Further studies on replant disease of apple in Nova Scotia[1]

R. G. Ross and A. D. Crowe

Growth of newly planted apple trees in orchards from which a pot test had shown an apple replant problem was significantly better at soil sites fumigated with chloropicrin than at nonfumigated sites. In a 6-year-old orchard poor tree performance was associated with a replant problem that did not appear to be caused by nematodes. Growth was less at high arsenic soil sites but it was not proven that arsenic was responsible.

Can, Plant Dis. Surv. 56: 88-92. 1976

La croissance de pommiers nouvellement plantes en vergers dans lesquels on avait constaté des difficultes de reprise a ete significativement meilleure dans les parcelles fumigees a la chloropicrine que dans celles non fumigees. Dans un verger de six ans, la mauvaise croissance des pommiers a ete associee a un problème de replantation qui ne semble pas être cause par les nematodes. La croissance a été moins rapide dans les sols a forte teneur en arsenic, mais il n'a pas ete prouve que cet element était en cause.

In an earlier paper, we showed that a replant problem exists in Nova Scotia apple orchards (9) but did not definitely establish that specific apple replant disease (SARD) (5,10) was present; however in a pot bioassay, apple seedlings grew much better in most orchard soils fumigated with chloropicrin than in nonfumigated soils. The possible causes of specific apple replant disease have received a lot of attention, with no one causal factor being identified (10). Recently Sewell and Wilson (11) have shown ***Thielaviopsis basicola*** (Berk. & Br.) Ferraris to be the probable causal agent of specific replant diseases of cherry and plum, but this fungus had no effect on the growth of apple.

This paper reports further investigations on the replant problem in apple orchards in Nova Scotia.

Materials and methods

The greenhouse pot bioassay method was essentially that used in previous work (9). Soil was fumigated with chloropicrin in glass jars or in the field and a comparison was made of the growth of Beautiful Arcade (BA) apple seedlings in fumigated and nonfumigated soil. Ten 11.5-cm clay pots each containing 500 cc of soil were used for each treatment and randomized in blocks on the greenhouse bench. The fumigants ethylene dibromide and Vorlex (methyl isothiocyanate 20% + 1,3 dichloropropene and related C_3 hydrocarbons 80%, Nor-Am) were used as described for chloropicrin (9). Benlate 50W (benomyl 50%, Dupont) and Dasanit 10G (fensulfothion 10%, Chemagro) were mixed with the soil just before potting.

Fumigation of tree planting sites with chloropicrin was done as described by Pitcher and Way (8). The land was first cultivated to a fine tilth to a depth of about 23 cm, and an area of 137 cm x 137 cm was fumigated by injecting with a hand injector, at a depth of 15 cm, 1.5 ml chloropicrin per 22.9 cm^2, totalling 54 ml per tree site. Treatment was facilitated by using a square fiberboard templet with 36 holes, on 22.9 cm squares, through which the hand injector was inserted, and with a hole in the center to fit over a stake marking each planting site. The soil was fumigated when moist but not wet. After fumigation the surface of the soil was compacted by tramping or by overlapping passes with a garden tractor fitted with wide rubber tires.

Arsenic content of the soil was determined using the arsine-molybdenum blue procedure given by Hoffman and Gordon (4). Samples for water soluble arsenic were prepared by shaking 50 g of air dried sieved soil with 500 ml water for 8 h, letting stand overnight and then filtering. For total arsenic, the soil was digested with nitric, sulphuric, and perchloric acids to solubilize the arsenic, and the digests were made to suitable volumes with 1 N HCl. Populations of the nematode ***Pratylenchus penetrans*** (Cobb) Filip, and Stek. were determined as outlined by Townshend (12).

Two apple orchards, A and B, both on sandy loam soil, were used. Orchard A, located at Woodville, N.S., had been planted to McInrosh apples on BA seedling rootstock in 1968, and subsequent variation in the growth of the trees (Table 1) suggested a replant problem. Orchard B, located at the Agriculture Canada Research Station, Kentville, N.S., was cleared of apple seedlings in 1972, and previous work showed that it had a replant problem (Orchard I in our earlier study [9]). Soil from another orchard (C) at Woodville with a suspected replant problem was used in one test.

