Studies on the Host Range of Xiphinema bakeri and Its Pathogenicity to Raspberry

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Abstract: Thirty-one kinds of plants representing 12 families were tested for host suitability to *Xiphinema bakeri.* Sixteen supported a significant population increase but only members of the Rosaceae and Solanaceae were severely damaged. Eight of the 12 weed species tested were good hosts; Mouse-ear chickweed allowed the greatest population increase of all plants tested. Populations of *X. bakeri* declined under selected members of the Cruciferae and Cucurbitaceae more than in fallow soil after 12 weeks. Numbers of *X. bakeri* as low as one per 5 cc of soil reduced root and top growth of raspberry 40-50%. Where 100 and 500 nematodes per 10.5 cm-diameter pot were used the mean weight of roots was reduced 54% and 77%, the tops 59% and 78% and the linear growth 48% and 78%, respectively. This is the first report of an ectoparasitic nematode pathogenic to raspberry. *Key Words:* Population dynamics, Feeding symptoms.

Xiphinema bakeri Williams was first described as a new species from specimens associated with raspberry (*Rubus idaeus* L.) plants at Hatzic, British Columbia (12). Since that time there have been other reports of this species associated with damage to forest nursery trees (1, 9, 10) and raspberry (6). A nematode survey of the Fraser Valley in southwest British Columbia showed *X. bakeri* to be widespread in the light soils, and native to the area. Populations in commercial berry fields may reach 1000-2000 nematodes per 500 cc of soil; under such conditions the plants became severely stunted and chlorotic. The purposes of this study were to determine (i) the host-status of several common weeds and horticulturally important crops grown in the Valley as an aid in establishing control programs and (ii) the pathogenicity of this species on raspberry under controlled conditions.

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MATERIALS AND METHODS

HOST RANGE: A preliminary study was made to determine the rate of population increase of *X. bakeri* on selected hosts. It was found (author's unpublished observations) that this nematode has a low survival rate when active, extracted nematodes are introduced into sterile soil. For this reason soil naturally infested with the nematode was used in this study. Soil was collected from around the roots of heavily infested raspberry (*Rubus idaeus* cv. 'Willamette') plants, thoroughly mixed, and 180 cc were put into each of 120 7.5-cm plastic pots. Twenty-four single plants each, of tomato (*Lycopersicon esculentum* cv. 'Rutgers'), strawberry (*Fragaria ananassa* cv. 'Northwest'), turnip (*Brassica rapa* cv. 'Aberdeen yellow'), and *Chenopodium amaranticolor* were used. All plants were seeded directly into the naturally infested soil, except strawberry which was started from runners and transplanted after rooted. One set of 24 pots, containing naturally infested soil, was fallowed during the experiment. All pots were maintained under 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature. Soil moisture was maintained by keeping the pots in a shallow pan to which a thin film of water was added every second day. The different treatment groups were maintained in separate pans. Previous observations showed this nematode to be adversely affected by the alternate wetting and drying cycles of normal greenhouse watering. Volunteer weeds were removed daily.

Six pots of each plant species and six pots of fallow soil were examined after 1, 4, 8 and 12 weeks. The nematodes were extracted from the soil by a modification of the Pitcher and Flegg final separation sieve technique (2, 8); 35 and 100-μ sieves were used to concentrate the nematodes. The residue contained on the 100-μ sieve was washed through a 90-μ nylon screen supported by a polyethylene ring. This was immediately placed in a plastic petri-dish bottom containing just enough water to submerge the screen surface. This method allowed recovery and counting of large numbers of active *X. bakeri* whereas other methods yielded low numbers of inactive nematodes.

