Journal of Nematology 17(2):100–107. 1985.

Population Trends and Vertical Distribution of Plant-Parasitic Nematodes Associated with *Vitis labrusca* L. in Michigan[1]

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Abstract: Nematode population trends and vertical distribution were monitored in a southwest Michigan vineyard (*Vitis labrusca* cv. Concord) from 1976 through 1983. Shallow (20 cm) and deep (90 cm) applications of 1,3-dichloropropene applied at 281 (shallow) plus 658 or 1,122 (deep) liters/ha provided excellent control of *Xiphinema americanum, Criconemella xenoplax,* and *Meloidogyne hapla.* Populations of *X. americanum* remained below detectable levels for the entire 8-year experimental period where the fumigant was applied. *X. americanum* and *C. xenoplax* populations exhibited multiyear cycling in nonfumigated plots. *M. hapla* was first detected in 1978 and increased in prominence from 1980 through 1982. *Criconemella* spp. were commonly parasitized by an endoparasitic fungus. Parasitism was monitored and reported as an indication of nematode population quality.

Key words: Xiphinema americanum, Criconemella xenoplax, Meloidogyne hapla, spatial distribution, population quality, grapes, dagger nematode, ring nematode, northern root-knot nematode, soil fumigation, peach rosette mosaic virus.

Information about the dynamics, spatial distribution, and quality of populations is necessary for understanding ecosystem biology (4,8,11). Many investigators have studied the population dynamics and distribution of plant parasitic nematodes (1,6,7,11). Most research has focused on short-term or within-season population dynamics. Relatively few studies have examined long-term nematode population trends or population quality (3,10).

Peach rosette mosaic virus (PRMV) causes a serious disease of 'Concord' grapevines (*Vitis labrusca* L.) and peach (*Prunus persica* Batsch.) in southwest Michigan (5,12,13). This nepovirus has been determined serologically to be present in at least 24 vineyards in this region (14). Based on symptomatology, PRMV is thought to occur in about 50 vineyards in Michigan. *Xiphinema americanum* Cobb, 1913, a vector of PRMV, has been recovered from soil 213 cm beneath diseased vines (12,13).

A southwest Michigan Concord vineyard containing many vines infected with PRMV was selected in 1974 as an experimental

Received for publication 2 April 1984.

[1] Michigan Agricultural Experiment Station Journal Article No. 11228.

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The authors thank John Davenport, Lindy Rose, Lorraine Graney, Jerri Gillett, Fred Beal, and Chuck Fuller for technical assistance.

site to evaluate soil fumigants for control of *X. americanum*, vineyard rejuvenation, and prevention of spread of the virus disease to noninfected areas of the vineyard. As previously reported (14), superimposed shallow and deep applications of soil fumigants reduced populations of *X. americanum* to nondetectable levels in the upper 1.8 m of soil for 6 years. Virus-free Concord grapevines planted in the fumigated plots remained free of PRMV for 6 years. Vines in nontreated plots were infected with PRMV by the fifth growing season. Populations of plant parasitic nematodes in the plots were assayed annually at six soil depths providing an opportunity to determine the long-term population trends and vertical distribution of plant parasitic nematodes in this vineyard. The objective of this study was to describe the multiseason population trends (1976–83) and vertical distribution (0–1.8 m) of *X. americanum, Meloidogyne hapla* Chitwood, 1949, and *Criconemella xenoplax* (Raski, 1952) Luc and Raski, 1981 associated with *V. labrusca* grown in fumigated and nonfumigated soil. The results of a 1978 nematode survey of southwest Michigan vineyards are included, and nematode population quality is evaluated.

Materials and Methods

A 30-year-old Concord vineyard in southwestern Michigan was selected for an experiment designed to reduce populations of *X. americanum* to nondetectable levels for as long as possible. The site was a sandy loam soil (72.6% sand, 6.0% silt, 21.4% clay) infested with *X. americanum* (sensu Lamberti and confirmed by F. Lamberti). Several large areas of vines were infected with PRMV. Ten rows of grape vines, each containing about 60 plants, were removed during the fall of 1974. Crowns and major roots were pulled, and the soil was disked several times during the 1975 growing season. The experimental site was divided into twelve 0.04-ha rectangular plots.

