Determining the Cause and Extent of Apple, Cherry, and Pear Replant Diseases Under Controlled Conditions

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ABSTRACT

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A replant disease of fruit trees was reproduced under growth chamber conditions. Apple, pear, and cherry seedlings, grown in nontreated apple, pear, or cherry orchard soils with histories of replant disease, were stunted and their roots were discolored and reduced in size. Although pretreatment of the soil with dichloropropene-dichloropropane and related C_3 hydrocarbons (DD) resulted in an improvement in plant growth and development over the nontreated check, it was inferior to the chloropicrin and steam treatments. Growth response of apple, pear, and cherry seedlings to soil treatments was greatest in the apple replant soil. This soil contained high populations of *Pratylenchus penetrans* and *Paratylenchus projectus*. The apple, pear, and cherry orchard soils were respectively sandy loam, loam, and loamy sand with pH values of 7.2, 5.5, and 5.7. We consider the replant disease of fruit trees in New York to be nonspecific and that biological agents in addition to plant parasitic nematodes (principally, *P. penetrans*) are involved in the replant disease of fruit trees in New York.

Additional key words: *Pratylenchus penetrans*, chloropicrin, DD, steam sterilization.

Problems with replanting fruit trees have been reported from numerous fruit-growing areas of the world. Oostenbrink and Hoestra (13) were first to recognize that replant diseases caused by *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans-Stekhoven and possibly other microorganisms are distinct from "specific replant diseases". Savory (16, 17, 18, 19) and Hoestra (4) in excellent comprehensive articles described and summarized observations and data concerning "specific replant diseases" and "nonspecific replant diseases". The former are characterized by poor root growth of trees planted in soil in which the same species or other species of the same genus had been grown. Nonspecific replant diseases include damaged root systems and poor growth for which plant parasitic nematodes are considered to be partly responsible but may occur without previous history of a tree crop of the same kind.

Pratylenchus penetrans is an important component of the complex causing a replant disease in numerous fruit orchards in New York (2, 6, 7, 8, 9, 14, 15). Although substantial numbers of other plant parasitic nematodes such as *Xiphinema americanum* Cobb, *Paratylenchus* spp. (chiefly, *P. projectus* Jenkins), and *Criconemoides* spp. were present in some New York orchards with replant diseases, only *P. penetrans* occurred in all such orchards that were studied. Mai and coworkers (1, 2, 8, 9, 10, 11) demonstrated that preplant treatment with a nematicide decreased tree mortality and increased growth and yield of trees in orchards with replant diseases.

A number of fungi and other microorganisms are present in soil of orchards with replant diseases and undoubtedly are important in causing the death of feeder roots (3, 12, 21). *Fusarium* spp., *Pythium* sp., and *Rhizoctonia* sp. were isolated from roots of cherry trees in New York orchards (3). Sonderhousen (21) reported that *Cylindrocarpon* spp., *Fusarium* spp., and *Papulospora* spp. were most frequently isolated from roots of apple seedlings grown in New York apple orchard soils. Isolates of these genera accounted for about 40% of all isolates recovered.

The objectives of this investigation were: (i) to reproduce replant diseases of fruit trees under controlled conditions, (ii) to determine the nature of the replant problem (specific or nonspecific), and (iii) to attempt to show if it is caused by plant parasitic nematodes alone or in association with other soil microorganisms.

MATERIALS AND METHODS

Soils were collected from apple, pear, and cherry orchards near Alton, Wayne County, New York in the fall of 1969 and 1970. These orchards showed characteristic replant disease symptoms. Top growth of such trees was uneven and poor and the roots were necrotic and small with very few branches. Samples were taken from the top 30-cm of soil under poorly growing trees. These soils were passed through a 6.4-mm screen and each was mixed thoroughly. The pipette method for particle size analysis (1) was used to determine soil texture. Chemical properties of the tree orchard soils were provided by the Soil Test Laboratory, Department of Agronomy, Cornell University, Ithaca, NY 14853.

Four soil treatments were evaluated in 1969 and 1970. These were: (i) nontreated check, (ii) steam-treated, (iii) chloropicrin (CP trichloronitromethane, 421 liters/ha), and (iv) DD (1,2-dichloropropane and 1,3-dichloropropene, 421 liters/ha).

