Agriculturally-polluted Irrigation Water as a Source of Plant-Parasitic Nematode Infestation[1]

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Abstract: Water from a major irrigation canal and water from a deep well was used to irrigate plants growing in methyl bromide fumigated screenhouse ground beds. Nematode populations in these beds were compared during three seasons of continuous cropping to alfalfa, bean, eggplant, mint, sugarbeet, or wheat. Beds irrigated with canal water became heavily infested with a variety of plant parasitic nematodes while those receiving well water did not. *Key Words: Ditylenchus dipsaci, Paratylenchus, Meloidogyne, Pratylenchus, Tylenchorhynchus,* Alfalfa, Bean, Eggplant, Mint, Sugarbeet, Wheat.

In a previous report (4) and in a concurrent paper we described the occurrence of large numbers of nematodes contaminating irrigation water in south central Washington. Populations in major canals ranged from approximately 150 to 16,000 nematodes/m^3 of water (seasonal averages) with plant parasites usually comprising 5 to 12% of the nematodes present. From the data it was postulated that most of the irrigated lands in the Yakima Valley and Columbia Basin receive an annual inoculum of 0.144×10^6 to 15.362×10^6 plant parasitic nematodes per hectare. These are conservative estimates since the extraction procedures were neither 100% effective for recovering active nematodes nor did we recover inactive stages (eggs and moulting specimens). Whether plant parasitic nematodes introduced to non-infested land via contaminated water can become established on host plants was not demonstrated. For this purpose the present study was initiated.

METHODS

During the summer of 1966 we constructed six 3.4 × 7.3 m screenhouses having 1.2 m high reinforced concrete foundations extending 45.7 cm above ground and resting on 15.2 cm × 30.5 cm concrete footings poured 76.2 cm below the soil surface. Corrugated fiberglass was used for roofing and 32-mesh plastic screen was used to cover 1.8 m high sidewalls. The houses were spaced 2.4 m apart along a 7% grade.

The upper foot of topsoil (Sagemoor fine sandy loam) contained abundant grass roots and was removed from the houses. Soil of the same type from a nearby fallowed field was used for replacement. The soil was thoroughly puddled to remove air pockets. Concrete walkways (61.0 cm × 10.2 cm) were poured along the center length of each house and sections of 20-gage galvanized steel sheeting (610 cm × 1.4 m) used to subdivide the soil beds into six 1.4 m × 2.4 m plots.

During the period from April 3 to April 15, 1967, the soil beds were fumigated in sequence under air-tight covers with methyl bromide at 2.8 kg/2.8 m^3. The covers remained in position for 48 hr following treatment. During this period soil temperatures (18.3 cm depth) and soil water levels averaged 13 C and 18%, respectively. The plots were then spaded and planted following a minimum of 96 hr aeration.

Six individual plots in each house were continuously cropped to either alfalfa (*Medicago sativa* L.), bean (*Phaseolus vulgaris* L.), eggplant (*Solanum melongena* L.), pep-

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permint (*Mentha piperita* L.), sugarbeet (*Beta vulgaris* L.), or wheat (*Triticum vulgare* Vill.) during the three successive years of the experiment. All seed used was disinfected in 3% NaOCl for 3 min and washed with tap water before planting. Mint was started by rooting tip cuttings in methyl bromide fumigated sand (0.9 kg/2.8 m^3). The developing plants were washed in tap water and transplanted to the ground beds. Planting dates and rates approximated those generally followed for each crop under commercial conditions.

The plots were irrigated as necessary with water from a deep well (nematode-free water source) or from an irrigation canal (nematode-contaminated water source) near Prosser, Washington. Because the screenhouses were located along a 7% grade, we irrigated the soil beds in the upper three houses with well water and the lower three with canal water. This was done to prevent contamination by downhill subbing from beds receiving canal water. During each irrigation the equivalent of 5.1 ha-cm of water was applied by simulated furrow irrigation.

To determine fertilizer requirements, soil samples from each plot were tested each year by the Washington State University Soil Testing Laboratory, Pullman, Washington. The recommended rates of nutrients were applied prior to planting.

Nematode populations in soil were estimated following the method of Christie and Perry (3), from roots by a modification of the spraying method of Chapman (2), and from water as described in an earlier report (4). The nematodes were then suspended in water and average counts from three 1-ml portions (1) were recorded.

