Acquisition and Distribution of Nematodes in Irrigation Waterways of the Columbia Basin in Eastern Washington[1]

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Abstract: The primary source of plant parasitic nematodes in irrigation waterways in the Columbia Basin Project of eastern Washington is irrigation runoff returned into the irrigation system. This has contributed to the rapid spread of plant parasitic nematodes observed during eight years of study. *Key Words: Ditylenchus dipsaci, Paratylenchus, Meloidogyne, Pratylenchus, Tylenchorhynchus, Xiphinema,* Irrigation, Nematode distribution.

A high count of plant parasitic nematodes in canals servicing the lower portion of Washington's irrigated Yakima Valley was reported in a recent paper (3). Plant parasitic and saprozoic nematode contamination in waterways of the more recently developed Columbia Basin Project has not been previously demonstrated, nor have attempts been made to follow patterns of acquisition and spread.

Results of observations during the early 1960's suggested the reuse of irrigation water was probably of primary importance in the rapid spread of certain nematode pests. For example, northern root-knot nematode, *Meloidogyne hapla* Chitwood, and alfalfa stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev were first noted in fields of the Columbia Basin Project in 1961. Their progressive spread throughout the Project followed the general direction of water flow and the infestations are surprisingly uniform; the spotty distribution normally associated with plant parasitic nematode infestations is the exception.

Our interest in nematode dissemination via irrigation water was stimulated both by such observations and by the potential impact this could have on irrigation developments being considered for the future. Plans have been drawn to increase the present irrigated area of eastern Washington (roughly 526,000 ha) by 202,550 ha. Future diversions from the Columbia and Snake rivers would allow development of an additional 2,316,550 ha, now classified as potentially irrigable (1).

The present study was designed to investigate the rapid spread of plant parasitic nematodes in existing irrigation developments and to indicate possible means for preventing nematode contamination of waterways.

MATERIALS AND METHODS

A survey to measure nematode contamination of waterways in the Columbia Basin Project was initiated in 1966. Water samples were collected at 32 locations throughout the growing season. The distribution pattern of irrigation water diverted from the Columbia River at Coulee Dam was followed through the Columbia Basin Project to points near Pasco, Washington, at the lower end of the irrigation system.

A test area representing both earlier and later-developed lands, and containing 17 of the original collection sites, was selected for continued study (Fig. 1). Initial results suggested that most factors influencing acquisition and distribution of soil-inhabiting nematodes in water were represented. For example, water samples taken from the West

Received for publication 6 May 1970.

[1] Scientific Paper 3440, Washington State University, College of Agriculture, Prosser, Washington 99350. Work was conducted under Project 1491 and partially supported by funds authorized by the United States Department of the Interior under the Water Resources Act of 1964, Public Law 88-379, through the State of Washington Water Research Center, Pullman, Washington 99163.

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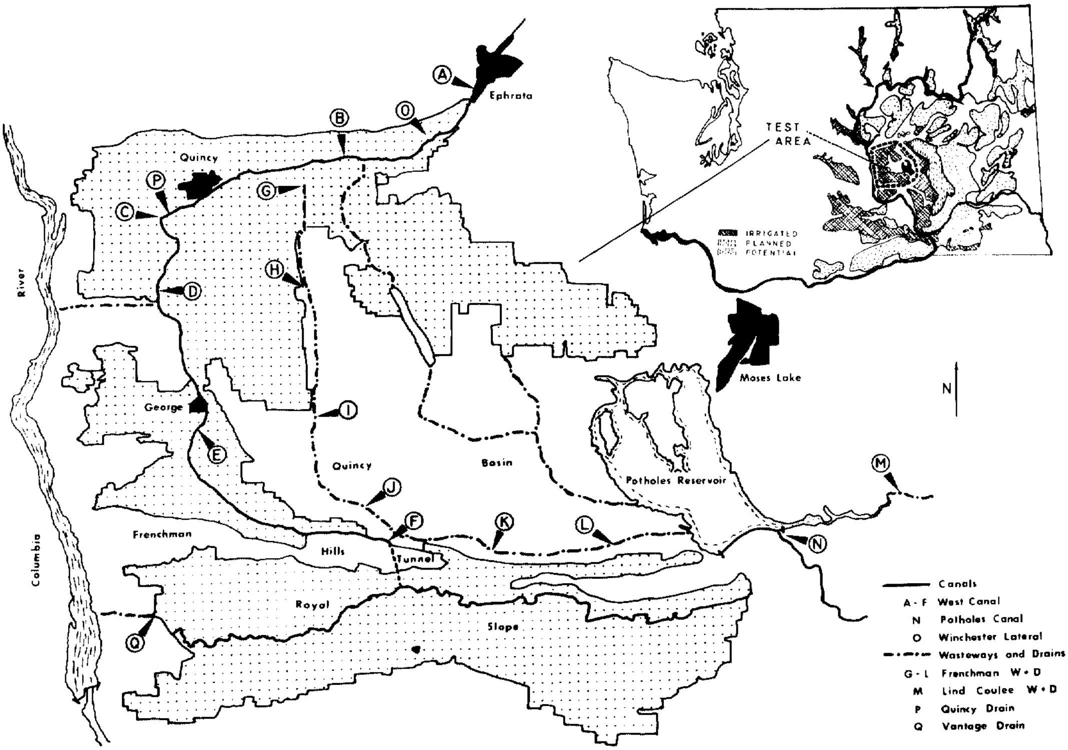