Early in October 1975 (Julian days 274–275), six soil fumigant treatments were applied as concomitant shallow and deep or shallow only (14). Nematode population data from two of the shallow and deep soil fumigation treatments are reported here. The deep applications of 1,3-dichloropropene, applied at 658 or 1,122 liters/ha at a depth of 90 cm, were made first with a single fumigation shank on 46-cm centers. The shallow applications of 1,3-D at 281 liters/ha were applied at a 20-cm soil depth with a 12-shank fumigator with the shanks spaced 20 cm apart. Soil temperature at fumigation was 13 C, and soil moisture was 5% of field capacity. The soil was sealed with a drag float immediately after fumigation. Each treatment consisted of one replicate.

Nontreated controls were areas between existing vines in border rows on either side of fumigated areas. Both border rows contained numerous PRMV-diseased vines and initial populations (Pi) of *X. americanum* (5/100 cm soil) similar to the fumigated area.

During the spring of 1976, certified virus-free Concord grapevines were planted on 2.44 × 3.05-m spacings in the fumigated plots, and 45 vines were planted beneath PRMV-infected Concord vines in the nontreated border rows. Soil samples for nematode analysis were taken on one sampling date each year from 1976 through 1983 between Julian days 176 and 242 ($\bar{x}$ = 209). On each of the eight annual sampling dates, soil samples were taken at six depths, 0–15, 15–30, 30–61, 61–91, 91–122, and 122–180 cm. Aggregate samples were taken from each plot. A gas-powered auger (Hoffco Co., Richmond, Indiana) was used to drill the sampling hole, and a 10.2-cm-d hand auger was used to take the soil samples. Nematodes were extracted from the soil using a modified centrifugal-flotation procedure (9). Plant-parasitic nematodes were identified and counted. SURFACE II, a three dimensional software package, was used to illustrate the spatial and temporal relationships of nematode population dynamics (18).

Fifty southwestern Michigan vineyards were sampled for nematodes between 19 April and 14 June (Julian days 109–166) 1978. Two vineyards were selected for monitoring within-season nematode population changes. These vineyards were sampled 10 times at 8–26-day intervals from 19 April through 11 September. The soil samples were taken on Julian days 109, 136, 151, 164, 172, 180, 200, 214, 228, and 254 with a 3-cm-d soil sampling tube to a soil depth of 30 cm. Samples were processed within 7 days of collection using

TABLE 1. Frequency, density, and prominence of nematodes associated with 50 southwestern Michigan vineyards.*

Nematodes	Absolute frequency (%)	Relative frequency (%)	Absolute density (/100 cm³ soil)	Relative density (%)	Prominence value†	Relative prominence
Criconemella spp.	96	20	195	40	19.1	44
Xiphinema americanum	72	15	47	10	4.0	9
Meloidogyne hapla	60	13	19	4	2.5	3
Pratylenchus spp.	46	10	13	3	0.9	2
Trichodorus/Paratrichodorus spp.	26	6	4	1	0.2	1
Hoplolaimus galeatus	26	6	9	2	0.5	1
Other plant parasites	60	13	56	12	4.4	10
Other nematodes	86	18	141	29	13.3	30

* Each vineyard sampled once between Julian days 109 and 166 in 1978.
† Prominence value = $(\sqrt{AF})(AD)/100$, where AF = absolute frequency and AD = absolute density.

the centrifugal-flotation technique (9). Plant-parasitic nematodes recovered were identified and counted. *Criconemella* spp. were examined microscopically for parasitism by fungi. Prominence values (PV = $[\sqrt{AF}][AD]/100$, where AF = absolute frequency and AD = absolute density) were used to compare nematode populations in the survey and fumigation sites (2,11).

RESULTS

Five phytopathogenic nematode taxa in addition to *X. americanum* were recovered from the PRMV fumigation site between 1976 and 1983. These included *C. xenoplax, M. hapla, Pratylenchus neglectus* (Rensch, 1924) Filipjev & Schuurmans Stekhoven, 1941, *Paratrichodorus minor* (Colbran, 1956) Siddiqi, 1974, and *Hoplolaimus galeatus* (Cobb, 1913) Thorne, 1949. *H. galeatus* was detected only in 1976 and occurred in very low population densities. *P. neglectus* was first detected in 1978, and *P. minor* in 1979. Both were present in low populations which remained relatively low through 1983.