Records were kept on the development of plant parasitic and saprozoic nematode populations, approximate number of nematodes introduced during each irrigation, irrigation water requirements for each plot, and crop yields. Only those nematodes which commonly parasitize higher plants are termed "plant parasitic." All others are termed "saprozoic."

RESULTS

Composite 473 cc (1 pt) soil samples (from 10 probes with a soil tube) were taken from the upper 76.2 cm of soil in each plot 3 days after the final application of fumigant. No live nematodes were extracted from these samples.

Subsequently, nematodes were extracted from 473-cc composite samples, taken from the upper 30.5 cm of soil in each plot at 2-week intervals during the 1967, 1968 and 1969 growing seasons (April through September), and at monthly intervals during the intervening months (October through March). The average populations of plant parasitic and saprozoic nematodes which developed during the course of this experiment in plots planted to alfalfa, bean, eggplant, sugarbeet or wheat are shown in Fig. 1. Saprozoic nematodes were the first to be observed in any of the plots and appreciable populations had developed by August of 1967 in plots receiving canal water. Equivalent populations of saprozoic nematodes did not develop in plots receiving well water until late spring of the following year. During the remainder of 1968 the saprozoic nematode populations in plots receiving well water greatly exceeded those in plots receiving canal water but had dropped to comparable levels by the end of the 1969 season.

Plant parasitic nematodes were first observed in plots receiving canal water in August of 1967, reaching appreciable numbers late in 1968, and thereafter the population levels remained relatively constant. Although plant parasitic nematodes were discovered in the alfalfa, bean, eggplant, sugarbeet and wheat plots receiving well water during the 1968 growing season, population levels re-

