Relationship of Grapevine Yield and Growth to Nematode Densities

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Abstract: Yield, growth, and vigor of individual grape vines were correlated with nematode population densities in a series of California vineyards. In a Hanford sandy loam soil, *Xiphinema americanum* densities showed negative correlations with yield, growth, and vigor of vines. When vines were categorized according to vigor, *X. americanum* densities had little relationship to yield of high-vigor vines, but were negatively correlated with yield of low-vigor vines. Densities of *Paratylenchus hamatus* were positively correlated with yield, growth, and vigor of vines. Correlations between *Meloidogyne* spp. densities and vine performance were variable, even when the vines were separated according to soil type and plant vigor. Densities of *Meloidogyne* spp. populations were generally higher on coarser-textured, sandy soils and the vines were less vigorous there. Densities of *P. hamatus* were greater in fine-textured soils. *Key Words: Longidorus africanus, Vitis vinifera.*

Several parasitic nematode genera are commonly found associated with grapevines in California. They include *Criconemoides, Meloidogyne, Paratylenchus, Pratylenchus, and Xiphinema* (8, 11). The effects of some plant-parasitic nematodes on grapevine growth have been studied under greenhouse conditions. Results have measured reproduction of the nematodes, but pathogenic effects on the vines were not clearly documented (12). *Meloidogyne* spp. and *Pratylenchus* spp. have been associated with premature decline of vineyards and inability to establish replants (8, 10, 11, 14).

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Longidorus africanus Merny and *X. americanum* Cobb have been shown to reproduce on young vines and to retard root growth under greenhouse conditions (3, 9). Frequently, evidence of pathogenicity is based upon association of high numbers of nematodes with declining vineyards, and yield increase after chemical treatment (11).

The objectives of this study were: (i) assess the damage caused by the common parasitic nematode populations and communities in vineyard soils; (ii) elucidate any correlations between nematode population levels and soil characteristics and vine vigor in commercial vineyards; and (iii) estimate threshold densities at which the nematode populations become economically significant and yield losses can be predicted under specific conditions.

MATERIALS AND METHODS

Data presented in this paper were collected in two series of experiments: (i) a spatial distribution study in a 37-year-old vineyard at McCall Avenue, Selma, California (5, 6); (ii) further studies in the McCall Avenue vineyard (sites 1a and 1b), a 7-year-old vineyard on Porter Avenue, Dinuba, California (site 2), and a 15-year-old vineyard at Mecca, California (site 3). The cultivar of grapes (*Vitis vinifera* L.) was Thompson Seedless at all locations except Porter Avenue where it was Muscat Canelli.

Physical characteristics, growth, vigor, and yield of individual vines were measured at all sites. Data were collected on visual vigor (1 to 5 scale, 1 indicating lowest vigor), trunk cross-sectional area, total cross-sectional area of branches from trunk (canes or spurs), number of buds, yield, weight of prunings from the vine, and sugar content of the grapes, Soil pH, electrical conductivity, and % of sand, silt, and clay were measured at each site. In two sites % bud break was determined on a given day in the spring months since some differences were noted across varying soil textures. Population densities of the nematodes associated with each vine were determined. In Experiment 1, the nematode assessments were made throughout the year, whereas in Experiment 2 they were made in the spring, and, in most cases, again after harvest.

Nematode densities on each vine were assessed by sampling with a 7.5-cm diam auger at points 30 cm from the vine in the row and 30 cm from the vine between rows. At each position, samples were taken at 15-cm intervals to a depth of 60 cm. In the spatial distribution study (Experiment 1), other positions and depths were also samples (6). Nematodes were extracted from the samples by sugar-flotation-sieving (2), and *Meloidogyne* egg densities (1) were also determined. The nematode counts for each vine were recorded as total number of nematodes in the eight 500-cc soil samples taken from that vine. Based on examination of the nematode density data (4), $\log_{10}$ transformation was used throughout.

Experiment 1: To relate nematode densities to yield in the spatial distribution study, we had to deal with the covariance of the nematode densities sampled on different dates (6). The average nematode density in the experimental area at each sampling date was estimated by the average nematode density on the six vines sampled on that date. We assume that the average density for any set of six vines would have been the same as for any other set of six on the same date. Standard covariance analysis assumes that the effect of time on the nematode densities would be linear (13), however, this was not the case (6). The densities followed a curve, the slope at any point in time being determined by the reproduction rate at that time and the environmental conditions. If we assume that over the 37 years of the vineyard's history the nematode/plant interaction on individual vines has stabilized, then vines with higher-than-average nematode densities and vines with lower-than-average nematode densities will maintain the same relative difference in densities throughout the year. Then, the time trend problem can be handled by proportionate difference from the mean on each sampling date. On a vine with nematode density 20% above the mean in October, the density will be 20% above the mean in April. Log transformation of the data effectively handles the proportional differences from the mean:

$$\Delta_t = \text{Log } X_t - \text{Log } \overline{X}_t = \text{Log}\frac{X_t}{\overline{X}_t}$$

$$\text{Log } X_{(t+1)} = \text{Log } X_{(t+1)} + \text{Log}\frac{X_t}{\overline{X}_t}$$

$$= \text{Log}\frac{X_t}{\overline{X}_t}(\overline{X}_{(t+1)})$$

Since $X_{(t+1)}$ is a constant when all nematode densities are adjusted to sampling date $(t+1)$, we used the Δ_t values for our regressions and correlations against yield and growth of the vines. Of the 78 vines for which yield data were available, we rejected some vines on the following bases: (i) four vines shaded by nearby trees which might affect vine growth by reducing light intensity (7), (ii) extremely low-vigor vines (five vines) in which there were obvious problems other than nematodes.

Experiment 2: Locations were selected with different soil types for threshold density studies, on the premise that plants would be able to withstand the nematode stress depending upon the levels of other stresses to which they were subjected. Eight vines of varying vigor were selected on each soil type. The relationship of vine yield and growth to spring nematode densities, soil conditions, and plant vigor was determined. In other studies, up to 40 vines of either very high or very low vigor were selected on each soil type.

RESULTS

Data for parameters showing no obvious relationships in linear or multiple regressions and correlations are not presented. Multiple regressions between plant growth or vigor and more than one nematode species were all nonsignifcant and are not presented.

Experiment 1: Correlations between nematode numbers and plant yield and growth were higher with *X. americanum* when the densities were based on eight samples from the upper 60 cm of soil 30 cm from the trunk (Sample set 2) than when based on 40 samples to depth of 120 cm throughout the root zone (Sample set 1) [Fig. 1-(A to C)]. Correlations with *Paratylenchus hamatus* Thorne & Allen were higher with all 40 samples (Sample set 1) (Fig. 1-D to F). Higher correlations were obtained when vines in which differences that could be attributed to other causes were omitted. No correlation was found between vine yield and growth and *Meloidogyne* egg

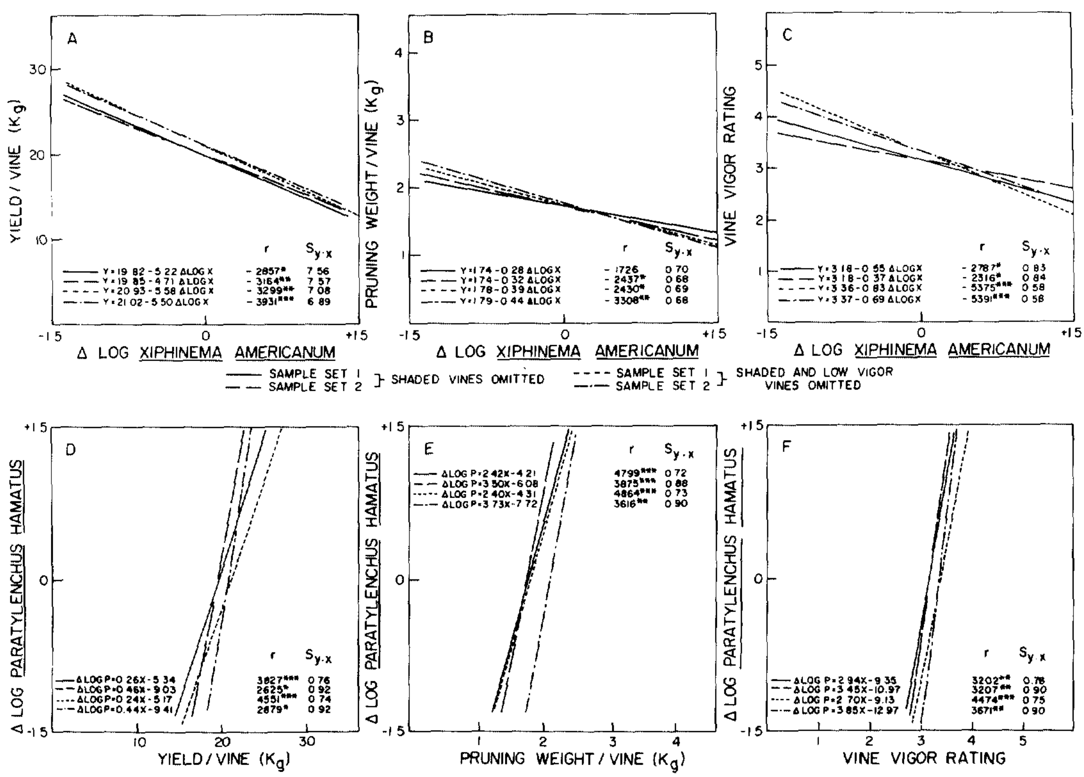


FIG. 1-(A to F). Relationship between nematode density and grapevine yield and vigor in experiment 1. **A**) Yield and *Xiphinema americanum*. **B**) Pruning weight and *X. americanum*. **C**) Vigor rating and *X. americanum*. **D**) *Paratylenchus hamatus* and yield. **E**) *P. hamatus* and pruning weight. **F**) *P. hamatus* and vigor rating.