Criconemella spp. and *X. americanum* ranked highest in all categories (absolute frequency, relative frequency, absolute density, relative density, prominence value, and relative prominence value) of the plant-parasitic nematodes recovered in the vineyard survey (Table 1). *Criconemella* spp. was detected in 48 of the 50 sites surveyed, *X. americanum* in 36, and *M. hapla* in 30. *Pratylenchus* spp., *Trichodorus-Paratrichodorus* spp., and *Hoplolaimus galeatus* were recovered from less than 50% of the vineyards surveyed. The mean vineyard population density was 484 nematodes/100 cm³ soil. The mean nematode prominence value per vineyard was 43.9.

Criconemella xenoplax was the most prominent nematode in both of the vineyards selected for evaluation of within-season population trends (Table 2). *X. americanum*

TABLE 2. Prominence of nematodes recovered from two southwestern Michigan vineyards in 1978.

Nematodes	Julian date prominence values*									
	109	136	151	164	172	180	200	214	228	254
Criconemella xenoplax	5.4	8.6	11.4	5.6	12.2	2.2	3.0	1.9	11.7	15.2
Xiphinema americanum	0.4	2.4	3.1	2.0	1.0	0.0	0.0	0.8	4.1	3.2
Meloidogyne hapla	0.1	2.6	0.1	0.1	1.4	0.3	0.0	0.7	0.1	4.4
Pratylenchus penetrans	0.3	6.0	0.6	0.0	0.4	1.4	0.1	0.7	2.0	2.2
Paratrichodorus minor	0.0	0.1	0.0	0.0	1.1	0.0	0.0	0.0	2.6	0.7
Hoplolaimus galeatus	0.8	0.0	0.0	0.7	0.0	0.0	0.0	0.3	0.6	0.3
Other plant parasites	0.0	3.0	8.6	10.0	7.9	2.2	0.9	0.6	29.5	10.2
Other nematodes	0.9	14.0	17.0	30.0	50.8	0.0	0.0	0.6	29.8	27.0
Total	7.9	36.7	40.8	38.4	74.8	6.1	4.0	5.6	80.6	63.2

* Prominence value = $(\sqrt{AF})(AD)/100$, where AF = absolute frequency and AD = absolute density.

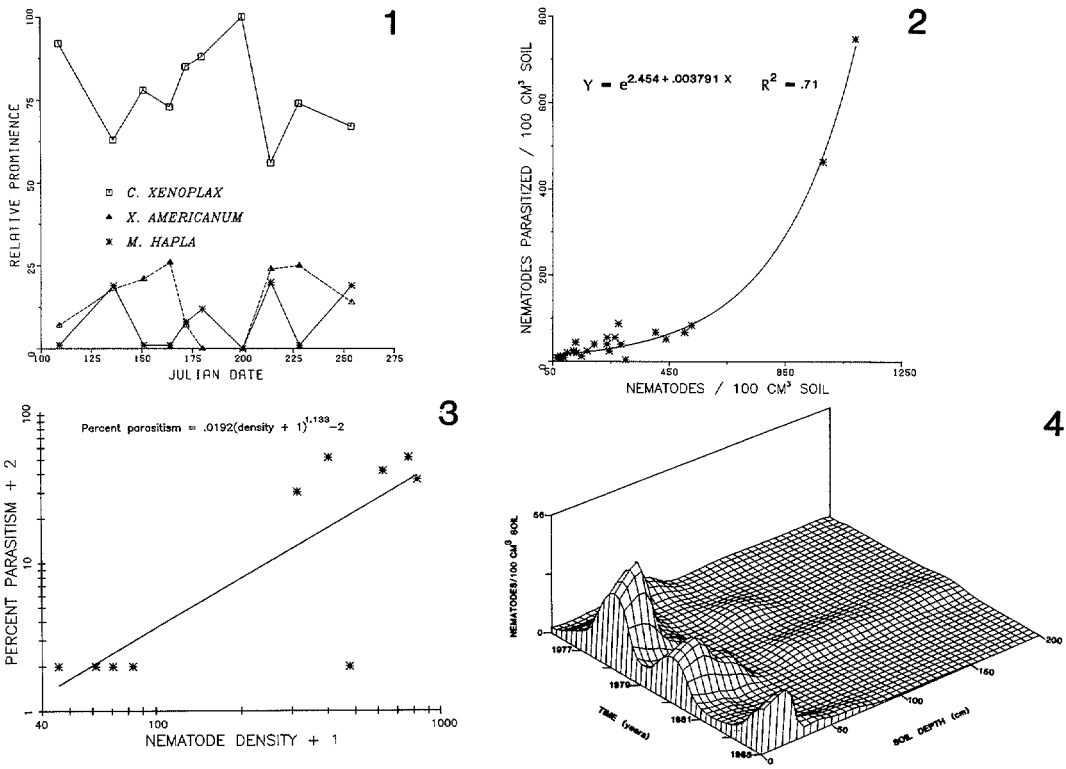


FIG. 1. Within-season (1978) relative prominence of *Criconemella xenoplax, Xiphinema americanum,* and *Meloidogyne hapla* associated with soil from two southwestern Michigan vineyards.