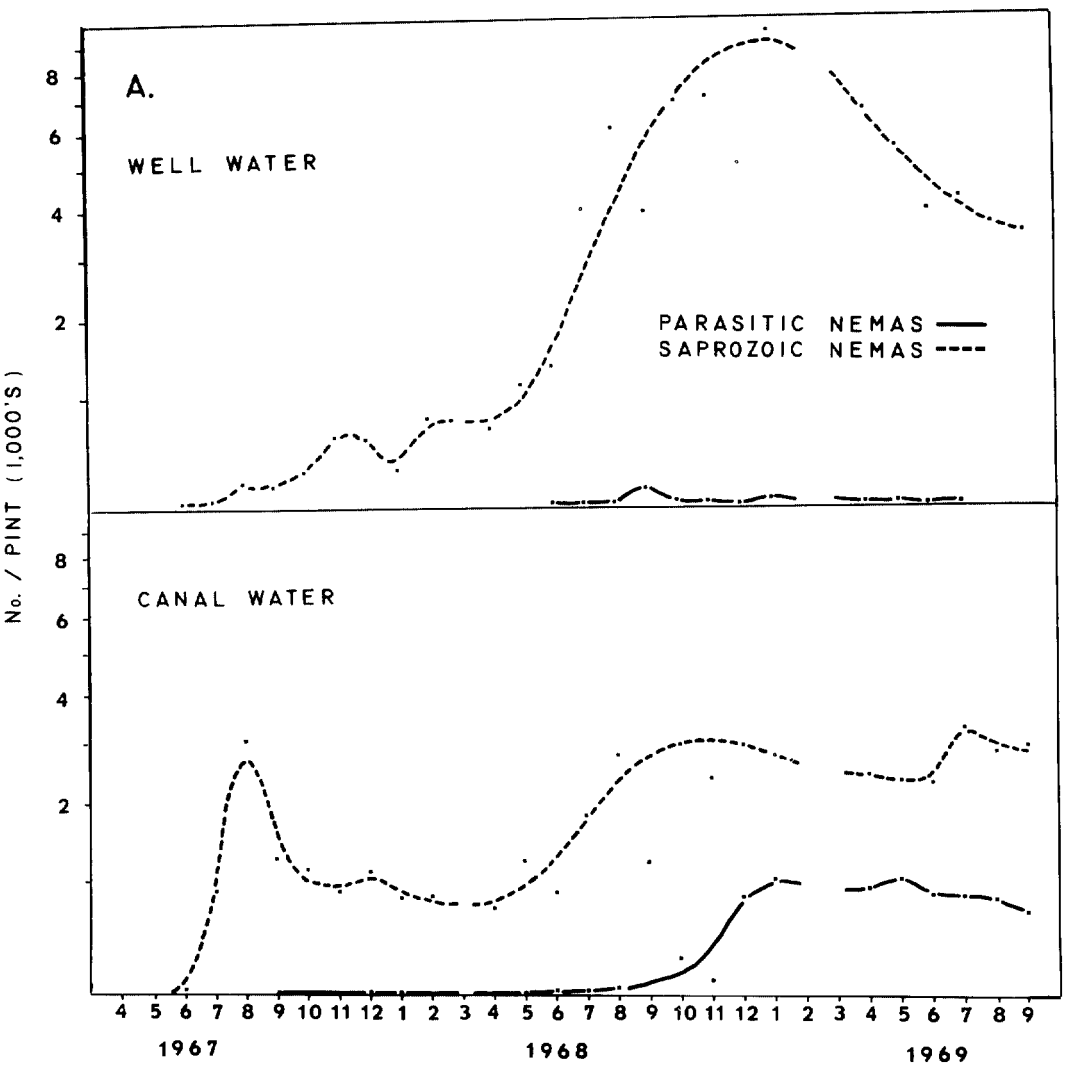

FIG. 1. Averaged plant parasitic and saprozoic nematode populations (per 473 cc soil) from alfalfa, bean, eggplant, sugarbeet, and wheat beds irrigated with well water or canal water.

mained relatively low throughout the remainder of the experiment.

The nematode populations which developed in plots planted to peppermint are shown separately (Fig. 2) since the plant parasitic nematode population was strikingly different from that associated with the above crops. Saprozoic nematodes in mint soil generally followed population trends similar to those described for other crops.

The only plant parasitic nematode extracted from soil in plots planted to mint is an undetermined species (or spp.) of *Paratylenchus*. By September 1967 this nematode had reached a peak population exceeding 3,000/473 cc of soil in mint plots receiving

