Effect of Soil Fumigation on the Apple Replant Disease in Washington

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ABSTRACT

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Chloropicrin and methyl bromide soil fumigation controlled the apple replant disease in Washington apple orchards. Nematicidal rates of Telone (1,3-dichloropropene, and related chlorinated hydrocarbons) failed to control this disease, which eliminated the possibility that nematodes are involved. Some biotic factor, not arsenic, may be the primary cause of the apple replant problem in the irrigated areas of eastern Washington, but no specific microorganism has been identified.

The growth of young apple trees on sites previously planted to apples, *Malus domestica* Brokh., in Washington frequently is moderate to poor. This problem has been recognized since the early 1930s and soil arsenic (As) toxicity has been considered to be the major cause (1). Benson (1) noted that apple seedlings planted in old orchard soils containing As seldom reached theoretical growth potential. Numerous researchers (4,5,8–11) have shown responses of perennial crops to soil fumigation under replant situations. In the case of apples, part of this replant disease complex has been termed "specific apple replant disease" (SARD) in Europe (4). The following studies were undertaken to determine if SARD occurs in the As-contaminated orchard soil in Washington. A report of the greenhouse phase of this work was published previously (2).

MATERIALS AND METHODS

Fumigation plots (Exp. 1) were established (in April of 1970) on former apple orchard soil at the Tree Fruit Research Center, Wenatchee, Washington. The soil As level was moderate to high, ranging 72–504 μg/g in the surface 30 cm. Treatments at this location consisted of: chloropicrin, 224 K/ha; Telone (1,3-dichloropropene plus related chlorinated hydrocarbons), 300 l/ha; replacement of the soil with approximately 0.14 m^3 ($0.52 \times 0.52 \times 0.52$ m) of non-orchard soil (new soil) at the planting site; and a check in which trees were planted in untreated soil. Each of eight replicates contained four trees except in the new-soil treatment for which only one tree was planted per replicate.

In the spring of 1972 additional paired chloropicrin plots (Exp. 2) were established in apple soil (soil previously planted to apples, and on adjacent sweet cherry soil (soil previously planted to sweet cherries). The As levels were low in both soils, 10 μg/g and only a trace, respectively. Treatments were replicated three times on each soil. Cherry and apples were planted alternately in each treatment site. Five trees of each species were planted in each subplot 21 days after fumigation.

In both experiments, the fumigant was shank-injected (~ 17 cm deep on 30.5-cm centers) into the soil, the surface was rototilled 5 cm deep, and then sealed with a power-driven roller. The width of the fumigated strips was 3.6 m and the length varied according to number of trees. The tree spacing was 1.5 m and one additional tree space was left at the beginning and at the end of each treated strip.

In the spring of 1972 a series of methyl bromide fumigation plots (Exp. 3) was established and the chemical was applied with a soil injection probe (7). Each tree site was treated with 454 g of fumigant injected at a single point 45–60 cm deep. The injection hole was sealed by the wood stake which marked the planting site. After 3–5 wk the trees were planted without further treatment. One tree was planted at each of ten fumigated and untreated check sites in each of five orchards.

The apple trees used for all experiments reported in this paper were various clones of Delicious grafted on seedling rootstock. The cherry (*Prunus avium* L.) cultivar was Bing grafted on Mazzard rootstocks. The trees were planted so that the bud union was slightly below (2.5–5.0 cm) ground level.

Soil samples were taken from each orchard for nematode and As assays. Fifteen to 20 core samples were taken with a 1.9-cm diameter soil tube from the surface 30 cm at each sampling site. In 1970, soil samples also were collected from the 30 to 60 cm depth. The soil samples were mixed and subsampled for both nematodes and As analysis. Nematode counts were based on 50 g of dry soil processed by a modified Baermann pan technique (12). Arsenic was analyzed by the Gutzeit method, modified by the use of silver diethyldithiocarbamate reagent (13).

Disease control was determined by growth measurement. Growth of trees following fumigation was determined as follows:

(i) Tree trunks were marked approximately 5 cm above the ground with paint.

(ii) Trunk circumference (in centimeters) was determined at that point at the time of planting.

(iii) Circumferences were taken at the same point at the end of each growing season for the duration of the test.

The growth response was arbitrarily considered positive when growth of the treated trees exceeded that of the nontreated trees by at least 50 percent.

RESULTS

Data from the fumigation established in 1970 (Exp. 1) are summarized in Tables 1 and 2. By the end of the second season, the average growth of trees planted in the "non-orchard" soil treatments was superior to that in all other treatments, with a trunk circumference increase of 4.68 cm. Those planted in chloropicrin-treated soil had a trunk circumference increase of 2.8 cm compared to 2.09 cm and 1.49 cm for those in the Telone and control treatments, respectively. The new-soil and chloropicrin treatments met our arbitrary criterion for positive disease control; their growth exceeded that of the check by $>50\%$.

The tree growth difference between the chloropicrin and new-soil treatments could be attributed to arsenic in the old orchard soil (at a mean level of 193 ppm). This level of As will reduce growth of

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trees in the absence of biotic factors. Levels of As seldom exceeded 200 μg/g in old orchard soils in eastern Washington.

At the site planted in 1970 the number of nematodes recovered from that site was low (Table 2) and no general conclusions with respect to control could be drawn.

In Exp. 2 (the chloropicrin plot established in 1972) there was only a slight response to fumigation in the apple soil. Total trunk increase of the apple after 4 yr was 9.27 cm in the untreated plot, but that of the trees in the chloropicrin plot was 11.06 cm. Thus, 4 yr after planting, apple trees growing in the fumigated soil were only 19% larger than those growing in untreated soil. There was even less response in the growth of cherries or apples on cherry soil.

