Seasonal Fluctuations in the Spatial Distribution of Nematode Populations in a California Vineyard

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Abstract: Distribution of *Xiphinema americanum* and four *Meloidogyne* spp. was studied in a vineyard over a 13-mo period. The *X. americanum* population was coned in the upper 60-cm of undisturbed soil in the vine row, whereas the *Meloidogyne* species were distributed both in and between rows and to greater depths, similar to the distribution of the root system. Samples for assessment of *X. americanum* densities had least variation when taken in the vine row from the upper 60-cm of soil. Sampling error is reduced in *Meloidogyne* populations by sampling within 40 cm of the vine both within and/or between rows. *Key Words:* population dynamics, sampling, *Xiphinema americanum, Meloidogyne* spp., population management.

The effects of pre- and postplant nematicidal treatments on establishment of grapevines and yield increases have received considerable attention in California (13, 15). Techniques have now been developed whereby movement of nematicides can be monitored and dosage levels in the soil can be measured (1, 10). Economic and environmental considerations dictate efficient use of nematicides at minimum dosages (16). To achieve this, information must be available on nematode distribution, their vulnerability, and threshold densities at which they become economically important. There are reports concerning the vertical distribution of nematodes around grapevines (14, 17), but we are unaware of any studies of seasonal variation in the grapevine root zone.

The objectives of this study were: (i) to investigate the spatial distribution and seasonal variation of nematodes in the grapevine root zone; (ii) to provide information on which to base soil-sampling techniques for determining nematode population densities in grapevine root zones; and (iii) to provide information leading to increased effectiveness of cultural practices and postplant nematicidal treatments in managing population levels of plant-parasitic nematodes in vineyards.

MATERIALS AND METHODS

An own-rooted, 37-yr-old vineyard of 'Thompson Seedless' grapes (*Vitis vinifera* L.) on McCall Avenue, Selma, California, was selected for study. The study area was four rows wide (rows 360 cm apart) and 50 plants long (plants 210 cm apart) in a strip of Hanford sandy loam soil in which vine growth was relatively poor. The sandy loam texture was relatively uniform with depth. There was a 10- to 20-cm-thick clay layer 105-180 cm deep, varying with location in the vineyard, although this did not show in the mechanical analyses. Soil physical characteristics and nutrient status are shown in Table 1. Other data collected were: soil temp at 5, 30, and 90 cm below the soil surface on a continuous basis; soil moisture determinations every 2 wk at 15, 30, and 90 cm depth; and irrigation and rainfall records. Other supporting data included timing of routine cultural practices, yield and sugar content of grapes, and vine pruning weights.

Soil samples were taken from the vineyard at 28-day intervals from 2 November 1972 to 27 November 1973, so that nematode community distribution and density changes could be followed in relation to time and season. On each of the 15 sampling dates, soil samples were taken from six vines chosen at random from the 200 vines in the site. The same vine was never sampled twice to avoid errors introduced by root damage during previous sampling, hence a total of 90 vines was sampled.

Various vineyard cultural practices were carried out during the year which may have influenced the nematode population dynamics reported in this paper. Manure was applied in alternate years at the rate of 6,725 kg/hectare (ha). Ammonium sulphate was applied annually at the rate of 68 kg of nitrogen/ha. A volunteer cover crop including some legumes was allowed to grow in the fall and winter months. Tillage operations involved disking and furrowing. The vineyard was irrigated through shallow furrows formed between the vine rows during

