Superimposed Shallow and Deep Soil Fumigation to Control *Xiphinema americanum* and Peach Rosette Mosaic Virus Reinfection in a Concord Vineyard

D. C. RAMSDELL, Professor of Plant Pathology, Department of Botany and Plant Pathology, G. W. BIRD, Professor of Nematology, Department of Entomology, J. M. GILLETT, Research Technician, Department of Botany and Plant Pathology, and L. M. ROSE, Research Technician, Department of Entomology, Michigan State University, East Lansing 48824

ABSTRACT

Ramsdell, D. C., Bird, G. W., Gillett, J. M., and Rose, L. M. 1983. Superimposed shallow and deep soil fumigation to control *Xiphinema americanum* and peach rosette mosaic virus reinfection in a Concord vineyard. Plant Disease 67:625-627.

Superimposed shallow plus deep fumigant applications 20 (8 in.) and 91 cm (36 in.) in vineyard soil from which vines uniformly infected by peach rosette mosaic (PRMV) had been removed the previous year reduced populations of *Xiphinema americanum* to zero or near zero in the top 1.8 m (6 ft) of soil for 6 yr. Deep and shallow superimposed treatments applied at high rates were Telone II, Terrocide 30D, Terrogel 67, and Vorlex. A lower rate of Vorlex (than the superimposed rate) applied shallow only failed to control *X. americanum* and reinfection in one of 40 vines by the sixth year after fumigation. Virus-free *Vitis labrusca* L. 'Concord' grapevines planted in the variously treated S plus D plots remained free of infection by PRMV for 6 yr, but in the control plot two of 16 vines became infected by the fifth season and three of 40 vines became infected by the sixth season.

Peach rosette mosaic virus (PRMV), a member of the nepovirus group (1), causes a serious disease of grapevines *Vitis labrusca* L. 'Concord' and peaches (*Prunus persica* Batsch.) in southwestern Michigan (3,7,8). Presence of the virus has been serologically confirmed in more than 25 vineyards (D. C. Ramsdell, *unpublished*) and is estimated to be in more than 50 vineyards, based on symptoms on vines. Information on ways the virus may be introduced into previously healthy vineyards has been published (7,8). The virus spreads slowly in a circular pattern in a vineyard at about one vine per year, and the nematode vector *Xiphinema americanum* Cobb. is found as deep as 213 cm (7 ft) beneath diseased vines (8). In California, long-term fallowing of soil (10 yr) failed to control *X. index* and reinfection of grapevines by grape fanleaf virus (9). Nematodes were recovered from vineyard soil after 10 yr of fallowing. The virus was detectable in old roots after as many as 5 yr of fallowing. As a result of these findings, deep-placement soil fumigation was tested as a control strategem and has given good results in controlling nematode vectors and subsequently reducing reinfection of healthy replant vines by grape fanleaf virus (5,10). In one test (10), high rates of 1,3-D fumigants were used, 307 L/ha (200 gal/acre) applied deep at 91 cm (36 in.) and 77 L/ha (50 gal/acre) applied shallow at 20 cm (8 in.). *X. index* populations were reduced to zero at depths of 2 m for 3 yr. At the end of 4 yr, no replant vines had become infected with fanleaf virus but vines in the unfumigated control area had.

In another California field test (11) involving 2,4-D treatment to kill old fanleaf virus-infected vines before their removal followed by deep (D) plus shallow (S) fumigation of soil with 383 L/ha (250 gal/acre) of 1,3-D, *X. index* populations remained at zero and replanted vines were free of disease for more than 6 yr.

Because of the success in controlling virus vectors and reducing reinfection of vines by grape fanleaf virus in California vineyards, we investigated a similar approach to the control of *X. americanum* and PRMV reinfection of replanted healthy Concord vines in Michigan.

MATERIALS AND METHODS

A vineyard containing Concord vines at least 30 yr old with several large areas of PRMV infection was chosen. A fairly uniform population (about 10/100 cm soil) of *X. americanum* (4; F. Lamberti, *personal communication*) existed beneath the diseased vines. An area of the vineyard was selected where the vines were uniformly diseased. The grower removed 10 rows of vines, each containing about 60 vines, during the fall of 1974. Crowns and major roots were removed.

The soil was thoroughly disked several times during the 1975 growing season. The area was divided into plots 12.2 × 30.5 m (0.04 ha or 0.11 acre), and on 12 October 1975, fumigants were applied as superimposed S and D applications or S only. The D applications were applied with a single shank 91.4 cm long mounted in the center of a tool bar on the rear of a 90-hp wheel tractor (Fig. 1). Deep-shank application was made on 46-cm (18-in.) centers. S applications (20.3 cm deep) were applied with a standard shank fumigant applicator (Fig. 2) with a ground-driven positive displacement pump. A total of 12 shanks on 20.3-cm spacing were used. A drag float was used to seal the soil. Soil temperature was about 13 C (55 F) and soil moisture was about 5% of field capacity. The soil was a very fine sandy loam.