Results

In 1973 the replant bioassay was done on soil from under five trees in row 1 of orchard A. The tree locations

[1] Contribution No. 1580, Research Station, Agriculture Canada, Kentville, Nova Scotia B4N 1J5

Table 1. Trunk cross-sectional area of McIntosh apple trees at five sites in Orchard A; growth of BA* apple seedlings in a pot bioassay, and pH, nematode population, and arsenic content of soil samples from each site

Tree†	Trunk cross section (cm^2)	Length of BA* seedlings (cm) Fumigated	Nonfumigated	pH	*Pratylenchus penetrans* no./kg dry soil	Arsenic (ppm) Total	Water soluble
12	67	47.1	17.2	6.3	6332	15.8	0.25
20	70	44.9	24.1	6.2	2190	17.4	0.58
27	35	43.1	8.3	5.2	3656	68.5	1.54
30	24	51.7	3.5	5.6	9957	97.0	2.21
36	29	56.8	15.3	5.4	598	75.3	2.43

* Beautiful Arcade
† Tree no. in row 1

in the row and the cross-sectional area of each tree trunk measured about 30 cm above ground level are given in Table 1. Arsenic analyses were done on the bioassay soil samples, and nematode counts were made on soil collected in June 1974.

The data on trunk cross section (Table 1) show the variation in growth among the trees in the row. When BA apple seedlings were grown in nonfumigated soil and in chloropicrin-fumigated soil from under these trees, there were significant (P.05) differences among nonfumigated soils and a highly significant (P.01) response to fumigation of soil from each site. There were no differences in the growth of the seedlings among the fumigated soils from the five sites. The pH tended to be lower and the arsenic levels lhigher in the areas of poorer tree growth. There was considerable variation in numbers of nematodes among the tree sites with the lowest count in soil from tree 36, which had made poor growth.

In 1974 the pot bioassay was done on soil from tree 30 in orchard A and on soil from orchard C that had received the treatments given in Table 2 and Figure 1. The results show that orchard C had a replant problem similar to that of tree 30 in orchard A. In soil from both orchards the fungicide Benlate had no effect on the growth of the apple seedlings and, while there appeared to be a slight response to the nematicide Dasanit, growth was not significantly different from that in nontreated soil. The three fumigants all gave a marked response, with small differences in seedling growth.

In orchard A the effect of field fumigation on the growth of apple trees was tested at 13 tree sites 2.7 m apart in a row adjacent to trees 30 and 36. On 10 October 1974, alternate tree sites were fumigated with chloropicrin. Soil temperature was 10.5°C. On 12 November soil for pot bioassays was taken from tree sites 2, 6, and 12 (fumigated sites) and 1, 5, and 11 (nonfumigated sites). On 12 May 1975, uniform maiden whips of Northern Spy apple trees on Malling 7A rootstock were planted at each of the 13 tree sites and headed back to about 60 cm. At the end of the growing season the length and number of shoots were recorded for each tree.

In the growth of the Spy trees in the field (Table 3) there was generally a marked response to soil fumigation with chloropicrin. At nonfumigated sites, growth varied from good at site 3 to poor at sites 11 and 13. In the pot bioassay, growth of BA seedlings in soil from the three field-fumigated sites was almost identical, whereas in soil from nonfumigated sites growth was variable and reflected that of the Spy trees in the field (Table 3). Growth of BA seedlings in greenhouse-fumigated soil was superior to that of seedlings grown in soil from field-fumigated sites.

Another test on the effect of field fumigation on the growth of apple trees was done in orchard B in conjunction with a paired observation trial of 10 apple strains and cultivars on BA rootstocks. Twenty planting sites 2.7 m apart were laid out in a single row and divided into adjoining pairs. On 5 May 1974, one site of each pair chosen at random was fumigated with chloropicrin. Soil temperature was 5°C and soil pH 6.0. Maiden whips of the 10 strains and cultivars were planted in pairs on June 5 with one whip of each pair being assigned at random to a fumigated site. Extension shoot growth was measured in the fall of 1974 and 1975.