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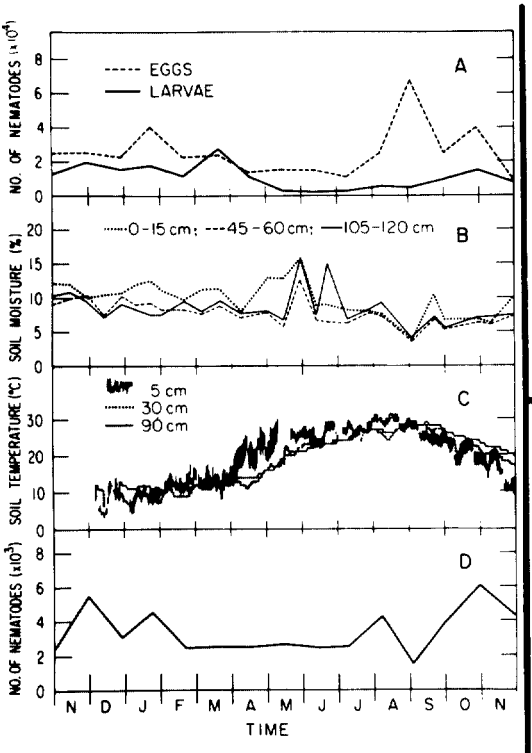
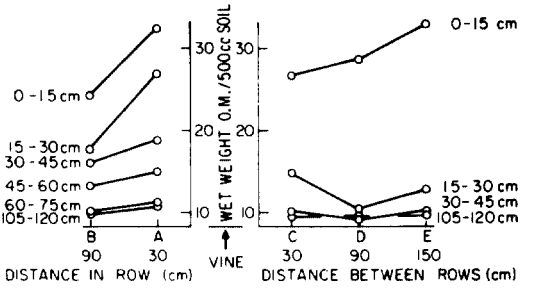


FIG. 1



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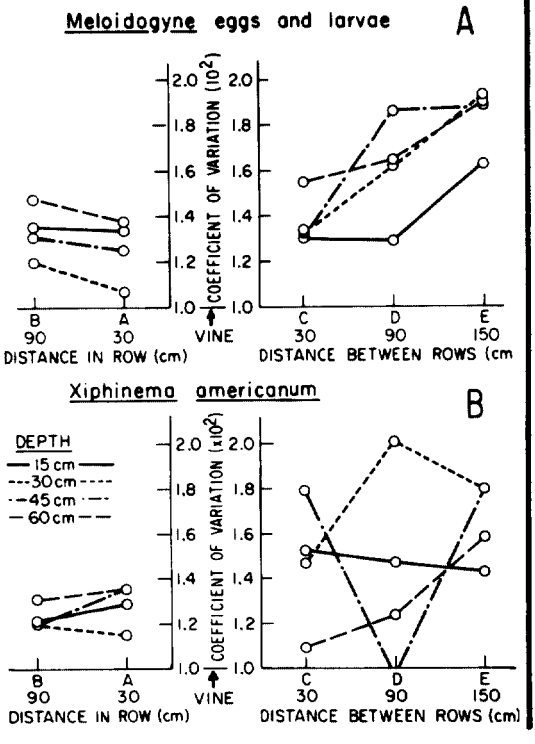

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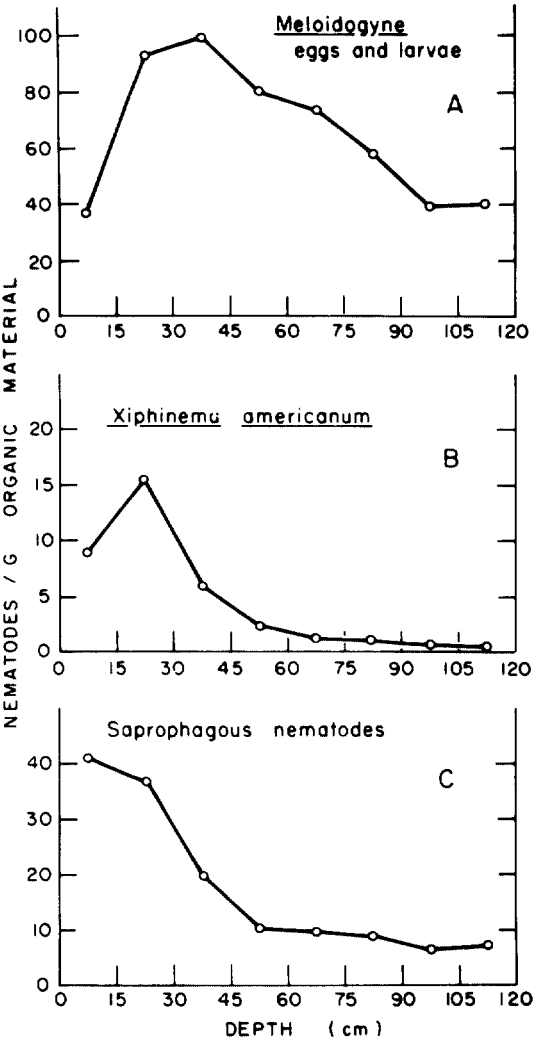

the spring and summer months. In the vine row, the soil was ridged to 30 cm high and 60 cm wide. The ridge had received an annual application of herbicides since 1962, and the soil in the vine row remained undisturbed during tillage operations since that date. The ridge is not compacted by equipment movement and irrigation water infiltrates into it from the area between rows. The area between rows is subject to root pruning during tillage and to soil compaction by equipment.