FIG. 1. *Large map*—Test area from which water samples were collected at 17 locations (A–Q) during three years of study. *Map inset*—State of Washington, showing location of the test area in relation to areas presently irrigated, planned for irrigation, and potentially irrigable.

Canal at or above Ephrata, Washington, did not contain plant parasitic nematodes. Runoff, from water lifted by pumps to irrigate blocks of land lying to the north and west of this canal, is returned to the West Canal at a number of locations and helps supply water for the lower Quincy Basin and Royal Slope.

Collection sites along the Frenchman and Lind Coulee Waste and Drainways were selected because these deliver large volumes of runoff water to the Potholes Reservoir for reuse farther down the irrigation system.

Water samples were collected at weekly intervals during the 1966 irrigation period, April through September, and at biweekly intervals for the same periods during 1967 and 1968. On each sampling date three 18.9-liter (5 gal.) samples were collected from each of the 17 sites, transported to the laboratory, and processed for extraction of nematodes within a 24-hour period.

A continuous flow chemical centrifuge (International Model 450) fitted with a manganese bronze 12.7 cm dia solid basket head (International Model 1343) was used to concentrate each sample to 300 ml. Intake flow was adjusted to approximately 3.79 liters/min (1 gal/min) at 4,000 rpm (1150 *g*). The basket head was lifted from the centrifuge and its contents washed into a 473 ml (1 pt) plastic cup. Separan NP10® (Dow Chemical Company, chemical composition not available) was added to flocculate particulate matter. Nematodes were extracted by a modification of the Christie and Perry method (2) and counts of parasitic and saprozoic genera were made as described in a previous report (3).

For the purpose of this study the soil-borne nematodes which feed primarily on higher plants are listed as parasites. All others are termed saprozoic.

RESULTS

Acquisition of plant parasitic nematodes in the West Canal (Fig. 1, A–F) is via return of runoff water from irrigated fields. Samples from Site A failed to yield plant parasites during three years of testing.

Nematode populations were measured at two locations (Sites O & P) where runoff water is returned to the West Canal. Site O is located at the terminal end of a lateral, supplied by the Winchester Pumping Station (located near Site B). Runoff water from fields above this lateral is also collected and carried in an easterly direction, and returned to the West Canal at Site O. Site P is located at the end of a drain, collecting runoff from the area surrounding Quincy, Washington, which lies to the north of the canal. Seasonal averages of plant parasitic and saprozoic nematodes/m^3 of water passing Site O were 6,786 and 47,241, respectively. At Site P these averages were 5,319 and 148,916. Flow rates of water passing Sites O and P were estimated at 0.08 and 0.70 m^3/sec. Thus the combined nematode load of water passing these points might be expected to annually introduce over 1.67×10^{12} nematodes into the West Canal with approximately 4% of these being plant parasitic forms.

Population densities of nematodes were followed through a 73 km long portion of the West Canal (Sites A through F). The average monthly concentrations of nematodes/m^3 of water during the three-year test period are given for each of these collection sites in Table 1.

As noted above, samples collected at Site A, just above the point where runoff water first re-enters the West Canal, did not contain plant parasites. Population densities of both parasitic and saprozoic nematodes steadily increased through Sites B, C, and D covering that portion of the West Canal

TABLE 1. Monthly averages of plant parasitic and saprozoic nematodes per m^3 water passing six collection sites on the West Canal in the Columbia Basin of Washington (See map, Fig. 1, A–F).