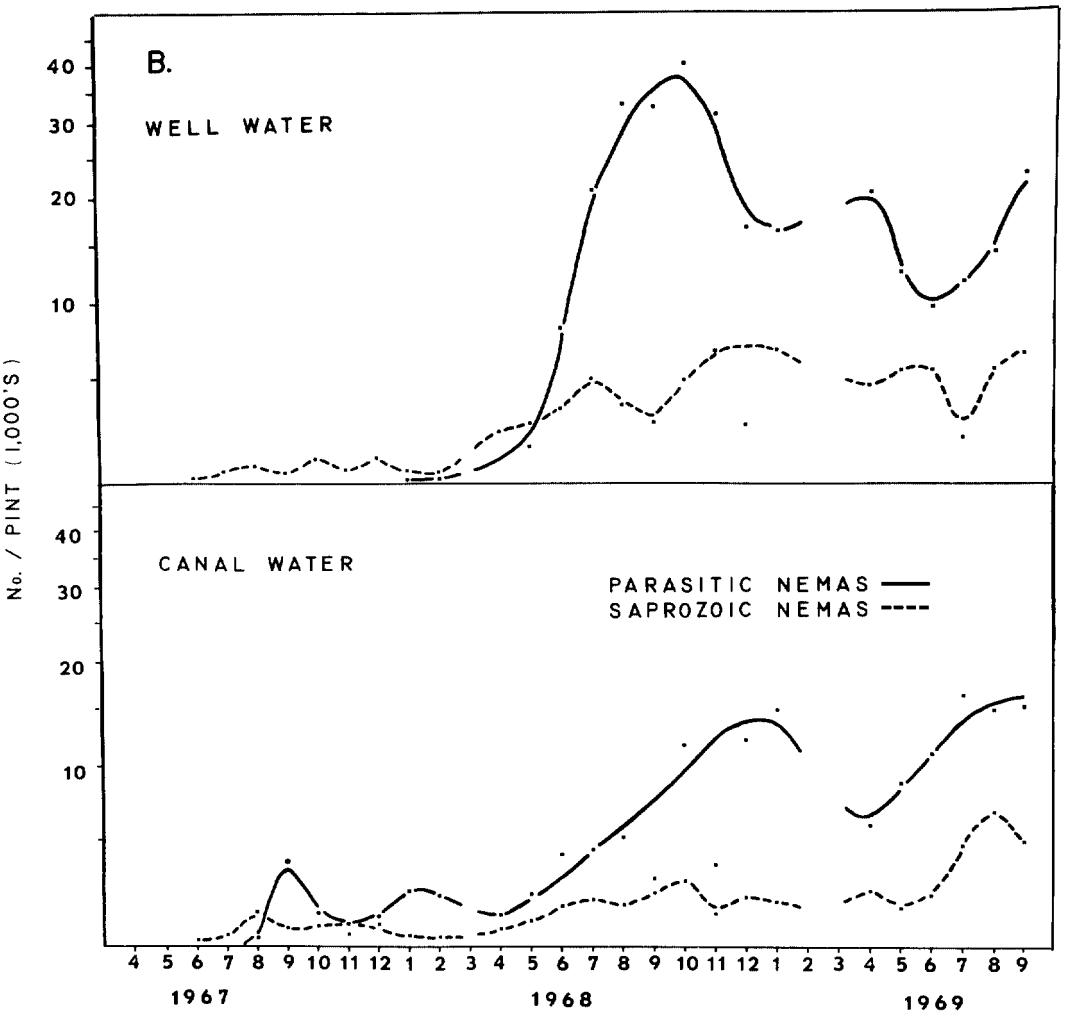

FIG. 2. Plant parasitic and saprozoic nematode populations (per 473 cc soil) from mint beds irrigated with well water or canal water.

canal water and increased to approximately 15,000/sample in peak periods of 1968 and 1969. *Paratylenchus* was not extracted from soil in the mint plots receiving well water until early in 1968 but by August of that year had exceeded 30,000/sample.

The average amounts of water required to irrigate crops in the six screenhouses are shown in Table 1. Irrigation rates applied in the houses at the upper end of the 7% grade receiving well water were roughly equivalent to rates used to grow these crops in commercial fields. Conversely, the crops in houses at the lower end of the grade receiving canal water were affected by subbing, requiring much reduced irrigation rates. Also included (Table 1) are the approximate numbers of nematodes introduced annually via each water source. No nematodes were extracted from samples of well water while

TABLE 1. Average irrigation rates required by plants grown in soil beds in six screenhouses and the numbers of nematodes introduced per plot via well or canal water.

House number	Water source	Average irrigation rate (ha-cm/yr)	Annual number of nematodes introduced per plot*	
			Saprozoic	Parasitic
1	well	91.44	0	0
2	well	88.90	0	0
3	well	88.39	0	0
4	canal	55.12	29,048	2,437
5	canal	43.69	23,024	1,937
6	canal	37.59	19,811	1,662

* Numbers were calculated from the seasonal averages of nematodes/3.7854 liter (1 U. S. gallon) of water from each source.

samples of canal water averaged approximately 15,787 saprozoic nematodes plus 1,325 plant parasitic nematodes per m^3.

Among the plant parasitic nematodes introduced via canal water, species of *Paratylenchus, Meloidogyne, Heterodera, Tylenchorhynchus,* and *Pratylenchus* were well established by the end of the third growing season (Tables 2 & 3). In Table 2 these genera are listed in their order of dominance on the respective indicator hosts, as ascertained through extractions (seasonal averages) from soil samples. Also shown for comparison are the average populations of plant parasitic nematodes from plots receiving well water, but these data will be discussed later.

The average numbers of endoparasitic nematodes (*Meloidogyne*—larvae only and *Pratylenchus*—all stages) extracted per gram (dry weight) of host roots are given in Table 3. No attempt was made to extract nematodes from sugarbeet roots since *Heterodera schactii* was the only endoparasite observed in the sugarbeet plots and had obviously reached high populations by the end of the third growing season.

TABLE 2. Average annual numbers of plant parasitic nematodes extracted per 473 ml soil sample from beds irrigated with well or canal water. Nematode genera are listed in order of dominance on the indicated crops.