To accommodate differences in vine root system development and nematode distribution in the row and between rows, sampling positions were selected as follows: 30 cm and 90 cm from the trunk of the vine in the row; 30 cm, 90 cm, and 150 cm from the trunk of the vine between rows. At each sampling position, soil samples were taken at 15-cm intervals to a depth of 120 cm with a 7.5-cm diam auger, a total of eight samples at each position and 40 samples from each vine.

Samples were handled carefully to avoid summer heat and direct sunlight. They were stored at 5 C within 5-12 h of the start of sampling. There was no difference in nematode numbers from these samples and from samples placed directly into iced containers in the field. Soil samples were mixed in the laboratory by passing them twice through a sample splitter; a 50-cc aliquant of each sample was processed by a flotation-sieving technique (4) to recover nematodes and a 500-cc aliquant was processed to recover *Meloidogyne* eggs (3). The egg extraction process was modified so that a wet weight of the organic material caught on the 420-μm (40-mesh) screen was obtained. In samples unaffected by surface debris this could be used as a crude estimate of root weight. An extra 100-ml aliquant was used on several sampling dates in a tomato bioassay. A root galling index (5) verified *Meloidogyne* population densities determined by the extraction techniques. Species of *Meloidogyne* associated with the vines were identified by perineal patterns and chromosome number.

RESULTS AND DISCUSSION

The major groups of plant-parasitic nematodes present in the sampling area were *Meloidogyne* spp., *Xiphinema americanum* Cobb, and *Paratylenchus hamatus* Thorne & Allen. Of these, the effect of *Paratylenchus* on grapevine vigor is uncertain, but the other two are known pathogens (13). In this paper, only the data for *Meloidogyne* and *Xiphinema* are presented. Chromosome numbers and perineal patterns of *Meloidogyne* spp. indicated that *M. hapla* Chitwood, *M. incognita* (Kofoid and White) Chitwood, *M. javanica* (Treub) Chitwood, and *M. arenaria* (Neal) Chitwood, with chromosome numbers of 17, 42, 43, and 36, respectively, were present. Bioassay determinations of *Meloidogyne* population densities confirmed results from egg extraction and flotation-sieving procedures.

Population trends of *Meloidogyne* spp. and *Xiphinema americanum* are shown as the total number of individuals found in the 40 samples from each vine averaged over the six vines at each sampling date (Fig. 1-A and 1-D). Soil temp and moisture are shown on the same time scale (Fig. 1-B and 1-C). Soil moisture remained relatively steady during the winter rainfall period, but fluctuated in summer between periods of irrigation and high evapotranspiration. Lowest soil moisture was recorded in August when irrigation ceased. This is a standard cultural practice used to increase sugar content and decrease the tendency for berry splitting. Soil temp remained low during the winter months and reached 18 C in late March and early April. Maximum soil temp occurred in

FIG. 1-4. **1)** Population changes of *Meloidogyne* spp. and *Xiphinema americanum* and soil temp and moisture regimes in a vineyard from November 1972 to November 1973. **1-A)** *Meloidogyne* eggs and larvae. **1-B)** Soil moisture at three depths. **1-C)** Soil temperature at three depths. **1-D)** *Xiphinema americanum*. Points plotted in A and D represent the total nematode counts from 40 samples of 500 cc of soil taken throughout the root zone and averaged across six vines on each date. **2)** Coefficients of variation among nematode counts in six samples in different locations of the grapevine root zone. Each point represents a mean of 15 groups of samples taken over a period of 13 mo. **2-A)** *Meloidogyne* spp. eggs and larvae. **2-B)** *Xiphinema americanum*. **3)** Wet weight of organic material extracted from different locations in the root zone of grapevines. The organic material below 15 cm was mainly roots. Each point represents an average of 72 samples taken over a period of 11 mo. **4)** Number of nematodes per gram of organic matter in 500-cc soil samples taken at different depths in a grapevine root zone. Each point represents an average of 360 samples taken over a period of 11 mo. Below 15 cm, the organic matter was mainly roots. **4-A)** *Meloidogyne* spp. eggs and larvae. **4-B)** *Xiphinema americanum*. **4-C)** Saprophagous nematodes.

