrigation is unavailable. Because seedling and rooted cuttings were injured by nematodes, as shown by Bird and Jenkins (3) and Zuckerman (9), one might speculate that soil fumigation before planting a new bog might lead to an increased rate of root development, faster foliage growth and ground coverage, and perhaps a shorter period of time to full production.

Circular areas containing thinning centers surrounded by fringes of more lush growing vegetation were visible from the dikes of Bog 11 during the final summer of research. Hlubik and Varney (5) reported that a *Phialophora* sp. was associated with these new "dieback disease" areas. Cranberry cuttings developed leaf yellowing, defoliation, desiccation, and necrotic roots, when inoculated with high levels of *Phialophora* sp. (4). Although further research is necessary, this fungus appears to be associated with dieback disease of cranberries.

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