In a second study, 31 plants (Table 1) representing 12 families were tested for suitability as hosts of *X. bakeri*. In this test 300 cc of soil naturally infested with approximately 370 nematodes were put into each of 315, 10.5-cm, plastic pots. All except blueberry, raspberry, strawberry and potato were started from seed in steam-sterilized sand. Seedlings were transplanted into the nematode-infested soil 3-10 days after germination, depending on plant vigor. Blueberry, raspberry, and potato

TABLE 1. Host suitability for *Xiphinema bakeri* of some greenhouse grown crops and weeds common in the Fraser Valley of British Columbia.

Scientific Name	Common Name	Cultivar	Susceptibility Rating†	% Population Increase‡
Cerastium vulgatum	Mouse-ear chickweed		3	3017 a
Stellaria media	Common chickweed		4	1460 b
Chenopodium album	Lamb's-quarters		4	1310 bc
Fragaria ananassa	Strawberry	'Northwest'	5	837 cd
Echinochloa crus-galli	Barnyard grass		2	544 de
Rumex crispis	Curly dock		2	436 ef
Dactylis glomerata	Orchard grass	'Danish'	4	360 ef
Rubus idaeus	Raspberry	'Willamette'	5	313 fg
Solanum tuberosum	Potato	'Saco'	5	285 fg
Secale cereale	Rye	'Storm'	3	285 fg
Fragaria vesca	Strawberry	'East Malling Vesca'	5	260 fg
Lycopersicon esculentum	Tomato	'Rutgers'	5	186 gh
Spergula avensis	Corn Spurry		2	115 hi
Plantago major	Broad-leaf plantain		2	84 ij
Plantago lanceolata	Narrow-leaf plantain		2	76 ij
Chenopodium amaranticolor			5	54 jk
Vaccinium corymbosum	Blueberry	'Weymouth'	4	51 jk*
Capsella bursa-pastoris	Shepherd's purse		2	42 jk*
Pisum sativum	Pea	'Progress 18'	3	40 k*
Senecio vulgaris	Groundsel		2	39 k*
Taraxacum officinale	Dandelion		2	16 l*
Brassica rapa	Turnip	'Aberdeen yellow'	2	−3 m*
Trifolium repens	White clover	'Ladino'	2	−4 m*
Cucumis sativus	Cucumber	'SMR-18'	2	−7 m*
Zea mays	Corn	'Jubilee'	2	−20 mn*
Brassicae oleracea var. *capitata*	Cabbage	'Flat Dutch'	2	−30 no*
Phaseolus vulgaris	Bush bean	'Blue Lake'	2	−49 no*
Brassica oleracea var. *gemmifera*	Brussels sprouts	'Jade Cross'	2	−56 op
Brassica oleracea var. *botrytis*	Broccoli	'Rex'	2	−85 p
Cucumis sativus	Cucumber	'National Pickling'	2	−90 p
Brassica oleracea var. *botrytis*	Cauliflower	'Snowball Y'	2	−92 p

† Host susceptibility rating: 1 = no swellings, 2 = light-few small swellings, 3 = moderate, many small but no large swellings, 4 = heavy, many small and a few large swellings but no stunting of root system, 5 = severe, many large swellings and stunted root system.

‡ Values are the means of six replications and are expressed as percentages of fallow soil populations. Values followed by the same letter do not differ significantly ($P = 0.05$), and those followed by an asterisk are not significantly different from those in fallow soil, ($P = 0.05$), according to Duncan's Multiple Range Test.

started from cuttings and strawberry from runners were transplanted into the nematode-infested soil when adequate root systems had developed. Six replications of each plant species were grown in nematode-infested field soil, three replications of each grown in steam-sterilized field soil and 36 replicate pots of fallow soil.

All pots were maintained as in the first experiment. After 12 weeks the plants were harvested, and the nematodes extracted from the soil and counted, using the method described above. The plants were rated for susceptibility to nematode damage in terms of root galling and stunted growth.