Site	April	May	June	July	August	Sept.	Site average
			PLANT PARASITIC NEMATODES				
A	0	0	0	0	0	0	0
B	95	95	8	3	0	0	33.5
C	138	303	413	55	55	28	165.3
D	193	468	165	83	386	55	225.0
E	110	193	111	55	14	8	81.8
F	83	220	83	83	28	0	82.8
Monthly avg	103.2	213.2	130.0	46.5	80.5	15.2	
			SAPROZOIC NEMATODES				
A	28	72	146	248	8	19	86.8
B	133	263	102	135	19	3	112.5
C	2892	3553	5096	1598	1873	385	2566.2
D	3112	6142	3967	3498	2368	2149	3539.3
E	2920	3939	4296	1873	1363	543	2489.0
F	1156	2259	1652	1460	771	1102	1400.0
Monthly avg	1710.1	2704.6	2543.2	1468.7	1067.0	700.1	

which receives runoff water. Nematode densities then decreased through a zone (Sites E and F) where no additional runoff water is returned.

Seasonal population trends are also indidicated for each collection site in Table 1. Population densities generally increased through May, then decreased over the remainder of the growing season. Exceptions occurred at Site D, where plant parasites exhibited a second population peak in August, and at Site A where the peak population, all saprozoic forms, was not reached until July.

Nematode populations were also followed through a combination drain and wasteway system, here designated as the Frenchman Wasteway and Drainway (Sites G through L). This system acquires most of its flow (averages 9.22 m^3/sec at Site J) as runoff from irrigated fields. Average population densities ranged from 2,887 parasitic and 78,748 saprozoic nematodes/m^3 at Site G to 1.3 and 365.0 at Site L, 53.68 km downstream (Table 2).

Population decline was proportionally greater in the Frenchman Wasteway and Drain than in the West Canal. For example, the distances between Sites D and F on the canal and between Sites H and K on the wasteway are comparable (35 and 34 km, respectively). Yet population densities of plant parasites declined from 225.0 to 82.8/m^3 in a 35 km portion of the West Canal, whereas they declined from 2645.8 to 4.7/m^3 in a 35 km portion of the wasteway. It is possible that dilution and/or rate of flow could account for part of these differences. However, since decline occurred at approximately the same rates in both waterways, 1.8% and 2.8%/km, respectively, these differences are probably real.

A wide variety of soil-inhabiting nematodes was extracted from the water samples. However, only the dominant plant parasitic genera were recorded separately. The per cent composition of plant parasitic forms is given in Table 3. *D. dipsaci* was the most

TABLE 2. Average number of plant parasitic and saprozoic nematodes per m^3 water passing six collection sites on the Frenchman Hills Wasteway in the Columbia Basin of Washington (See map, Fig. 1, G–L).

Site	April	May	June	July	August	Sept.	Site average
			PLANT PARASITIC NEMATODES				
G	339	3388	4557	799	689	0	2886.6
H	742	7417	3471	1487	468	386	2645.8
I	248	2396	1873	689	331	0	922.8
J	0	661	689	496	110	0	326.0
K	3	14	11	0	0	0	4.7
L	0	0	8	0	0	0	1.3
Monthly avg	222.0	2312.7	2601.5	578.5	263.3	64.3	
			SAPROZOIC NEMATODES				
G	23810	149492	186295	26168	19778	12010	78748.6
H	38433	223181	103032	19448	19520	11486	75333.8
I	11321	63163	35039	18593	9861	7713	24282.3
J	5234	28262	15012	10247	3471	2617	10807.4
K	410	1226	1229	771	83	358	679.5
L	220	1074	543	138	138	83	365.7
Monthly avg	10767.2	77733.0	56858.3	12560.8	8808.5	5711.2	

TABLE 3. Dominant plant parasitic nematode genera observed in samples from the West Canal and Frenchman Hills Wasteway (% of the total population of plant parasitic nematodes).

Genus	% Composition: West Canal	% Composition: Frenchman Hills Wasteway
Ditylenchus	84.41	77.17
Paratylenchus	8.26	10.53
Meloidogyne	3.67	5.27
Pratylenchus	2.74	3.51
Tylenchorhynchus	0.92	1.59
Xiphinema	Trace	0.03

prevalent plant parasite observed, followed by species of *Paratylenchus, Meloidogyne* (larvae), *Pratylenchus, Tylenchorhynchus,* and *Xiphinema,* respectively.