TABLE 1. Soil characteristics of the 'Thompson Seedless' grape vineyard on McCall Ave., Selma, California

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	E.C.[a] (mmho/cm)	pH	S.P.[b] (%)	P[c] (ppm)	K (ppm)	Ca+Mg (me/L)	Na (me/L)	N (ppm)
15	53.2	29.2	17.6	3.2	5.4	23	28.0	103	13.5	1.10	603
30	59.0	22.1	18.9	1.5	6.1						
45	53.0	29.4	17.6	1.0	6.5	19	13.0	100	2.7	0.67	247
60	53.0	29.4	17.6	0.7	6.6						
75	73.5	8.5	18.0	0.7	6.5	18	11.3	57	4.2	0.84	206
90	48.5	36.9	17.6	0.7	6.8						
105	48.1	32.8	19.1	0.7	7.1	19	10.0	40	4.1	0.84	197
120	54.8	26.3	18.9	0.7	7.1						
150	53.9	28.4	17.7	0.5	6.8	22	15.2	37	4.9	1.30	172
180	57.2	23.9	18.9	0.6	7.1						

[a]Electrical conductivity of the saturation extract of the soil. A measure of salt content.
[b]Saturation percentage. Amount of water required to saturate 100 g of soil. The value is approximately twice field capacity.
[c]Samples for soil nutritional analysis were taken in July, 1973.

August and declined in the fall. Daily temp fluctuated greatly in the upper 5-cm of soil, but not at 30 cm and deeper.

The number of *Meloidogyne* eggs and second-stage larvae (Fig. 1-A) in the soil remained relatively constant during the winter months. As soil temp reached 18 C in early April, eggs hatched and their numbers in the soil declined. These hatched eggs probably represent the infective inoculum for the current growing season, since overwintering larvae were somewhat vacuolated and probably of reduced infectivity (2). After the egg hatch period, the number of larvae in the soil decreased, presumably because they had invaded the young rootlets which develop in early spring (18).

Egg and larval densities in the soil were lowest during the summer months until late August when egg density increased markedly. The population peak corresponded with the low soil moisture level at harvest. Presumably soil moisture was below the minimum level for egg hatch at this time. We infer from our data that this critical moisture level would be about 4-5% in the Hanford sandy loam soil. When soil moisture increased due to postharvest irrigation in September, egg hatching resumed, egg densities decreased and larval densities increased. Egg hatching was probably suppressed by low soil temp at the end of October.

Population levels of *X. americanum* (Fig. 1-D) were higher in fall and winter than in spring and summer. An increase in population densities occurred in August, but this was curtailed by low soil moisture. As soil moisture increased, *Xiphinema* levels increased, becoming limited, possibly by temp, in late October. Little information is available on the reproductive cycle of *X. americanum*, although Flegg (7) reported the period from egg to adult as 2-3 yr for *Xiphinema* spp. in southeastern England. We infer from our data that there may be a reproductive flush in the fall of the year under field conditions. A late-summer increase in population densities of *X. americanum* was reported in Iowa (11), corresponding to an increase in numbers of gravid females.

The spatial distribution pattern of *Meloidogyne* spp. (Fig. 5) showed highest densities in the row, particularly in the upper 60 cm of soil. Population densities were rather low and variable in the upper 15-cm, where environmental conditions were most extreme. There were few *Meloidogyne* eggs and larvae between rows in the upper 30-cm of soil, particularly beyond 45 cm from the vine. In this region a certain amount of root pruning and soil compaction occurs during tillage. In the immediate center of the area between rows there was less soil compaction, less root pruning, and possibly some overlap of roots from the rows on each side (8) resulting in more roots and more nematodes. Densities declined with depth, but they were still present at relatively high levels 120 cm below the soil surface. A few *Meloidogyne* larvae occurred at depths of 330 cm and a few eggs at 180 cm.