The growth response of apples to single point injections of methyl bromide (Exp. 3) is presented in Table 3. Also included in Table 3 are the nematode counts and mean As levels in the five treatment sites. The nematode and As samples were taken 12–14 mo after planting. At the end of the fourth growing season, trunk circumference was increased from 55–168% following methyl bromide fumigation. These five sites represented a wide range of As levels; the means ranging from a low of 10 μg/g to a high >200 μg/g. The mean As content of the methyl bromide-fumigated soil was only slightly higher than that of the nonfumigated soil, and that small difference was not considered significant. Three years' data from the Okanogan River Valley paralleled those obtained for the five sites presented in Table 3 with respect to nematodes, As, and growth response.

Root lesion nematodes (*Pratylenchus* spp.) were recovered from soil at all five sites (Table 3). In sites 1 and 2 the level of parasitic nematodes was considered to be too low to be of economic importance. At sites 3, 4, and 5 *Pratylenchus* spp. may approach economic levels. Additional information is needed on the levels and role of plant parasitic nematodes in the apple replant problem.

DISCUSSION

The apple replant problem in eastern Washington is complex and involves both biotic factors and As. Control with general biocides such as chloropicrin and methyl bromide would indicate that this replant problem is similar to or identical to the SARD reported from Europe. In two orchards with a severe replant problem, heat also controlled the agent. In those orchards tree growth was minimal except where the stump piles had been burned when the old orchards were removed. Bollard (3) reported that a replant problem in New Zealand was overcome by steam sterilization.

While there is no doubt that As contributed to the poor growth of apple trees in old apple soil in Washington, it can be concluded from our data that under most situations it is not the major limiting factor. This conclusion can best be illustrated by the data from Table 3, Orchard 3, which show adequate commercial growth of trees growing in fumigated soil, even though the As content of the soil was above 200 μg/g.

Comparison of data of Exp. 2 and 3 shows that a replant problem does not exist in all old Washington apple soils. Although there was only a slight response to fumigation in Exp. 2, the tree growth was comparable to that of the trees grown in fumigated sites in Exp. 3.

The cause of the apple replant disease in Washington is still

TABLE 1. Fumigation effects on apple replant disease in Washington. Increase in trunk circumference of apple trees at the end of the second growing season, number of dead trees, and arsenic content of orchard soil

Soil treatment	Increase in trunk circumference[a] (cm)	Dead trees (no.)	Soil arsenic μg/g	
			Mean	Range
New soil	4.68 a	0	0	0
Chloropicrin	2.82 b	2	193	82–450
Telone	2.09 c	6	202	113–504
Check	1.49 c	7	170	72–420

[a] Mean of eight replications with single-tree replications for the new soil treatment and four trees per replication for each of the other treatments. Numbers followed by different letters are significantly different, $P = 0.01$.

TABLE 2. Fumigation effects on nematodes in apple orchard soil with a history of apple replant disease in Washington. Nematodes recovered at two depths following soil fumigation treatments applied in 1970

Soil treatment	Topsoil (10–30 cm)[a]		Subsoil (30–60 cm)[a]	
	Pa[b]	Pr[c]	Pa[b]	Pr[c]
New soil	0	0	2.5	10
Chloropicrin	0	3.2	0	0
Telone	2.5	0	0	2.5
Check	2.5	0	7.5	8.7

[a] Based on number of nematodes recovered from 50 grams of soil 2 mo after fumigation. Data represent an average of eight replications of each treatment.
[b] *Paratylenchus* spp.
[c] *Pratylenchus* spp.

TABLE 3. Growth of apple trees in five apple orchards with histories of apple replant disease following soil fumigation with methyl bromide

Orchard	Treatment	Total tree growth[a] (cm circumference)				Percent of check	Nematode populations[c] (50 g soil)		Arsenic[d]
		1972	1973	1974	1975[b]		Pr	Pa	μg/g
1	MB	0.60	5.45	8.63	11.84	155	8	2	60.6
	Check	0.20	1.76	4.45	7.63		6	4	42.2
2	MB	1.37	4.53	8.31	13.32	174	0	0	77.6
	Check	0.50	1.87	3.91	7.65		6	0	68.4
3	MB	0.24	2.86	6.70	10.26	234	0	0	213.8
	Check	0.23	1.40	3.04	4.39		30	0[e]	232.0
4	MB	0.88	2.39	4.40	6.77	268	0	0	88.2
	Check	0.42	0.57	1.34	2.53		54	12	66.3
5	MB	0.75	3.03	6.95	9.55	154	0	0	<10.0
	Check	0.58	2.16	4.38	6.20		42	0	<10.0

[a] Increase in trunk circumference (centimeters) (average of 10 single-tree replications).
[b] The difference in total growth between check and methyl bromide treatments within each orchard was significant, $P = 0.01$, in 1975.
[c] Abbreviations: Pr = *Pratylenchus* spp.; Pa = *Paratylenchus* spp.; bulk sample from 10 sites collected 12–14 mo after planting.
[d] Average of 10 samples.
[e] Eighteen *Tylenchorynchus* spp. nematodes were counted in this sample.

unknown. The comparatively low number of nematodes recovered from most of the experimental orchards, and the lack of growth response to Telone, led us to believe that nematodes are not a primary cause of this disease.

Although nematodes are a problem on apples elsewhere (5,6), little data have been published on the direct effect of plant parasitic nematodes on the growth of apples in the irrigated areas of eastern Washington, and no information is available on the interaction of nematodes and As. Greenhouse and field experiments currently are underway to determine the role of As and the nature of the biotic factors, including nematodes, in the SARD as it exists in old apple soil in the irrigated areas of eastern Washington.

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