In the first year all except 2, Jonagold and Kress McIntosh, of the 10 selections showed a growth response to fumigation with chloropicrin (Table 4). However, in the greenhouse bioassay BA seedlings grown in soil from the fumigated sites of these two selections showed the same response as those in soil from other fumigated sites. With these two selections the response to fumigation came in the 2nd year when growth was considerably greater at the fumigated than at the nonfumigated sites.

Sites for another paired observation trial in orchard B, using the same layout as above, were fumigated with chloropicrin on 8 October 1974. Soil temperature was

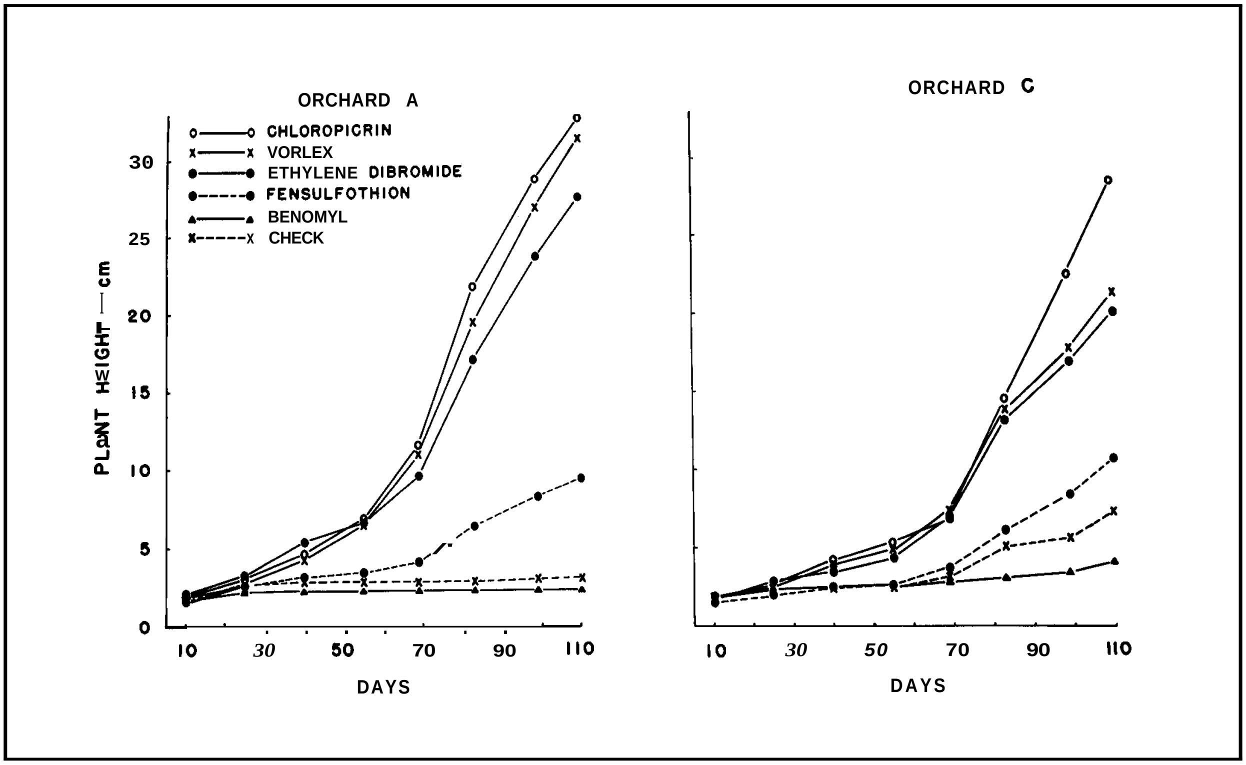

Figure 1. Growth of Beautiful Arcade apple seedlings in a greenhouse test with soil from orchard A (tree 30) and orchard C