PATHOGENICITY: Pathogenicity studies were conducted under controlled conditions using rooted 'Willamette' raspberry cuttings. In the first experiment, cuttings were planted in 500 cc of autoclaved, fine sand in 10.5-cm plastic pots. At potting time the plants were inoculated by pouring 5 ml suspensions of 0, 500 or 1000 *X. bakeri* over the roots. All treatments were replicated six times. The plants were grown under conditions similar to those mentioned above.

Twelve weeks after soil infestation the plants were harvested, the fresh weights of tops and roots and linear growth of the canes recorded. Linear growth was measured from soil level to the tip of the growing point. Nematodes were extracted from the soil by the technique mentioned above.

In the second experiment the following soils were used: (i) a silt loam naturally infested with 100 *X. bakeri* per 500 cc as the only plant parasite; (ii) the same infested soil plus 400 *X. bakeri* per pot giving a total of 500 nematodes per 500 cc of soil; (iii) the same infested soil autoclaved. The soil was obtained from about the roots of a raspberry planting infested with this nematode. Weighed cuttings were planted in 500 cc of each of the soils in 10.5-cm plastic pots. Each treatment was replicated six times and the experiment was conducted similar to the first.

RESULTS AND DISCUSSION

HOST RANGE: The results of Experiment 1 are summarized in Fig. 1. Strawberry and tomato were good hosts for *X. bakeri*, allowing increases of 4.2 and 3.4 times that of the fallow check, respectively, after 12 weeks. The pathological reaction of these plants was typical of the root malformation caused in many plants

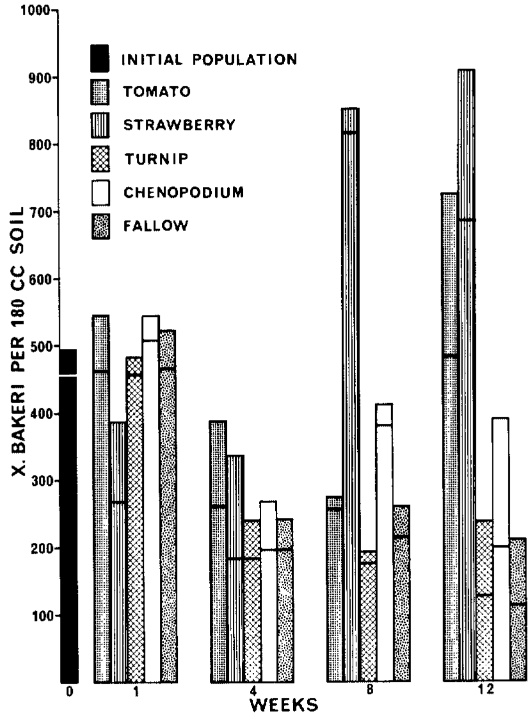

FIG. 1. *Xiphinema bakeri* population change under various plants grown for 12 weeks under a 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature. Upper portions of bars represent numbers of females; lower portions represent numbers of larvae. Males not present.

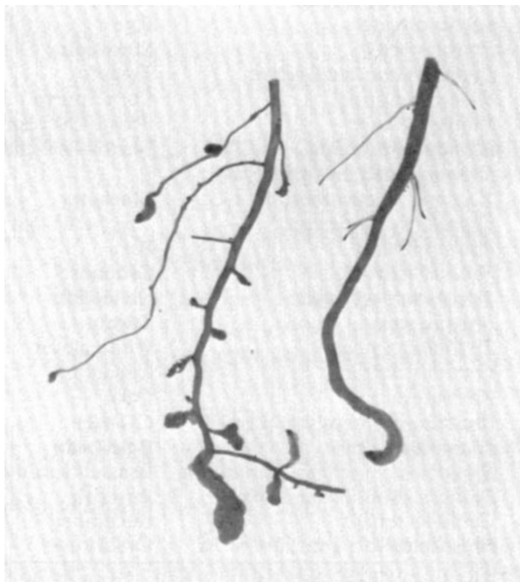

FIG. 2. Typical symptoms caused by feeding of *Xiphinema bakeri* on strawberry roots. Note characteristic swellings and "fish-hook" curling of the root tip.