and larval densities. Since *P. hamatus* was positively correlated with vine yield and vigor, we plotted it as a dependent variable on the premise that population densities of this nematode are dependent on the welfare of the vine. Higher correlations were achieved with the larger soil sample set for yield, pruning weight, and rating (Fig. 1-D to F). The standard deviation from regression $s_{y.x}$ improved as the appropriate data set was reached; however, it was too large in most cases for the equations to have any predictive value (Fig. 1-A to F).

Of the five vigor categories, five vines were rated 1, six were rated 5, and 44 were rated 3. No correlations were found between nematode density and vine yield or growth in the medium-vigor category. On the high-vigor vines, increasing densities of *X. americanum* had no apparent effect on yield, whereas on the low-vigor vines, yield decreased as *X. americanum* densities increased (Fig. 2-A). *P. hamatus* was positively related with yield of low-vigor vines but only when the restricted sample set was considered on high-vigor vines (Fig. 2-B). *Meloidogyne* egg and larval densities were not correlated with either yield or pruning weight of the low- and high-vigor vines for either sample set.

Experiment 2:—1) *Effects of soil physical factors on nematode density and distribution.*—Higher populations of *Meloidogyne* spp. were measured on the sandy loam soil at McCall Avenue (site 1a) (Table 1) and were positively correlated with % sand (Fig. 3-A). Multiplication, as measured by the postharvest/spring population ratio (P_f/P_i) was also greater on the coarser-textured soil (Table 1) and positively correlated with increased sand (Fig. 3-A), although these vines were generally less vigorous and yielded less than those on the finer soil (Table 1). At Porter Avenue (site 2) there were no correlations between *Meloidogyne* populations and soil physical factors (Fig. 5). Initial densities were similar on the sand and loam soils although multiplication was higher on the sand (Table 3) where again vines yielded less and were less vigorous. At Mecca (site 3) there were no correlations between *Meloidogyne* populations and soil physical factors (Fig. 6).

Population densities of *Xiphinema americanum* were greater in the sandier soil at sites 1a and 1b (Table 1 and 2), but were not correlated with soil physical conditions (Fig. 3). Population levels at site 2 were negatively related to sand percentage (Fig. 5-A). However, there were very few *X. americanum* in the sandy area (Table 3), possibly related to DBCP treatment 5 years previously.

At site 3, numbers of *Longidorus africanus* (Table 4) were correlated with the clay content of the soil and negatively related to the electrical conductivity below the 30-cm depth (Fig. 6-A, B). However, conductivity increase was correlated with lower clay content, and either or both of these factors could be

TABLE 1. Means and ranges of factors considered in correlations determined for the vineyard at site 1a (McCall Ave., Selma, California).

	Across soils		Hanford sandy loam		Hesperia fine sandy loam	
Factor	Mean	Range	Mean	Range	Mean	Range
1. P_i *Meloidogyne*[a]	3.24	0.80-30.98	5.13	1.10-30.98	2.29	0.80-11.18
2. P_i *Paratylenchus*[a]	0.60	0.02-1.94	0.06	0.02-0.36	0.56	0.10-1.88
3. P_i *Xiphinema*[a]	0.23	0.00-10.06	1.52	0.28-10.06	0.31	0.00-9.54
4. % Sand	58.4	53.6-65.1				
5. pH	6.1	6.0-6.3				
6. Trunk area (cm^2)	81.2	22.2-114.9	67.5	22.2-92.0	91.1	71.6-114.9
7. Cane area (cm^2)	2.3	0.6-4.2	2.1	0.6-3.5	2.5	1.0-4.2
8. No. of buds	12.4	6.0-20.2	14.8	10.5-20.2	10.6	6.0-13.0
9. Vigor rating	3.3	1-5	3.1	1-5	3.5	1-5
10. P_f/P_i *Meloidogyne*	6.0	0.1-26.6	10.0	0.9-26.6	3.1	0.1-8.7
11. P_f/P_i *Paratylenchus*	3.5	0.4-16.2	6.4	1.6-16.2	1.4	0.4-3.5
12. P_f/P_i *Xiphinema*	7.3	0.4-101.0	3.0	0.6-8.7	10.3	0.4-101.0
13. Yield/vine (kg)	15.8	1.1-39.6	13.7	1.1-27.9	17.4	8.4-27.6
14. % Sugar	19.1	16.3-21.5	19.1	16.3-21.5	19.1	16.8-21.0
15. Pruning wt. (kg)	2.6	0.4-5.1	2.0	0.4-5.1	3.0	1.5-4.8

[a]($\times 10^3$). Based on numbers of nematodes in eight samples of 500 cc soil taken from each vine. Log_{10} transformations of these numbers were used in correlations.