Table 2. Pot test with Beautiful Arcade apple seedlings grown in soil from two locations receiving diffe- rent treatments

Treatment	Dose/liter of soil	Growth of seedlings (cm)		
		Tree 30 Orchard A	Orchard C	Mean
Chloropicrin	0.20 ml	32.7	28.4	30.5 a
Ethylene dibromide	0.50 ml	27.5	20.1	23.8 b
Vorlex	0.50 ml	31.3	21.2	26.3 ab
Benlate 50W	0.50 g	2.4	4.2	3.3 d
Dasanit 10G	0.25 g	9.4	10.8	10.1 c
Check		3.1	7.3	5.2 cd

The small letters indicate treatments which do not differ significantly at the 0.05 level according to Duncan's Multiple Range Test.

12°C. Immediately following fumigation the fumigated sites were covered with polyethylene sheeting which remained in place over winter. On 4 November soil for greenhouse tests was taken from a fumigated plot and from a nonfumigated plot at each end of the row. Also included in the pot bioassay were samples of greenhouse-fumigated soil from sites that had not been treated in the field.

There was no significant difference between the height of seedlings grown in greenhouse-fumigated and field-fumigated soils but there was a significant difference (P.01) between growth in fumigated and nonfumigated soils (Table 5). Maiden whips were planted at these sites in the spring of 1975, but because of adverse growing conditions they did not grow satisfactorily and put out little or no extension growth.

Discussion

This investigation has not met the criteria needed (5,10) to definitely establish that specific apple replant disease (SARD) is present in Nova Scotia. Nevertheless, at sites where a pot bioassay for SARD indicated a replant problem, fumigation of the planting site with chloropicrin resulted in a marked increase in the growth of apple trees (Tables 2 and 3). Field fumigation with chloropicrin tended to equalize any variability among planting sites.

The variation in the growth of the McIntosh trees planted in orchard A in 1968 (Table 1) was also probably due to

Table 3. Effect of fumigation (F) with chloropicrin on the extension growth of Spy apple trees in orchard A and of Beautiful Arcade apple seedlings in pots of soil from that orchard

Site No.	Spy shoot growth		BA seedlings in pots of soil		
	No.	Length (cm)	Field fumigated	Greenhouse fumigated	Not fumigated
1	6	136		38.4	21.2
2 (F)	7	262	30.6		
3	9	320			
4 (F)	8	268			
5	9	151		46.8	17.5
6 (F)	14	346	30.3		
7	7	185			
8 (F)	7	234			
9	5	186			
10 (F)	5	230			
11	4	79		52.3	7.3
12 (F)	6	213	30.6		
13	6	79			

Table 4. Effect of field fumigation with chloropicrin on the performance of 10 strains and cultivars of apple trees in orchard B

Soil treatment	Average no. of shoots per tree		Length of shoot growth per tree (cm)	
	1st yr	2nd yr	1st yr	2nd yr
Fumigated	15.2	34.3	121.6	1037.9
Nonfumigated	10.1*	27.4	63.7**	757.7*

*P 0.05;**P 0.01

a replant problem. Tree sites 27, 30, and 36 were definitely in a replant area but it is not known if the area of sites 12 and 20 had been in orchard. The arsenic levels were not particularly high compared to those reported by Benson et al. (2). They found that arsenic was more toxic to growth in alkaline than in acid soil. They suggested that if the arsenic content was not over 100 ppm and the soil pH was less than 6.5, fumigation with methyl bromide would alleviate the replant problem; otherwise the soil at the planting site should be replaced with arsenic-free soil (2). In composite samples of Nova Scotia apple orchard soils Bishop and Chisholm (3) reported total arsenic levels ranging from 9.8 to 124.4 ppm.