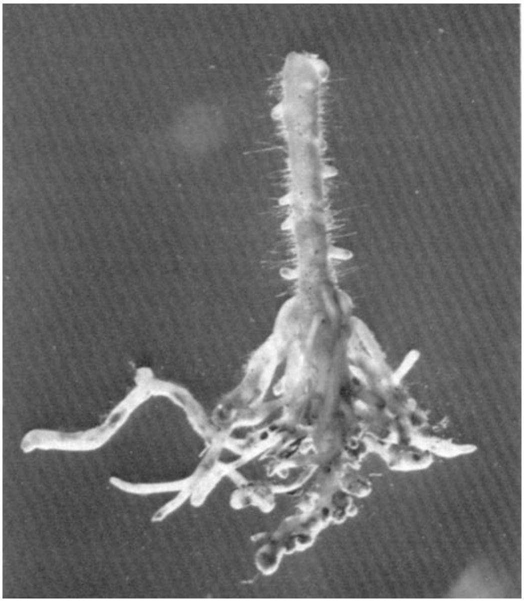

FIG. 3. Tomato grown for 12 weeks under a 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature in 180 cc of soil infested with 500 *Xiphinema bakeri.*

by this species (Fig. 2 and 3); terminal root swellings and curling of the tip in a "fish-hook" fashion. *C. amaranticolor* and turnip appeared to be poor or non-hosts; final populations were only slightly greater than in fallow soil.

However, the reason for lack of population increase was not necessarily the same with all plants. Strawberry and tomato were good hosts for this nematode but full population potential was probably not realized because the nematode so devastated the roots that its food supply was considerably reduced (Fig. 3). The same was true of *C. amaranticolor*; after 8 weeks very little root system remained.

Turnip did not support large populations. Even though many of the primary roots were heavily galled, the secondary roots were abundant, free of galls, and healthy. The total number of larvae decreased by the twelfth week to approximately that of the fallow check. Even though the nematode obviously fed on the roots and evoked a plant response it was unable to reproduce.

There was a cyclic fluctuation of the percentage of females both in presence of a host and under fallow conditions (Fig. 1). On tomato for example the percentages of females in the population were 8, 30, 6 and 34 for 1, 4, 8 and 12 weeks respectively. Similarly for the fallow check, percentages were 9, 20, 9 and 42 for the same intervals. A similar pattern existed under all the plants tested. The exact reasons for these fluctuations are not known but may suggest that under the experimental conditions *X. bakeri* has a life cycle of approximately 8 weeks.

In the second experiment, 16 of the 31 kinds of plants tested supported a significant population increase of *X. bakeri* (Table 1). The greater reproductions were obtained with mouse-ear chickweed (6.6 X), common chickweed (4.6 X), lamb's-quarters (4.2 X), and strawberry (2.8 X). The first three plants listed produced an abundance of roots which apparently compensated for the damage caused by the high populations. Strawberry, raspberry, tomato and potato roots were severely galled and stunted by nematode feeding even though populations were considerably lower than those of the above-mentioned weeds. A comparison of the host susceptibility rating with the percent population increase (Table 1) shows clearly that a plant may be very suitable for *X. bakeri* reproduction, supporting high populations and yet be little affected. By contrast, other plants, especially in the Rosaceae and Solanaceae, may support similar or much lower populations but be severely damaged. This is evident from the pathogenicity studies with raspberry in which populations of *X. bakeri* as low as approximately 1 per 5 cc of soil reduced root and top growth 40-50%.

The high rate of reproduction on weeds is of considerable importance. Chickweed, lamb's-quarters and barnyard grass are common in the Fraser Valley and all support high populations of *X. bakeri*. These weeds growing in the rows with highly susceptible crops such as strawberry or raspberry with their roots intermingled, would encourage the build-up of large nematode populations and perhaps cause greater damage than in weed-free fields. In any case, fields should be maintained weed-free to minimize population increase.