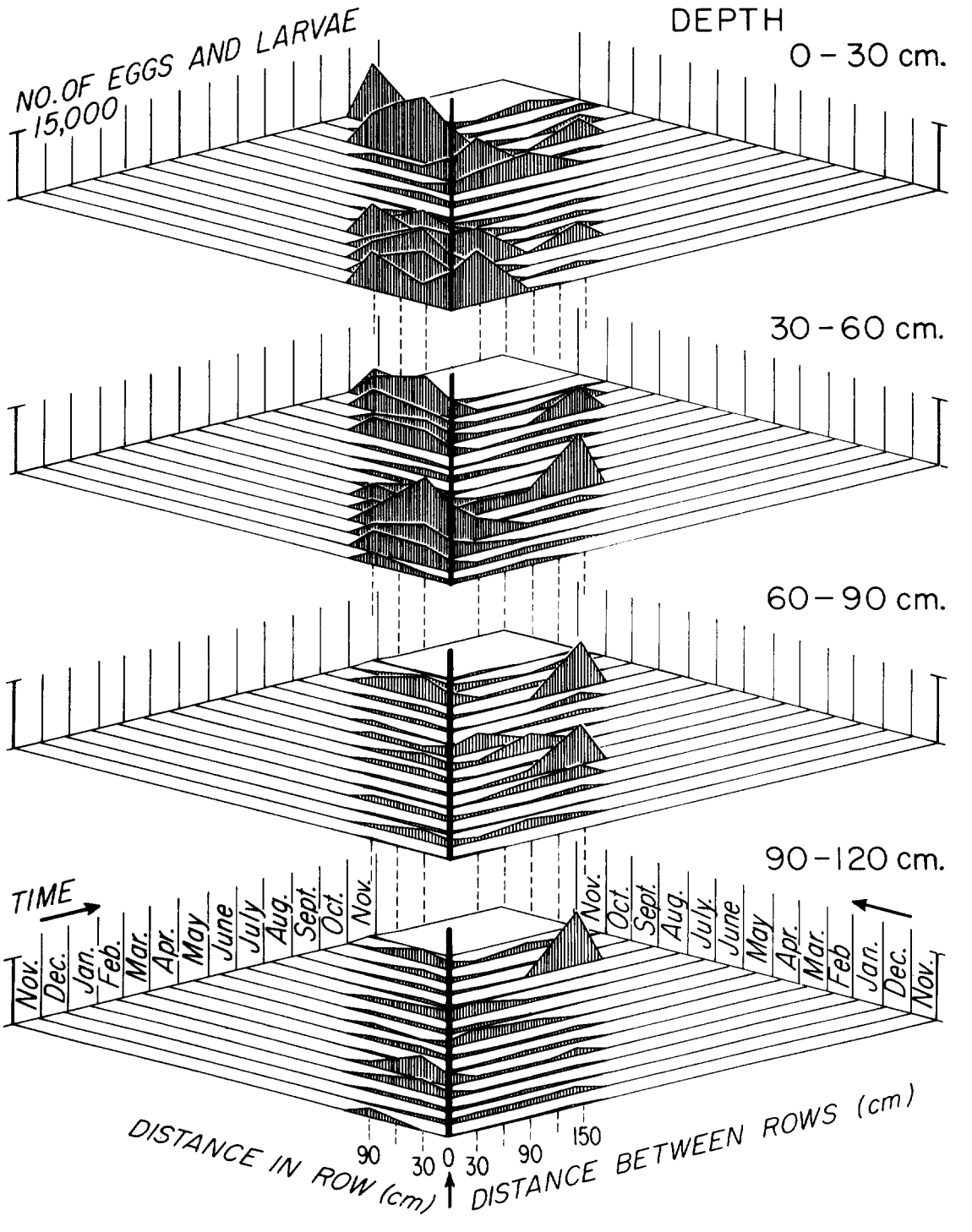

FIG. 5. Spatial distribution of *Meloidogyne* spp. on grapevine roots from Nov 1972 to Nov 1973. Each plane represents a 30-cm depth interval from the soil surface. Points plotted are the average of the number of nematodes in 500 cc of soil from the upper and lower 15 cm of each depth interval. The solid black line represents the position of the vine, points to the left are samples taken in the row, and points to the right are samples taken between rows. The closest set of axes is the first sampling date, and the furthest set is the last sampling date.