According to Hoestra (5) *P. penetrans* is the most important nematode in apple orchards in the Netherlands and can cause serious damage to trees grown on light soils. The numbers reported here (Table 1) indicate a heavy infestation (5, 7) but there was no correlation between numbers and tree performance. In the pot bioassay the nematicide Dasanit did not significantly improve apple seedling growth in soil from the site most heavily infested with *P. penetrans* (Table 2, Fig. 1), although the fumigants ethylene dibromide and Vorlex gave a good response. These fumigants have generally not given as good a response as chloropicrin in the treatment of replant disorders (5, 10). The seedlings did not respond to the fungicide Benlate, which has been used successfully to control cherry replant disease caused by the fungus *Thielaviopsis basicola* (11).

In the paired observation trial in orchard B (Table 4) there was a good response in tree growth to field fumigation with chloropicrin. Most selections responded in the first year, but in two selections the response did not occur until the second year after planting. It had been thought that replant disease affected trees only in their first or second year, but Jackson (6) has recently shown that in later years growth was directly related to the size of the fumigated area.

Despite the fact that the cause of replant disease of apples in Nova Scotia is not known, the pot bioassay should be useful to indicate if a replant problem exists. Field fumigation with chloropicrin appears to alleviate the problem but further work is required to determine if one or more factors such as SARD, soil arsenic, and nematodes are the cause of the replant problem in Nova Scotia.

Table 5. Height (cm) of BA apple seedlings grown in soil from orchard B fumigated with chloropicrin in the field and in the greenhouse

Treatment	Site 1	Site 2	Mean
Field fumigated	13.3	14.8	14.1
Greenhouse fumigated	17.5	18.2	17.8
Nonfumigated	3.2	8.6	5.9

Acknowledgments

The authors thank the following from the Research Station, Kentville, N.S.; D. Chisholm for the arsenic analyses, G. L. Brown for the statistical analyses, D. N. Crouse and R. J. Newbery for technical assistance, and J. Kimpinski, Research Station, Charlottetown, P.E.I. for determining the nematode populations.

Literature cited

1. Anonymous. 1974. Replant disease in cherry rootstocks controlled with Benlate drench. The Grower 82:513.
2. Benson, D. N. R., R. P. Covey, and W. A. Haglund. 1974. Soil fumigation helps replants in old apple orchards. The Goodfruit Grower 24:7-8.
3. Bishop, R. F., and D. Chisholm. 1962. Arsenic accumulation in Annapolis Valley orchard soils. Can. J. Soil Sci. 42:77-80.
4. Hoffman, I., and A. D. Gordon. 1963. Arsenic in foods: Collaborative comparison of the arsine-molybdenum blue and the silver diethyldithiocarbamate methods. J. Assoc. Offic. Agr. Chem. 46:245-249.
5. Hoestra, H. 1968. Replant disease of apple in the Netherlands. Meded. Tab. Phytopath. 240. 105 p.
6. Jackson, J. E. 1973. Effects of soil fumigation on the growth of apple and cherry rootstocks on land previously cropped with apples. Ann. Appl. Biol. 74:94-104.
7. Mai, W. F., K. G. Parker, and K. D. Hickey. 1970. Root diseases of fruit trees in New York State. II. Populations of *Pratylenchus penetrans* and growth of apple in response to soil treatment with nematicides. Plant Dis. Rep. 54:792-795.
8. Pitcher, R. S., and D. W. Way. 1967. Replant disease - new moves against an old problem. The Grower 68:234-235.
9. Ross, R. G., and A. D. Crowe. 1973. Replant disease in apple orchard soil. Can. Plant Dis. Surv. 53:144-146.
10. Savory, B. M. 1966. Specific replant diseases. Common- W. Agric. Bur. Farnham Royal, Bucks, England. 64 p.
11. Sewell, G. W. F., and J. F. Wilson. 1975. The role of *Thielaviopsis basicola* in the specific replant disorders of cherry and plum. Ann. Appl. Biol. 79:149-169.
12. Townshend, J. L. 1963. A modification and evaluation of the apparatus for the Oortenbrink direct cottonwool filter extraction method. Nematologica 9:106-110.