Of equal interest, is that many of the Cruciferae and Cucurbitaceae actually reduced population levels below those in the fallow soil. Even though the reason for this is not known, these crops may be of value in rotations intended to reduce the numbers of *X. bakeri*. This will be further tested in the field.

Rye or pasture is often used in rotation with strawberry or raspberry but these do not reduce numbers of *X. bakeri*. This nematode reproduces well on rye, and although legumes are poor hosts, orchard grass, which is usually included in the pasture mix, allows for considerable reproduction. These crops should not therefore be used in a rotation without supplementary chemical control where this nematode is a problem. The results reported here show that *X. bakeri* is able to reproduce on a considerable range of plants and that this ability is not necessarily related to visible symptoms. It is also evident that this nematode cannot be controlled by the rotation practices currently in use. However, weed control is very important in preventing population increase, and the use of certain cole crops in a rotation may also aid in population reduction.

PATHOGENICITY: Twice during the first experiment the plants dried nearly to the wilting point because of the difficulty in maintaining constant moisture in the sand. This reduced the final nematode population to approximately 10% of the inoculum but feeding had been sufficient to decrease the growth of inoculated plants (Fig. 4). With 500 and 1000 nematodes per pot, the mean weight of roots was reduced by 25% and 59%, and the top weight by 22% and 50% respectively.

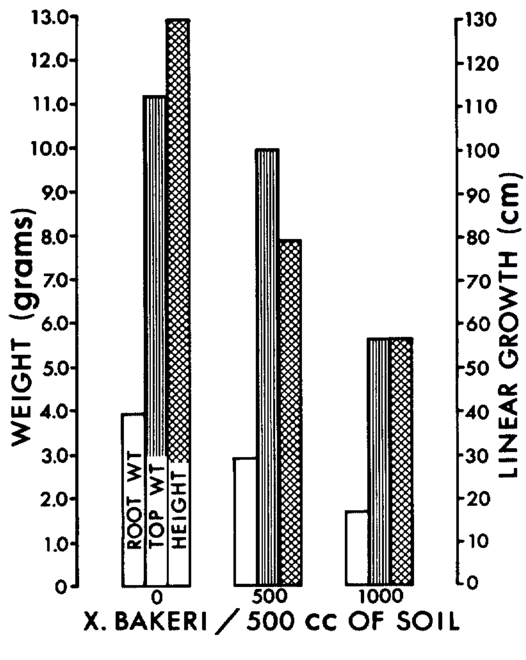

FIG 4. The effect of *X. bakeri* on raspberry grown for 12 weeks under a 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature in fine sand artificially infested with different levels of the nematode.

Linear growth of the tops was reduced by 39% and 57% respectively.

In a second run of the experiment a constant moisture supply was more easily maintained due to the use of sub-irrigation and mean populations increased two- to four-fold. Greatest nematode population increases were obtained with inoculum levels of 100 nematodes per pot, and in some pots increases were six- to seven-fold. In treatments of 100 and 500 nematodes per pot, the mean weight of roots was reduced by 54% and 77%, the tops by 59% and 78% and the linear growth by 48% and 78% respectively (Fig. 5, 6). The effect of the namatode populations on raspberry growth is most strikingly reflected in the total plant weights. The mean increase in weight of the plant was 30.5% and 12.0% of the control for treatments of 100 and 500 nematodes per pot, respectively.

The above-ground parts of plants growing in infested soil were stunted and leaf color was light-green to yellow. Root systems of these plants also were stunted and the root tips swollen and curved, having a "fish-hook" appearance (Fig. 7). Lateral roots emerging from a main root were frequently galled before they reached 2 mm in length. Occasionally normal root growth resumed after a period of nematode feeding resulting in a malformed root with a healthy tip (Fig. 7).