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Soils were placed in glazed clay crocks (30-cm long and 20-cm in diameter) and treated. The two fumigants were pipetted into a 7.5-cm-deep hole in the soil at the center of each crock. All crocks were enclosed immediately after treatments in large double plastic bags. The soil temperature at treatment time was 23 C and soil moisture was about field capacity. One additional soil sample was sterilized by autoclaving for 90 min at 120 C and 1.05 kg/cm^2. The untreated and steam-treated soils also were enclosed in plastic bags. All treatments were incubated for 2 wk at 20 to 24 C. After incubation, all soils were aerated, mixed thoroughly, and placed in 10-cm clay pots (500 ml soil/pot).

Seeds of Cortland apple, Barlett pear, and Montmorency cherry were soaked overnight in water, treated with captan 50 WP, placed in plastic bags containing moist peat moss, and stored in a cold room at about 5 C until a high percent of seed germination had occurred. Small seedlings (1-2 cm long) were planted in 6-cm diameter clay pots filled with steam-treated sandy loam soil. These pots were placed in large flats containing sterilized Vermiculite to prevent drying. The flats were kept in a growth chamber maintained at 21 C for 24 days. Then one seedling was transplanted into each 10-cm pot filled with one of the orchard soils. For each soil, treatments were replicated five times for each tree crop. Seedlings comparable in size and vigor were selected for each treatment. Experiments were conducted in a growth chamber at 21 C, 50-55% relative humidity, and 21,520 lx fluorescent light 12 hr/day. Pots were watered twice daily and fertilized with about 50 ml/pot of a complete fertilizer (16-32-16) once every 2 wk.

The experiments were terminated 12 wk after transplanting. Plant height and top weight were recorded. The roots were washed, weighed, and rated on a scale of 1 to 5 for both necrosis and size. A rating of 1 referred to smallest or most severe necrosis, whereas a rating of 5 indicated the largest or least necrotic root system. Soil population densities of plant parasitic nematodes were determined using the Seinhorst elutriation technique (20). Nematode counts were made prior to soil treatments, at planting time, and at harvest time. The number of *P. penetrans* per root system or per gram root tissue was determined by a shaker technique. Feeder roots of each seedling were cut into small segments, placed in water, and incubated for 72 hr at room temperature on a Burrell wrist-action shaker. A portion of the resultant nematode suspension was placed in a counting dish and the nematodes were counted using a binocular microscope. Where appropriate, data were analyzed by the Waller-Duncan's Bayesian K-ratio (LSD) rule (22).

RESULTS

Plant growth.—Height, top weight, and root weight of apple and pear seedlings grown in the apple replant soil treated with CP and steam were higher than those grown in nontreated or DD-treated apple soil (Fig. 1). Similar growth responses of apple and pear seedlings also were obtained in the pear and cherry replant soils. Generally, seedlings grown in DD-treated soils were better than those grown in the untreated soils. Rating of roots for size and necrosis gave results similar to those obtained from weight measurements. Roots of seedlings grown in CP- and steam-treated soils were larger and white to yellow in color. In contrast, roots of seedlings grown in the nontreated check soils were smaller and necrotic. Growth of apple and pear seedlings in the DD treatment was less than the growth of seedlings in the CP and steam