FIG. 2. Relationship between *Criconemella* spp. population density and parasitism by fungi in Michigan vineyards.

FIG. 3. Relationship between nematode population density and fungal parasitism of *Criconemella xenoplax* in two southwestern Michigan vineyards.

FIG. 4. Population trends (1976–83) and vertical distribution of *Xiphinema americanum* associated with *Vitis labrusca* cv. Concord.

and *M. hapla* were also present in these vineyards. The mean nematode prominence value per sampling date was 35.6. Nematode prominence increased from the first sampling date, reached a maximum on Julian day 172, then declined rapidly to a low equilibrium (Julian days 180–214). Nematode prominence for the last two sampling dates increased to near the earlier maximum. The within-season dynamics of the prominence of *C. xenoplax, X. americanum,* and *M. hapla* were relatively similar. The relative prominence of *C. xenoplax,* however, declined on Julian days 136 and 214 because of population increases of *X. americanum* or *M. hapla* (Fig. 1).

Criconemella spp., predominately *C. xenoplax* recovered in the survey, were frequently parasitized by endoparasitic fungi. Nematodes from 24 of the 50 sites sampled were parasitized. This represented 9.6% of the specimens examined microscopically. Parasitism increased exponentially with increases in nematode population density (Fig. 2). Infection reached a maximum of 68% parasitism at 1,092 *Criconemella* spp./ 100 cm³ soil. Although there was no direct relationship between parasitism and sampling date in the two vineyards sampled throughout 1978, fungal parasitism was associated with high nematode population densities (Fig. 3). No detectable relationship existed between predaceous nematodes and total nematode population densities in the survey vineyards ($R^2 = 0.1005$) or the two within-season evaluation vineyards.

The first year after soil fumigation in the PRMV plot, both treatments had reduced population densities of *X. americanum* at all soil depths to nondetectable levels. No *X. americanum* were recovered from any soil