The results of this study show that *X. bakeri* is an important pathogen of raspberry. Under the experimental conditions, populations as low as approximately one per 5 cc of soil reduced root and top growth of 40-50%. While this study was conducted under artificial

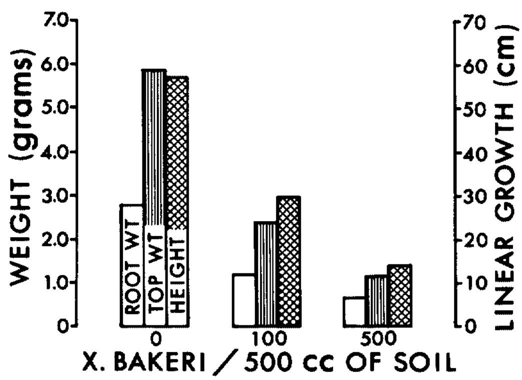

FIG. 5. The effect of *X. bakeri* on raspberry grown for 12 weeks under a 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature in soil naturally infested with different levels of the nematode.

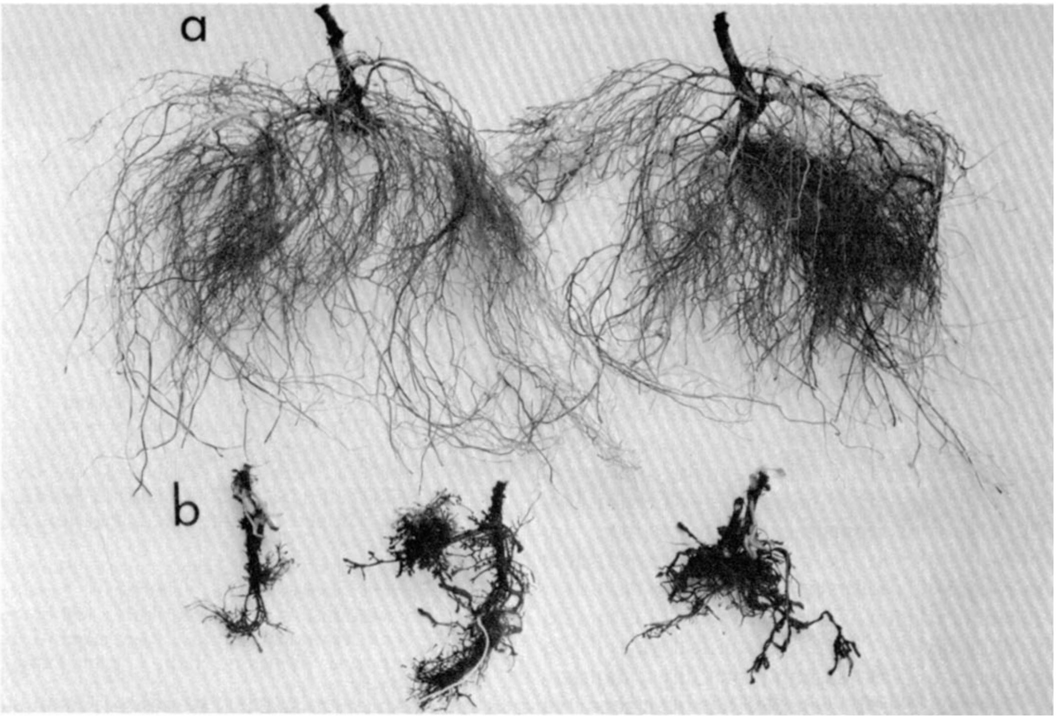

FIG. 6. The effect of *X. bakeri* on raspberry grown for 12 weeks under a 16-hr photoperiod at 600 ft-c and 22 ± 2C average temperature in naturally infested soil: (a) roots of plants grown in nematode-infested soil which had been steamed; (b) roots of plants grown in soil containing 500 nematodes per 10.5-cm pot.