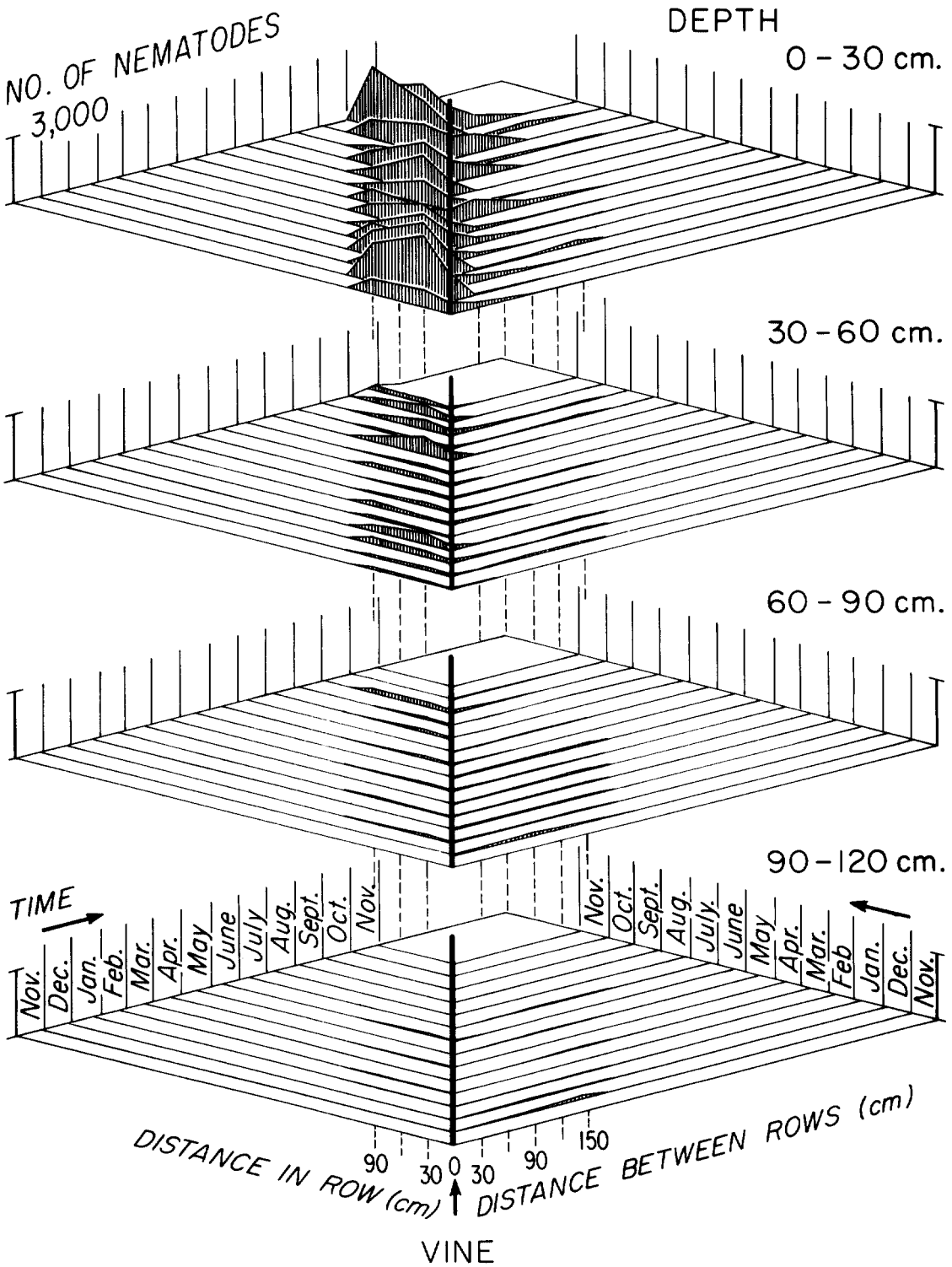

FIG. 6. Spatial distribution of *Xiphinema americanum* on grapevine roots, from Nov 1972 to Nov 1973. Each plane represents a 30-cm depth interval from the soil surface. Points plotted are the average of the number of nematodes in 500 cc of soil from the upper and lower 15-cm of each depth interval. The solid black line represents the position of the vine, points to the left are samples taken in the row and points to the right are samples taken between rows. The closest set of axes is the first sampling date and the most distant set is the last sampling date.