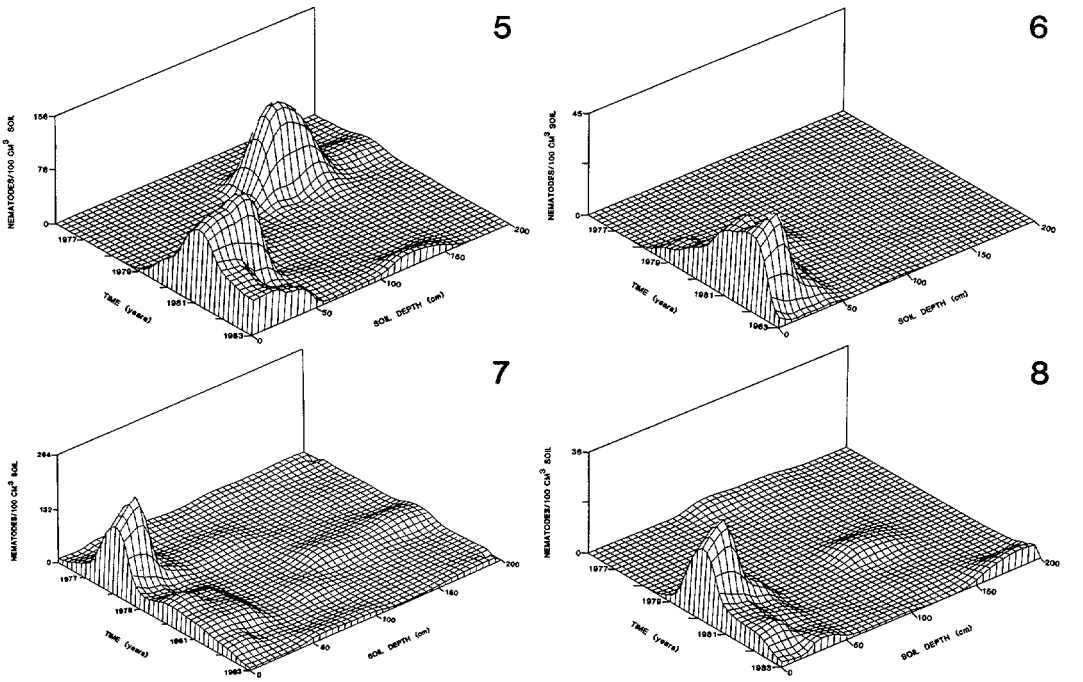


FIG. 5. Population trends (1976–83) and vertical distribution of *Meloidogyne hapla* associated with *Vitis labrusca* cv. Concord after superimposed shallow plus deep soil fumigation with 1,3-dichloropropene (281 liters/ha at 20 cm and 658 liters/ha at 0.9 m).

FIG. 6. Population trends (1976–83) and vertical distribution of *Meloidogyne hapla* associated with *Vitis labrusca*.

FIG. 7. Population trends (1976–83) and vertical distribution of *Criconemella xenoplax* associated with *Vitis labrusca* cv. Concord.

FIG. 8. Population trends (1976–83) and vertical distribution of *Criconemella xenoplax* associated with *Vitis labrusca* cv. Concord following superimposed shallow plus deep soil fumigation with 1,3-dichloropropene (281 liters/ha at 20 cm and 658 liters/ha at 0.9 m).

depth in these fumigated plots throughout the 8 years of observation. The nontreated control rows, however, maintained a moderate population denstiy of *X. americanum* during the entire 8-year experimental period (Fig. 4). Although this nematode was detected at a soil depth of 180 cm, the majority of the population was in the upper 50 cm of soil. Population densities of *X. americanum* cycled, reaching a maximum in 1978, with secondary maxima in 1980 and 1983. Population densities declined in 1979, 1981, and 1982. The mean population density cycle for *X. americanum* was 2.5 years.

Meloidogyne hapla was not known to occur in the PRMV fumigation site until it was first detected in 1978 at soil depths greater than 90 cm in the 281–658 liters/ha 1,3-D treatment (Fig. 5). The population density peaked in this treatment in the upper 30 cm soil depth in 1981 then declined to an equilibrium in 1982–83. *M. hapla* was first detected in the nontreated control rows in 1979 (Fig. 6). The population increased to a maximum in 1981–82 and declined by 1983. *M. hapla* was first detected in 1980 in the 281–1,122 liters/ha 1,3-D treatment with the majority of the population in the upper 50 cm of soil.

Criconemella xenoplax was present in the PRMV site throughout the 8-year period (Fig. 7). The population density reached a maximum in 1978, occurring in the upper 20 cm of soil. The population density at 0–20 cm deep stabilized at about 50 *C. xenoplax*/100 cm³ soil during 1979–83. Deep and shallow soil fumigation with 1,3-D provided control of *C. xenoplax* for 3 years, 1975–78. The population then increased to a maximum in 1979 before declining through 1983 (Fig. 8).

The relative prominence of *Criconemella* spp. recovered from the 50 vineyard sur-

TABLE 3. Relative prominence of six taxa of plant-parasitic nematodes recovered from a fumigation plot after removal of *Vitis labrusca* L. cv. Concord grapevines infected with peach rosette mosaic virus (PRMV) and nematode survey of southwestern Michigan vineyards.

Nematodes	Relative prominence*		
	1978 nematode survey		PRMV plot (1976–83)
	50 vineyards	Within-season	
Criconemella spp.	73	62	65
Xiphinema americanum	15	14	19
Meloidogyne hapla	6	8	13
Pratylenchus spp.	3	10	2
Paratrichodorus / Trichodorus spp.	1	4	1
Hoplolaimus galeatus	2	2	1

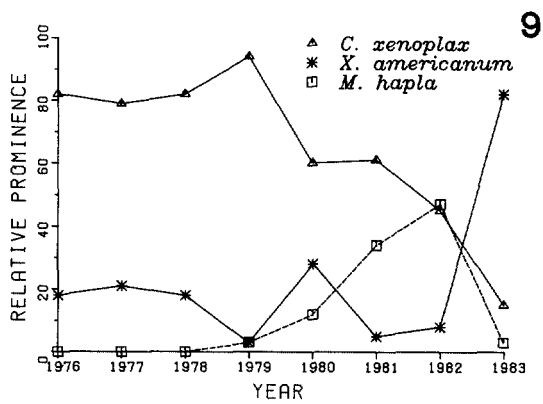
* Based on mean frequencies and population densities.