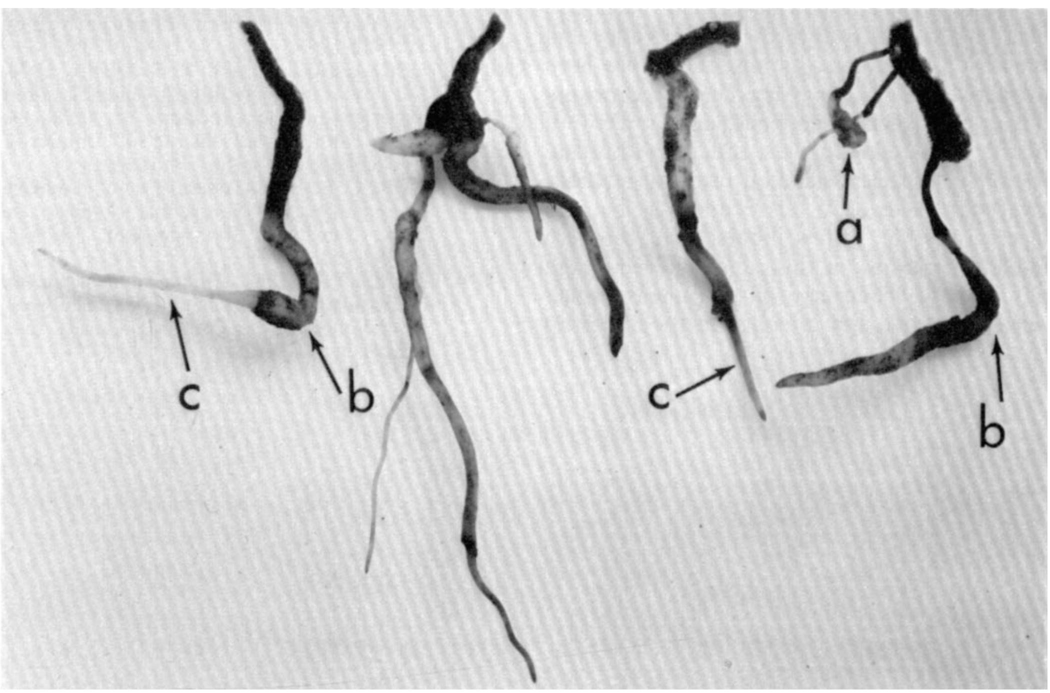

FIG. 7. Raspberry root malformations caused by feeding of *X. bakeri:* (a) gall formation and irreversible cessation of root elongation; (b) typical swelling and "fish-hook" curling of the root; (c) resumption of normal elongation after temporary cessation and swelling.

conditions, populations ten to twenty times the above level commonly occur under field conditions with similar reductions in plant growth. In such heavily infested areas root systems are almost completely destroyed, new cane growth in the spring is slow or lacking, and plants are generally much smaller than those growing in non-infested soil. Observations of infested fields also indicated that yields decreased and the fruit was smaller and of poorer quality.

This paper reports the first demonstration of an ectoparasitic nematode causing direct damage to raspberry. *X. diversicaudatum* was reported associated with galled raspberry roots and implicated in transmission of strawberry latent ringspot virus and arabis mosaic virus (4). The extent of damage caused to raspberry by the nematode in the absence of the viruses is not known; however, *Longidorus elongatus* transmits raspberry ringspot virus (11), tomato black ring virus (5), and spoon leaf virus (7) to raspberry but causes no known direct damage. *Xiphinema americanum* also has been reported as associated with, but not directly affecting, raspberry (3).

While *X. bakeri* is widespread in raspberry plantings in light soils in the Fraser Valley and is native to the area, its importance has been overlooked for many years. This was probably due in part to inadequate methods for recovery of this nematode from the soil. As with many *Xiphinema* species, standard recovery methods give poor yields of *X. bakeri* and they become inactive within a few hours. The recovery method described in this paper allowed a high percentage recovery of specimens which remained active and infective in the dishes up to two weeks.

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