The seven plot treatments were as follows: 1) Terrocide 30D (70% 1,3-dichloropropene, 1,2-dichloropropane, and related hydrocarbons plus 30% chloropicrin), 280.6 L/ha (30 gal/acre) S plus 561.2 L/ha (60 gal/acre) D; 2) Telone II (92% 1,3-dichloropropene) 280.6 L/ha (30 gal/acre) S plus 654.8 L/ha (70 gal/acre) D; 3) Telone II 280.6 L/ha (30 gal/acre) S plus 1,122.4 L/ha (120 gal/acre) D; 4) Vorlex (20% methyl isothiocyanate, 80% dichloropropenes, dichloropropane, and related chlorinated hydrocarbons) 187.1 L/ha (20 gal/acre) S plus 374.2 L/ha (40 gal/acre) D; 5) Vorlex 280.6 L/ha (30 gal/acre), S only; 6) Terrogel 67 (67% methyl bromide and 33% chloropicrin) 168.5 kg/ha (150 lb/acre) S plus 337.0 kg/ha (300 lb/acre) D, applied using pressurized nitrogen; and 7) an untreated control. The control plot consisted of areas between the old remaining vines in the border rows on either side of the fumigation plots. Both border rows contained many diseased vines with nematode populations of about 10/cm^3 of soil at the time when the vines were pulled from the fumigation areas. Disease status of these old vines had previously been determined by sap indexing on *Chemopodium quinoa* Willd. (7). A normally randomly positioned control plot was omitted to accommodate the wishes of the vineyard owner.

Michigan State University Agricultural Experiment Station Journal Article 10532.

This research was supported in part by the Michigan Grape Research Council and grants from Dow Chemical Co., Great Lakes Chemical Co., and Nor-Am Agricultural Products.

Accepted for publication 11 November 1982.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

During the spring after fumigation, virus-tested certified Concord grapevines were planted in a spacing of 2.44 × 3.05 m (8 × 10 ft) in the fumigated plots, and 45 vines were planted beneath PRMV-infected old Concord vines. Each treatment was replicated once. Further replication would have made each treatment area quite small, resulting in fumigant overlap and/or possible reinfestation by nematodes from one plot to another.

During mid-July to mid-August of 1976, soil sampling was begun on an annual basis to determine survival of *X. americanum* at depths of 15.2, 30.4, 61.0, 91.4, 122.0, and 243.8 cm (6 in., 1,2,3,4, and 6 ft, respectively). Seven aggregate samples were taken from each fumigation plot and from among the two control rows. A hand-held gasoline engine powered auger 10 cm (4 in.) in diameter was used to bore to the depth desired for sampling and then a hand-held auger was used to take the sample. Nematode extraction was done by the Jenkins sugar flotation method (2).

Beginning with the 1977 growing season, indexing was done with 40–45 vines from each fumigation plot and up to 45 vines from the control plots, depending on survival of the vines over the winter. The small control vines had some difficulties competing with the larger vines under which they were planted. Indexing was done annually through 1981 by sap inoculation to *C. quinoa* or by enzyme-linked immunosorbent assay (6).

Table 1. Survival of *Xiphinema americanum* in an untreated control plot in an old vineyard site in Lawton, MI

Soil depth sampled (cm)	No. of *X. americanum* per 100 cm³ of soil						Mean values (for 6 yr)
	1976	1977	1978	1979	1980	1981	
15.2	1.5	8.0	56.0	6.0	32.0	4.0	17.9
30.4	3.0	10.0	4.0	4.0	16.0	0.0	6.2
61.0	10.0	2.0	0.0	0.0	0.0	0.0	2.0
91.4	1.0	0.0	4.0	0.0	4.0	0.0	1.5
122.0	1.5	0.0	0.0	0.0	4.0	4.0	1.6
243.8	1.0	1.0	1.0	1.0	4.0	0.0	1.3
Σ	18.0	21.0	65.0	11.0	60.0	8.0	30.5
$\bar{X}$	6.0	3.5	10.8	1.8	10.0	1.3	5.1

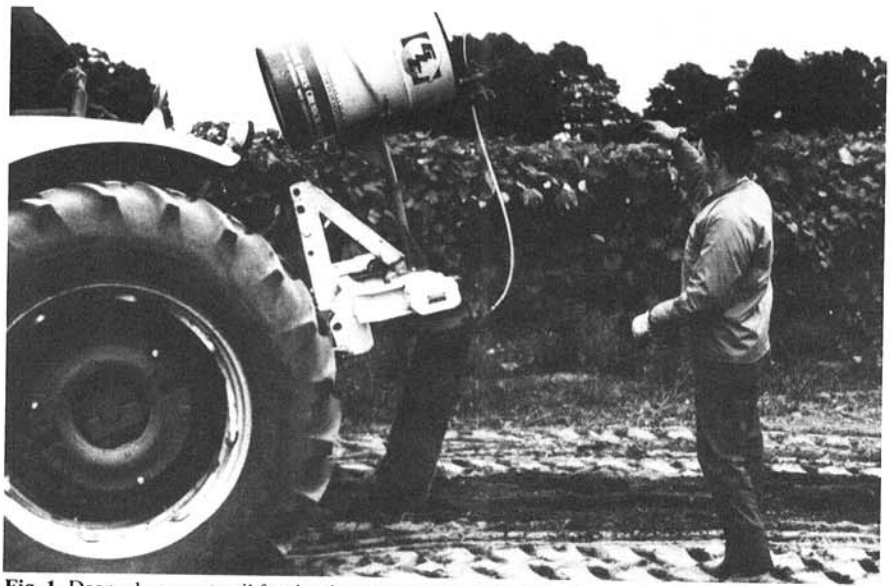

Fig. 1. Deep-placement soil fumigation shank, which fits on a three-point hitch of a large (90-hp) tractor.