Raski and Lear (14) reported *M. incognita* galls on grape roots 510 cm below the surface. Our data represent a composite of the four *Meloidogyne* spp. in the field; individual species patterns may differ.

Crude estimates of root density (Fig. 3), based on the wet weight of organic material in 500-cc soil samples, indicated that the pattern of root growth was similar to the *Meloidogyne* distribution, with most roots in the row and fewer between rows. Greatest quantities of organic material in the row were above 60 cm. Large quantities of leaf and cane debris were included in the estimates above 15 cm; however, below this depth the organic material was mainly roots. Between rows, we were unable to show differences in the amounts of root material in samples below 30 cm. Harmon and Snyder (8) found that 20.8% of the grapevine root system was in the upper 30 cm, 47.9% in the second 30 cm, and 24.8% in the third 30 cm.

Distribution of *X. americanum* (Fig. 6) was confined largely to the top 45-cm of undisturbed soil in the row. Apparently there are factors other than root distribution which limit the habitat of this nematode. Ponchillia (12) showed evidence of an oxygen requirement by demonstrating increased survival of *X. americanum* in soils with greater pore space. The nematode was more abundant in the environmentally fluctuating upper 15 cm of soil than at any other depth. In contrast, Lownsbery and Maggenti (9) found, under greenhouse conditions, that constant temp and narrow ranges of moisture fluctuation favored *X. americanum*. The distribution pattern observed indicates a possibility for reduction of the *X. americanum* population by row plowing, that is spreading and disturbing the soil ridge in the vine row. Some root damage may be caused by this technique, but if it was carried out in the winter the root system would be replenished by the spring flush of rootlets early in the next growing season. This cultural practice has become much less widely used since the advent of herbicides.

To investigate the influence of root distribution on nematode distribution the number of nematodes per gram of organic material averaged over the sampling period, was calculated for various depths. Few parasitic nematodes per gram of organic material (Fig. 4-A and 4-B) occurred at the surface due to the large amounts of leaf debris there; however, there were large numbers of saprophagous nematodes in this region (Fig. 4-C). The number of *Meloidogyne* eggs and larvae per gram of organic material remained high down to about 60 cm and then decreased, indicating that other factors became limiting, possibly oxygen. *X. americanum* and saprophagous nematodes per gram of organic matter decreased at shallower depth more than did *Meloidogyne;* this was possibly related to oxygen requirements.

Control of *X. americanum* by 1,2-dibromo-3-chloropropane (DBCP) and subsequent yield increase has been demonstrated (13). This control can be explained not only on the basis of the ectoparasitic habit of the nematodes, but also due to their accessibility to the chemical, being distributed in the upper region of the soil profile. Conversely, chemical control of *Meloidogyne* spp. in vineyards is seldom successful (13).

A coefficient of variation was calculated for each sampling date among the samples taken at each position on the six vines (Fig. 2). The coefficients of variation were very high, which is usually characteristic of nematode samples. They suggested the need for data transformation if statistical tests of differences were to be made (6). The variation in *Meloidogyne* densities among samples generally decreased closer to the vine (Fig. 2-A). This was particularly true between rows where root densities were lower and nematode distribution was sporadic. Since there were few *X. americanum* between rows (Fig. 6), the pattern of reduced variation closer to the vine was not apparent between rows with this nematode (Fig. 2-B). These results suggest that for reduction of sampling error in estimating nematode densities around grapevine roots, samples should be taken close to the vine, preferably in the row and possibly also between rows to allow for differences in root distribution. We have adopted a routine of taking a sample 30-45 cm from the vine in the row and between rows. In both cases the soil core is taken to a depth of 60 cm to pass through the region of highest nematode densities (Fig. 5 and 6). The samples may be bulked and mixed, or treated separately. Our intention is to sample each vine in an equivalent region of the root zone where nematode densities are greatest and variation least, in an attempt to reduce sampling error.

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