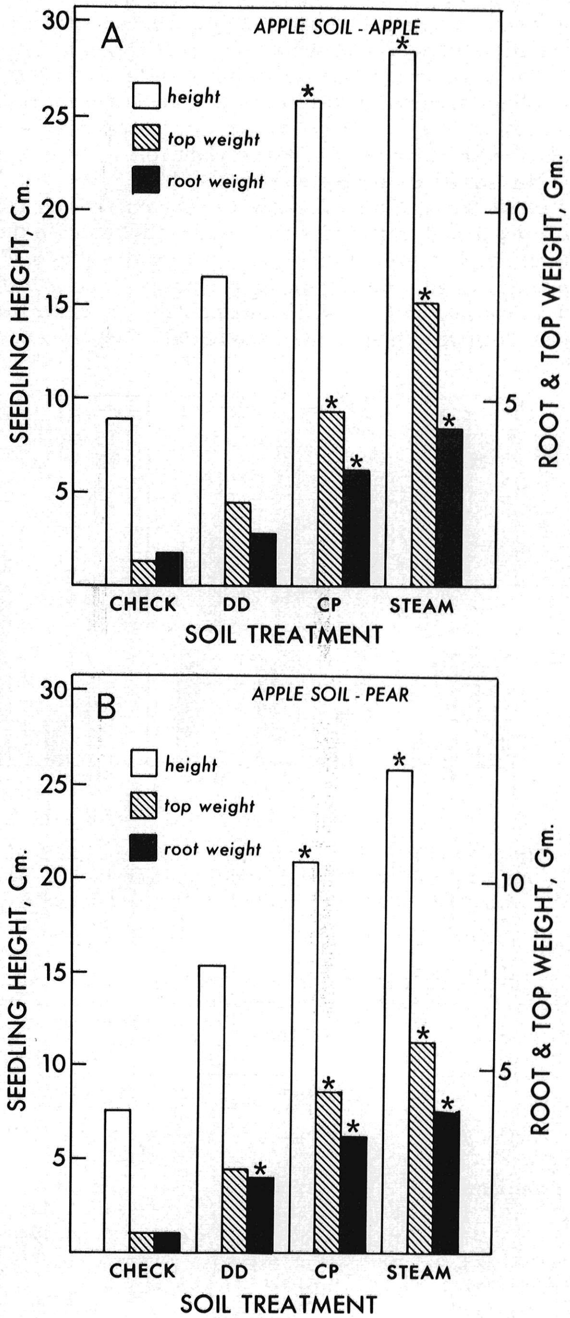

Fig. 1-(A, B). Growth of apple and pear seedlings grown in **A**) apple and **B**) pear orchard soils nontreated or treated with DD, chloropicrin, or steam in 1969. Data were analyzed by the Waller-Duncan's Bayesian K-ratio (LSD) rule (22). Asterisk (*) indicates significant differences ($P = 0.05$) from the control.

treatments, but it was considerably better than the growth of seedlings transplanted to the nontreated check soils. For example, the necrosis index of apple roots from seedlings grown in nontreated and DD-, CP-, or steam-treated apple replant soil (1969) was 1.8, 3.2, 4.2, and 4.2, respectively. Similarly, the size index of the same roots was 1.3, 2.6, 4.0, and 4.6, respectively. Similar results were obtained when this experiment was repeated in 1970; however, the weight data were not as conclusive due to variation that occurred within replicates (Fig. 2).

The most severe damage to apple, pear, and cherry seedlings occurred in the nontreated apple replant soil. Similarly, the best response to soil treatments was obtained by treating the apple replant soil.

Nematode populations.—*Pratylenchus*, *Paratylenchus*, *Xiphinema*, and *Criconemoides* were the plant parasitic nematodes most frequently found in the three orchard soils (Table 1). Population densities of *P. penetrans* and *Paratylenchus* spp. (mostly, *P. projectus*) were considerably higher in the apple than in either the pear or cherry replant soils. Although 500 *X. americanum* were recovered from 250 cm^3 of nontreated cherry soil, only 10 were found in the pear soil and none in the apple soil. In addition, the cherry soil had a very low population of *Criconemoides* spp.; however, this nematode was not recovered from either the apple or pear soils.

The steam, CP, and DD treatments were equally effective in reducing the populations of plant parasitic nematodes in the three soils (Table 1). Furthermore, the number of nematodes in these treatments remained very low even after growing apple, pear, and cherry seedlings in the soil for 12 wk (Table 2). Seedlings growing in soils treated with steam, CP, or DD had lower number of *P. penetrans* per gram of root tissue than the check (Table 3), although CP was not as effective as the steam or DD.