Crop	Nematodes, in order of dominance	Water Source and Season					
		Well			Canal		
		1967	1968	1969	1967	1968	1969
Alfalfa	1. *Paratylenchus*	0.0	5.8	2.0	3.6	25.7	340.3
	2. *Meloidogyne*[1]	0.0	0.0	0.0	0.0	0.0	444.1
Bean	1. *Paratylenchus*	0.0	0.0	0.0	2.5	2.2	1057.4
	2. *Meloidogyne*	0.0	0.0	0.0	0.0	0.0	136.5
	3. *Tylenchorhynchus*	0.0	0.0	0.0	0.0	0.0	46.6
Eggplant	1. *Meloidogyne*	0.0	0.0	0.0	0.0	14.6	165.3
	2. *Tylenchorhynchus*	0.0	0.7	0.0	0.0	126.9	95.0
	3. *Paratylenchus*	0.0	8.9	32.9	0.0	18.4	0.0
Mint	1. *Paratylenchus*	0.0	18,620.0	12,481.6	4946.8	1041.4	14,203.3
Sugarbeet	1. *Paratylenchus*	0.0	9.8	0.0	0.0	9.5	1,497.9
	2. *Heterodera*[1]	0.0	0.0	0.0	0.0	7.3	538.7
Wheat	1. *Paratylenchus*	0.0	2.4	0.0	0.0	0.0	45.0
	2. *Pratylenchus*	0.0	0.9	0.0	0.0	0.0	0.0
	3. *Tylenchorhynchus*	0.0	0.0	0.0	0.0	10.6	0.0

[1] For *Meloidogyne* and *Heterodera* the populations given are for larvae only.

TABLE 3. Average number of endoparasitic nematodes extracted from roots of indicator crops.

Crop	Nematode genus	Nematodes[1]/g of roots[2] water source	
		Well	Canal
Alfalfa	*Meloidogyne*	0	431
Bean	*Meloidogyne*	0	1,791
Eggplant	*Meloidogyne*	0	44,866
Mint	*Meloidogyne*	0	379
Sugarbeet	No data given	–	–
Wheat	*Pratylenchus*	311	1,614

[1] Counts were made at the end of the 1969 growing season only.
[2] Number/g based on dry weights of root tissues.

Yield data were taken each year but variation was too great to draw conclusions.

DISCUSSION

The numbers of plant parasitic nematodes introduced into nematode-free soil via canal water were roughly one-half of those one could expect when using the same water source under commercial conditions. This was due to the effects of subbing from soil beds receiving well water to those receiving canal water. Consequently, plants receiving canal water had greatly reduced irrigation requirements. Even so, the results demonstrated that the runoff water introduced into canals from irrigated fields is an important source of nematode infestations. Procedures need to be developed whereby waste water may be re-used without spreading important plant pathogens.

The populations of plant parasites which developed in association with mint (Fig. 2) differed greatly from those associated with the other crops (Fig. 1). Not only did *Paratylenchus* spp. dominate the composite population (saprozoic + parasitic forms) but this nematode reached highest population level in a plot irrigated with nematode-free water.

Paratylenchus sp. earlier was reported to reach population levels exceeding 42,000/473 cc soil sample on peppermint following soil fumigation in the field (5). In the present study we often measured populations of *Paratylenchus* exceeding 20,000/sample from mint plots receiving canal water. However, in one of the mint plots irrigated with well water, populations of this nematode ranged from 25,000 to over 115,000/473 cc sample. Samples from the two other mint plots receiving well water contained populations of this nematode averaging 1,000 to 2,500 during this period.

Since the screenhouse containing the peppermint plot with large *Paratylenchus* populations was located at the extreme west end of the row of houses, we postulated that this nematode was introduced during the severe dust storms which occurred early in 1968. The prevailing spring winds of eastern Washington come from the west and often carry heavy loads of extraneous matter ranging in particle size from fine silt to boulders. Preliminary tests indicate *Paratylenchus* sp. could well have been introduced by aerial means and a complete report on this possibility will be made at a later date.

One of the obvious discrepancies we observed was that alfalfa stem nematode *(Ditylenchus dipsaci* [Kühn] Filipjev) did not become established in plots receiving canal water. This nematode ranks first, both in population levels and frequency of occurrence, among the plant parasites extracted from irrigation water in eastern Washington. Field observations have consistently indicated that contaminated water is a major source of stem nematode infestations. We can only speculate that excessive air temperatures occurring in the screenhouses limited reproduction of stem nematodes. Screenhouse air temperatures usually exceeded field temperatures by 6 to 9° C producing monthly average temperature maxima ranging from approximately 29.2° C to 43.4° C.

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