vey, within-season evaluation of two vineyards, and 1976–83 PRMV fumigation ranged from 75 to 62 (Table 3). A similar uniformity among these three categories existed for the other five species. The relative prominence of *C. xenoplax* in the PRMV fumigation site declined from 1979 to 1983 (Fig. 9). The relative prominence of *M. hapla,* however, increased from 1979 to 1982 and declined in 1983. With the exception of a sharp increase in 1983, the relative prominence of *X. americanum* was relatively stable and low throughout the 8 years. The relationship between nematode population density recovered from the PRMV fumigation site and sampling date was similar to the data from the within-season nematode population analysis of two vineyards (Fig. 10).

DISCUSSION

Criconemella xenoplax, X. americanum, and *M. hapla* were frequently recovered in high population densities from southwest Michigan vineyards. A relatively high degree of similarity occurred among the nematode fauna recovered from 50 Michigan vineyards. Most of the nematode populations were located in the upper 50 cm of soil.

Although it is not possible to say why *M. hapla* was not detected in the PRMV fumigation nontreated controls until 1979, it appears that the 281–658 liters/ha 1,3-D treatment provided control of *M. hapla* only in the upper 100 cm of soil. The 1978 residual population of *M. hapla* below 100 cm deep most likely migrated upward and was responsible for the later infestation in the upper 50 cm of soil. Vertical migration patterns were not observed for *X. americanum* or *C. xenoplax.*



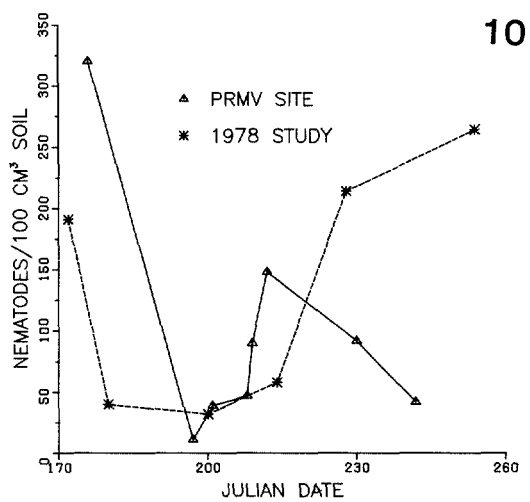


FIG. 9. Relative prominence of three species of plant-parasitic nematodes associated with Concord grape roots from 1976–83.

FIG. 10. Relationship between nematode population density and sampling data in a peach rosette mosaic virus fumigation trial and a 1978 within-season survey of two southwest Michigan vineyards.

Relatively little is known about multi-season population trends of plant-parasitic nematodes associated with agricultural ecosystems (2,6,11). The present study shows multi-season cycling of populations of phytoparasitic nematodes in a southwest Michigan vineyard. The nematode fauna of this vineyard were typical of vineyards in the region. Although the within-season nematode population study of two vineyards illustrates the fluctuation of within-season population dynamics, it does not appear likely that variation in the annual sampling date in the PRMV fumigation site was responsible for variations in the populations of specific nematodes during the 8 years of the study. The 1978 sampling date was optimum for the detection of high populations of *X. americanum* and *C. xenoplax,* and the sampling time might be partially responsible for the 1978 population density peaks for these two nematodes. The other nematode population variations through the 8 years can not be attributed to date of sampling. Although we attempted to minimize sampling date variation, the 66-day interval (Julian days 176–242) at the PRMV site was excessive. Nematode population densities in the upper 30 cm of soil in the PRMV fumigation plots will be sampled three times a year, from 1984 through 1990 to provide 15 years of data for analysis of long-term nematode population trends. The first sample will be taken between Julian 150 and 175, the second on or about Julian 200, and the third between Julian 225 and 250.

Fungal parasitism of *C. xenoplax* was presented as an indication of population quality. Parasitism of *C. xenoplax* appeared to be density-dependent (4,8). No similar relationship was observed among plant-parasitic and predacious nematodes.