Physical and chemical characteristics of soils.—The apple, pear, and cherry soils were classified as a sandy loam, loam, and loamy sand, respectively. Furthermore, percent (w/w) stones (caught on 2.38-mm-mesh screens) in the apple, pear, and cherry soils was 1.1, 3.1, and 5.1, respectively. Analysis of the chemical properties of these soils showed that the main difference among the three

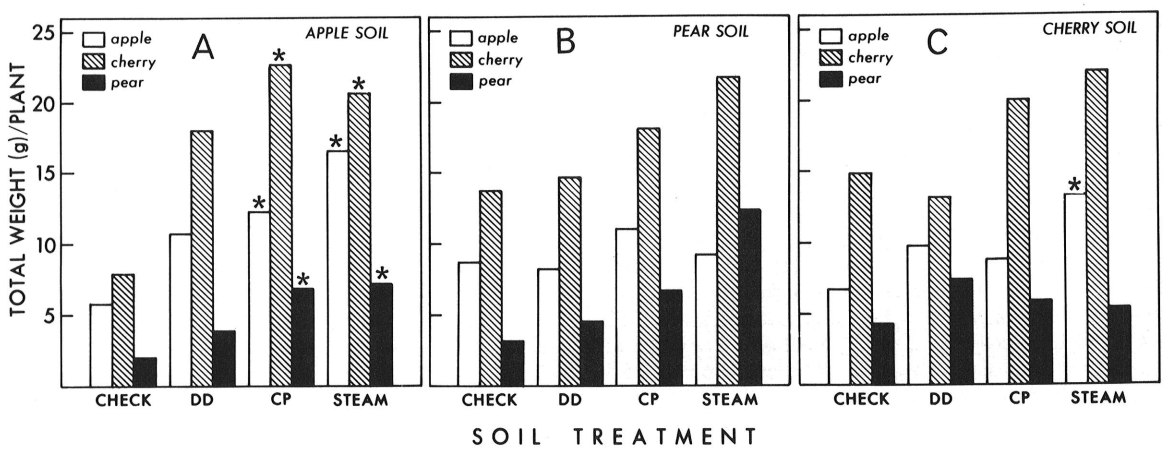

Fig. 2-(A to C). Fresh weight of apple, cherry, and pear seedlings each grown in **A**) apple, **B**) pear, and **C**) cherry orchard soils non-treated or treated with DD, chloropicrin, or steam in 1970. Data were analyzed by the Waller-Duncan's Bayesian K-ratio (LSD) rule (22). Arterisk (*) indicates significant differences ($P = 0.05$) from the control.

TABLE 1. Population densities of plant parasitic nematodes in three orchard soils after treatment with selected pesticides

Nematode genera	Orchard soil	Nematodes per 250 cm^3 soil[a]			
		Nontreated	DD	Chloropicrin	Steam
Pratylenchus	Apple	1,130	4	5	8
	Pear	125	2	0	<1
	Cherry	17	<1	3	0
Paratylenchus	Apple	1,445	59	29	4
	Pear	70	26	<1	1
	Cherry	60	3	<1	<1
Xiphinema	Apple	0	0	0	0
	Pear	30	0	0	0
	Cherry	420	0	0	0
Criconemoides	Apple	0	0	0	0
	Pear	0	0	0	0
	Cherry	0	0	<1	1

[a]Nematode counts for 1969 and 1970 generally were similar, therefore an average of the two years in presented here.

soils was in their pH. The pH of the apple, pear, and cherry soils was 7.2, 5.5, and 5.7, respectively. Also, the apple soil had a considerably higher amount of P, K, and Mg than did the pear and cherry soils.

DISCUSSION

We consider the orchard replant disease in New York to be nonspecific as indicated by the poor growth of apple, pear, and cherry seedlings grown in natural apple soil with a history of severe replant disease. Treatments of problem soil with CP or steam were equally effective and superior to the other treatments, based upon growth response of apple, pear, and cherry seedlings in the apple soil. Generally, soil treatment with DD improved plant growth. Nematode kill, however, was essentially the same with the CP, DD, and steam treatments. Thus, nematodes probably were not the only causal agents of the nonspecific replant disease in the apple soil. Apparently, a second organism(s) was present which was controlled by the CP and steam but not by the DD treatment. In a preliminary test, soil treatment with the fungicide Dexon (P-dimethylaminodiazo sodium sulfate, 33 WP) at a rate of 15.7 kg (a.i.) ha did not result in a growth improvement

TABLE 2. Effect of soil treatments with selected pesticides in three orchard soils on populations of *Pratylenchus penetrans* and *Paratylenchus* spp. nematodes in soil after 12-wk of growth of apple, pear, and cherry seedlings