Fig. 2. Standard shank soil fumigator used for shallow placement of soil fumigants.

RESULTS

By the first year after fumigation (1976), all treatments had reduced the levels of *X. americanum* to zero, with the exception of treatment 6 at the 244-cm depth that contained 0.5/100 cm³ of soil. The 1978–1981 data show that *X. americanum* levels were zero in all treated plots, with the exception of treatment 5. In that plot, 1.0/100 cm³ of soil was detected at 61 cm in 1981. The control plot had a moderate population throughout the 6 yr (Table 1).

Since 1976, annual indexings of replanted vines to detect PRMV reinfection have shown no infected vines in any of the S plus D fumigated plots. In 1980, however, two of 16 vines in the control plot tested positive for PRMV infection when indexed on *C. quinoa*. In 1981, three of 40 vines in the control plot tested positive for PRMV and one of 40 vines tested positive in the treatment 5 plot, where a low level of nematodes had become established.

DISCUSSION

Superimposed S plus D fumigation will be necessary to control *X. americanum* in vineyards that have PRMV infection foci. Although we demonstrated virtual eradication of the vector nematode to a depth of at least 244 cm and no subsequent reinfection in 6 yr, reestablishment of the *X. americanum* population may occur at some future date (as apparently happened in the treatment 5 plot).

The cost of building a deep-placement shank is about $500. Ours was made of 2.45-cm (1 in.) cold-hardened steel by the Department of Agricultural Engineering, Michigan State University. This shank will fit any three-point hitch tool bar of a tractor. It requires a large tractor (with about 90 draw-bar horsepower). Fumigation costs about $2,470/ha ($1,000/acre). Because only 10% or less of the

total acreage of most vineyards is infected, however, this method could be a cost-effective way to stop further spread of this disease. Success in controlling further spread of existing infection foci in a vineyard is predicated upon thorough mapping around infection foci in a vineyard to identify all infected vines before their removal. This situation is complicated by the fact that vines recently infected with PRMV are symptomless. Symptomless vines in and around the infection area must therefore be indexed to determine their disease status. This is a laborious procedure not readily adaptable to general agricultural conditions. As a result, a project has been initiated to test the feasibility of using color and black and white infrared aerial detection of diseased vines.

LITERATURE CITED

1. Dias, H. F. 1975. Peach rosette mosaic virus. Descriptions of plant viruses. No. 150. Commonw. Mycol. Inst./Assoc. Appl. Biol. Kew, Surrey, England.
2. Jenkins, W. R. 1964. A rapid centrifugal flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.
3. Klos, E. J. 1976. Rosette Mosaic. Pages 135-138 in: Virus Diseases and Noninfectious Disorder of Stone Fruits in North America. U.S. Dep. Agric. Handb. 433 pp.
4. Lamberti, F., and Bleve-Zacheo, T. 1979. Studies on *Xiphinema americanum sensu lato* with descriptions of fifteen new species (Nematoda, Longidoridae). Nematol. Mediterr. 7:51-106.
5. Lear, B., Goheen, A. C., and Raski, D. J. 1981. Effectiveness of soil fumigation for control of fanleaf-nematode complex in grapevines. Am. J. Enol. Vitic. 32:208-211.
6. Ramsdell, D. C., Andrews, R. W., Gillett, J. M., and Morris, C. E. 1979. A comparison between enzyme-linked immunosorbent assay (ELISA) and *Chenopodium quinoa* for detection of peach rosette mosaic virus in 'Concord' grapevines. Plant Dis. Rep. 63:74-78.
7. Ramsdell, D. C., and Myers, R. L. 1974. Peach rosette mosaic virus, symptomology and nematodes associated with grapevine generation in Michigan. Phytopathology 64:1174-1178.
8. Ramsdell, D. C., and Myers, R. L. 1978. Epidemiology of peach rosette mosaic virus in a Concord grape vineyard. Phytopathology 68:447-450.
9. Raski, D. J., Hewitt, W. B., Goheen, A. C., Taylor, C. E., and Taylor, R. H. 1965. Survival of *Xiphinema index* and reservoirs of fanleaf virus in fallowed vineyard soil. Nematologica 11:349-352.
10. Raski, D. J., Hewitt, W. B., and Schmitt, R. V. 1971. Controlling fanleaf virus-dagger nematode disease complex in vineyards by soil fumigation. Calif. Agric. 25(4):11-14.
11. Raski, D. J., and Schmitt, R. V. 1972. Progress in control of nematodes by soil fumigation in nematode-fanleaf infected vineyards. Plant Dis. Rep. 56:1031-1035.