Data were collected at Site M because it represented a completely separate drainage system (Lind Coulee) and also helps supply water to the Potholes Reservoir. Population densities here averaged 912 plant parasites and 28,327/m^3 saprozoic nematodes over the three growing seasons.

Large numbers of nematodes enter waterways serving the Potholes Reservoir. Here the Frenchman and Lind Coulee Wasteways and Drains serve as examples. However, relatively few nematodes (64/m^3), none of which were plant parasitic forms, were collected at Site N. At this point water passes from the reservoir into the Potholes Canal for use farther down the irrigation system.

Runoff water from irrigated areas in the Columbia Basin must eventually find its way back to the Columbia River. Site Q is an example. At this location the average population densities were 2,213 plant parasites and 40,860 saprozoic nematodes/m^3 of water.

Populations of nematodes extracted from the water samples varied among the three growing seasons studied. Trends within and among the three growing seasons are shown in Fig. 2. Sites J and M were selected as representative because runoff water from large drainage areas passes each location and flow data are also available for each. Even

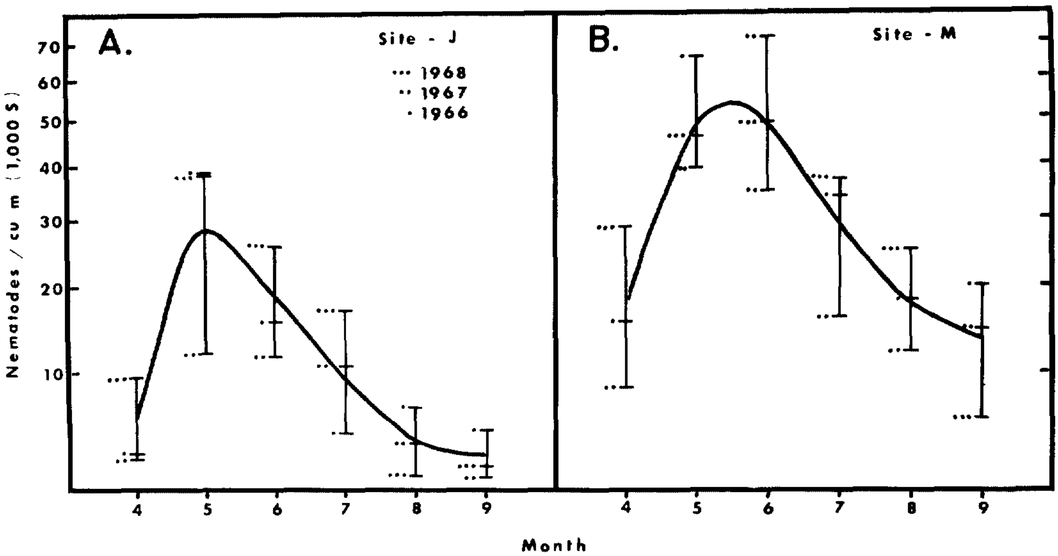

FIG. 2. Variation in nematode populations/m^3 of water at two locations during three growing seasons. **A.** Site J on Frenchman Wasteway and Drain. **B.** Site M on Lind Coulee Wasteway and Drain.

though population densities varied widely among seasons, when the averages were plotted (graph line) rather typical population curves resulted.

DISCUSSION

The return flow of runoff water from irrigated fields into canal systems is the primary source of nematode-contaminated irrigation water. The use and reuse of irrigation water in localities could well be responsible for the rapid and uniform spread of plant parasitic nematodes observed in the Columbia Basin Project.

Of prime importance, however, is that the data suggest possible means for controlling spread of plant parasitic nematodes in irrigation systems. Data collected at Sites J and M, where flow data were available, were used to calculate the approximate numbers of plant parasitic nematodes entering inlets of the Potholes Reservoir. Should these nematodes survive passage through this reservoir, one might expect the Potholes Canal to receive approximately 349×10^9 plant parasitic nematodes annually from these sources alone and deliver them to fields lower in the irrigation project. Fortunately this is not the case.

We now need to determine why heavily contaminated water was virtually free of nematode pests by the time it had passed through inlets of the Potholes Reservoir and why no plant parasitic nematodes were found in water flowing from this reservoir. Studies to determine the effects of various types and sizes of water impoundments on nematode dissemination and the physical and biological factors affecting survival of nematodes in water are being initiated.

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