Host	Nematode[b] species	Orchard soil	Nematodes per 250 cm³ soil[a]			
			Nontreated	DD	Chloropicrin	Steam
Apple	*P. penetrans*	Apple	225	0	4	7
		Pear	33	0	1	2
		Cherry	9	<1	2	1
	Paratylenchus spp.	Apple	629	1	2	2
		Pear	4	0	0	2
		Cherry	40	<1	0	1
Pear	*P. penetrans*	Apple	179	<1	2	0
		Pear	90	0	0	<1
		Cherry	7	0	<1	<1
	Paratylenchus spp.	Apple	495	<1	0	0
		Pear	9	0	0	0
		Cherry	8	0	0	2
Cherry	*P. penetrans*	Apple	454[c]	0	3	0
		Pear	8	0	0	0
		Cherry	4	0	0	<1
	Paratylenchus spp.	Apple	130	0	0	0
		Pear	25	0	1	0
		Cherry	<1	0	0	0

[a]Nematode counts for 1969 and 1970 generally were similar, therefore an average of the two years is presented here.
[b]Populations of *Xiphinema americanum* and *Criconemoides* spp. remained low in all treatments.
[c]Cherry seedlings were not included in the 1969 test.

TABLE 3. Effect of soil treatment with selected pesticides on the buildup of *Pratylenchus penetrans* in roots of apple, pear, and cherry seedlings grown for 12 wk in three different orchard sites with a replant disease problem

Host	Orchard Soil	*P. penetrans* in root tissue[a]			
		Nontreated (no./g)	DD (no./g)	Chloropicrin (no./g)	Steam (no./g)
Apple	Apple	993	1	75	1
	Pear	147	<1	<1	4
	Cherry	39	<1	<1	1
Pear	Apple	1,078	<1	249	2
	Pear	530	0	15	4
	Cherry	73	<1	0	12
Cherry	Apple	3,039[b]	<1	24	0
	Pear	580	0	<1	0
	Cherry	48	<1	0	0

[a]Nematode counts for 1969 and 1970 generally were similar, therefore an average of the two years is presented here.
[b]Cherry seedlings were not included in the 1969 test.

of apple, cherry, or pear seedlings over those growing in nontreated soils (Mai and Abawi, *unpublished*). Dexon is known to be effective only against pythiaceous fungi. Perhaps a microorganism other than a pythiaceous fungus was involved in the replant disease or that it may have been necessary to control the nematode, the incitor of the disease, to obtain a growth response from controlling other organisms. Previously Hoestra (4) and Savory (17, 18, 19) concluded that toxins or plant nutrients were not major factors in specific and nonspecific replant diseases or at least in the differential growth response of fruit trees obtained from soil treatments with different fumigants.

Growth of apple, pear, and cherry seedlings was poorest in nontreated soil, and their response to fumigation was highest in the apple soil as compared to those growing in the pear and cherry soils. Several factors may be involved in this differential growth response in the three soils. First, the population of *P. penetrans* was found to be much higher in the apple soil. Since Mai and coworkers (5, 7, 8, 9, 11, 14, 15) demonstrated that *P. penetrans* causes considerable damage to fruit trees under both natural and greenhouse conditions, this may have been an important factor.

The difference in growth response might have been due to differences in soil texture. The apple soil was sandy loam, whereas the cherry and pear soils were loam and loamy sand, respectively. Population densities of *Pratylenchus penetrans* are known to increase more rapidly and to higher levels and thus cause greater damage in sandy soils. Also, soil texture effects soil hardness and drainage which could also influence growth of trees and their response to treatments. In fact, the pear soil drained poorly, and this could have been a major factor in the poor performance of fruit trees in this soil. Difference in the pH of these soils may have had some unknown effect on growth of fruit trees.

It also is possible that an unknown biological agent(s) that operated in the apple soil was absent, present in lower numbers, or suppressed by other factors in the pear and cherry soils and thus was not involved to the same extent as in the apple replant soil. More research is needed to further study the role of other biological agents in addition to *P. penetrans* in the replant diseases of fruit trees in New York. These organisms need to be isolated and identified to determine their role in the replant problem, including the interaction with nematodes and other soilborne organisms.

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