Soil fumigation with shallow plus deep injections of 1,3-D provided excellent control of *X. americanum, C. xenoplax,* and *M. hapla. X. americanum* was reduced to a nondetectable level for 8 years. This is 2 years longer than previously reported for the Michigan PRMV fumigation site (14), and 2 years longer than reported for *Xiphinema index* in a grape fan leaf virus fumigation trial (15–17). The 281 plus 658 liters/ha treatment with 1,3-D reduced *M. hapla* and *C. xenoplax* in the upper 50 cm of soil to nondetectable levels for 3 years. This period of nematode control is longer than generally achieved by soil fumigation. Multi-season nematode control may have resulted from the relatively high rate of fumigant applied in the superimposed shallow plus deep injections and the deep sandy nature of the soil at the site. It should also be noted that the fumigated vineyard with newly planted vines and complete weed control provided very limited and narrowly distributed host tissues for plant-parasitic nematode feeding and reproduction.

Information about the dynamics, spatial distribution, and quality of nematode populations is imperative for an understanding of the role of plant-parasitic nematodes in agricultural ecosystems. Although the site used for this soil fumigation study was designed to provide information on the control of PRMV and its nematode vector *X. americanum,* we believe the multi-season population and vertical distribution data provide a stimulus for future nematology research on long-term population dynamics of plant-parasitic nematodes, including information relating to population quality.

Literature Cited

1. Barker, K. R., and C. L. Campbell. 1981. Sampling nematode populations. Pp. 451–474 *in* B. M. Zuckerman and R. A. Rohde, eds. Plant parasitic nematodes, vol. 3. New York: Academic Press.

2. Bird, G. W., and N. Knobloch. 1978. Criconematinae habitats and *Lobocriconema thornei* n. sp. (Criconematidae: Nematoda). Journal of Nematology 10:61–70.

3. Bird, G. W., O. L. Brooks, and C. E. Perry. 1974. Dynamics of concomitant populations of *Hoplolaimus columbus* and *Meloidogyne incognita.* Journal of Nematology 6:190–194.

4. Blower, G. J., L. M. Cook, and J. A. Bishop. 1981. Estimating the size of animal populations. London: Geo. Allen & Unwin.

5. Dias, H. F. 1975. Peach rosette mosaic virus. Descriptions of plant viruses No. 150. Kew, Surrey, England: Commonwealth Mycological Society/Association of Applied Biologists.

6. Ferris, H., and M. V. McKenry. 1974. Seasonal fluctuations in the spatial distribution of nematode populations in a California vineyard. Journal of Nematology 6:203–210.

7. Goodell, P., and H. Ferris. 1980. Plant-parasitic nematode distributions in an alfalfa field. Journal of Nematology 12:136–141.

8. Haynes, D. L., and R. L. Tummala. 1974. Development and use of predictive models in the management of cereal leaf beetle populations. Pp. 53–68 *in* R. L. Tummala, ed. USSR/USA Symposium on IPM. Michigan State University, East Lansing.

9. Jenkins, W. R. 1964. A rapid centrifugal-flo-

tation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

10. Mankau, R. 1981. Microbial control of nematodes. Pp. 475–494 *in* B. M. Zuckerman and R. A. Rohde, eds. Plant parasitic nematodes, vol. 3. New York: Academic Press.

11. Norton, D. C. 1978. Ecology of plant-parasitic nematodes. New York: John Wiley & Sons.

12. Ramsdell, D. C., and R. L. Myers. 1974. Peach rosette mosaic virus, symptomology and nematodes associated with grapevine degeneration in Michigan. Phytopathology 64:1174–1178.

13. Ramsdell, D. C., and R. L. Myers. 1978. Epidemiology of peach rosette mosaic virus in a 'Concord' grape vineyard. Phytopathology 68:447–450.

14. Ramsdell, D. C., and G. W. Bird. 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.

15. Raski, D. J., W. B. Hewitt, A. C. Goheen, C. E. Taylor, and R. H. Taylor. 1965. Survival of *Xiphinema index* and reservoirs of fanleaf virus in fallowed vineyard soil. Nematologica 11:349–352.

16. Raski, D. J., W. B. Hewitt, and R. V. Schmitt. 1971. Controlling fanleaf virus-dagger nematode disease complex in vineyards by soil fumigation. California Agriculture 25:11–14.

17. Raski, D. J., and R. V. Schmitt. 1972. Progress in control of nematodes by soil fumigation in nematode-fanleaf infected vineyards. Plant Disease 56: 1031–1035.

18. Sampson, R. J. 1978. Surface II, graphics systems. Kansas Geological Survey. Lawrence, Kansas.