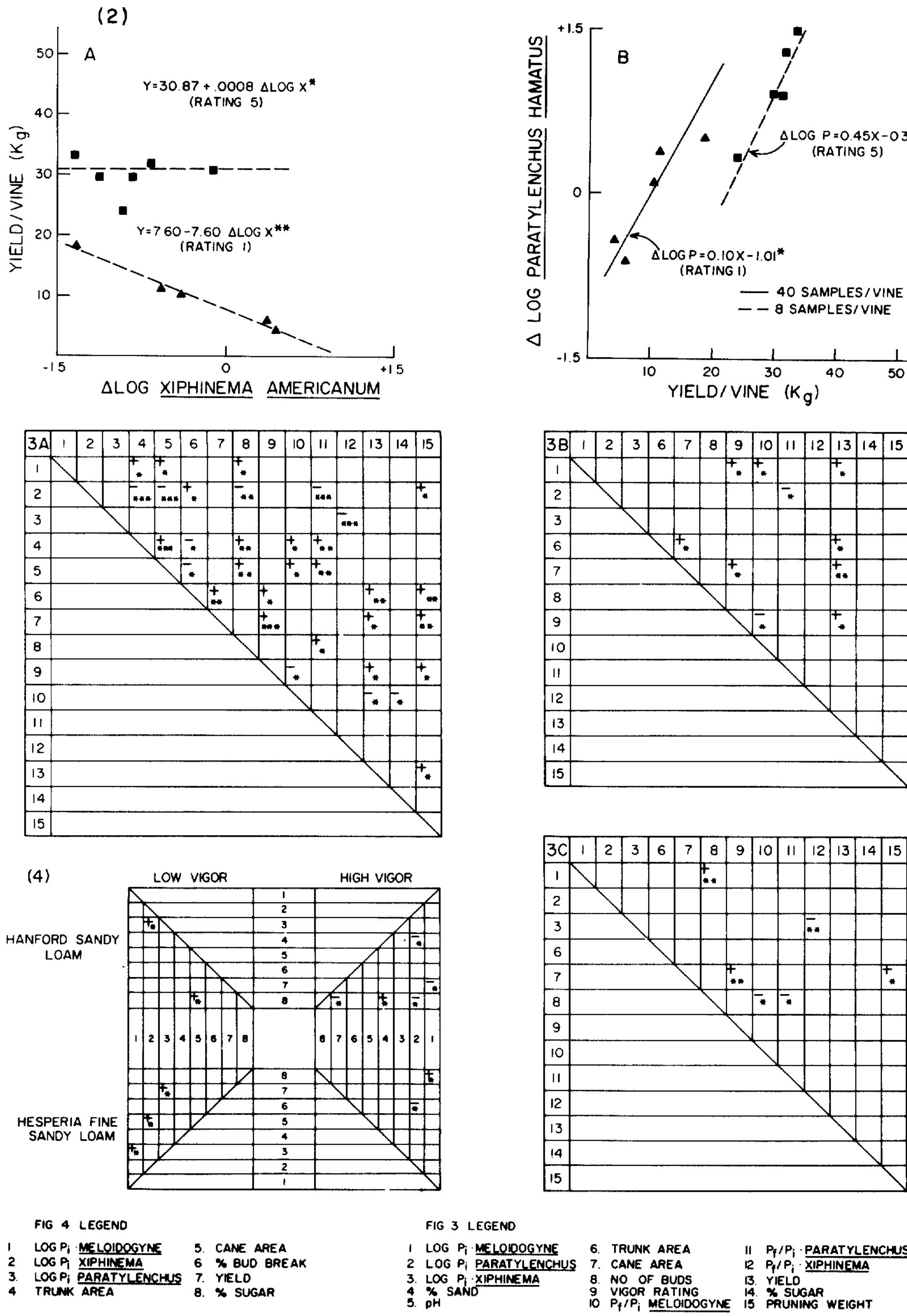


FIG. 2-4. 2) Relationships between nematode density and yield of high and low-vigor grapevines in experiment 1. 2-A) *Xiphinema americanum*. 2-B) *Paratylenchus hamatus*. 3) Correlation matrices of nematode densities, vine yield and growth, and soil factors at McCall Avenue (site 1a) in experiment 2. 3-A) Across soil textures. 3-B) Sand soil (Hanford sandy loam). 3-C) Silty soil (Hesperia fine sandy loam). 4) Correlation matrix of nematode densities and vine yield and growth at McCall Avenue (site 1b) in experiment 2.

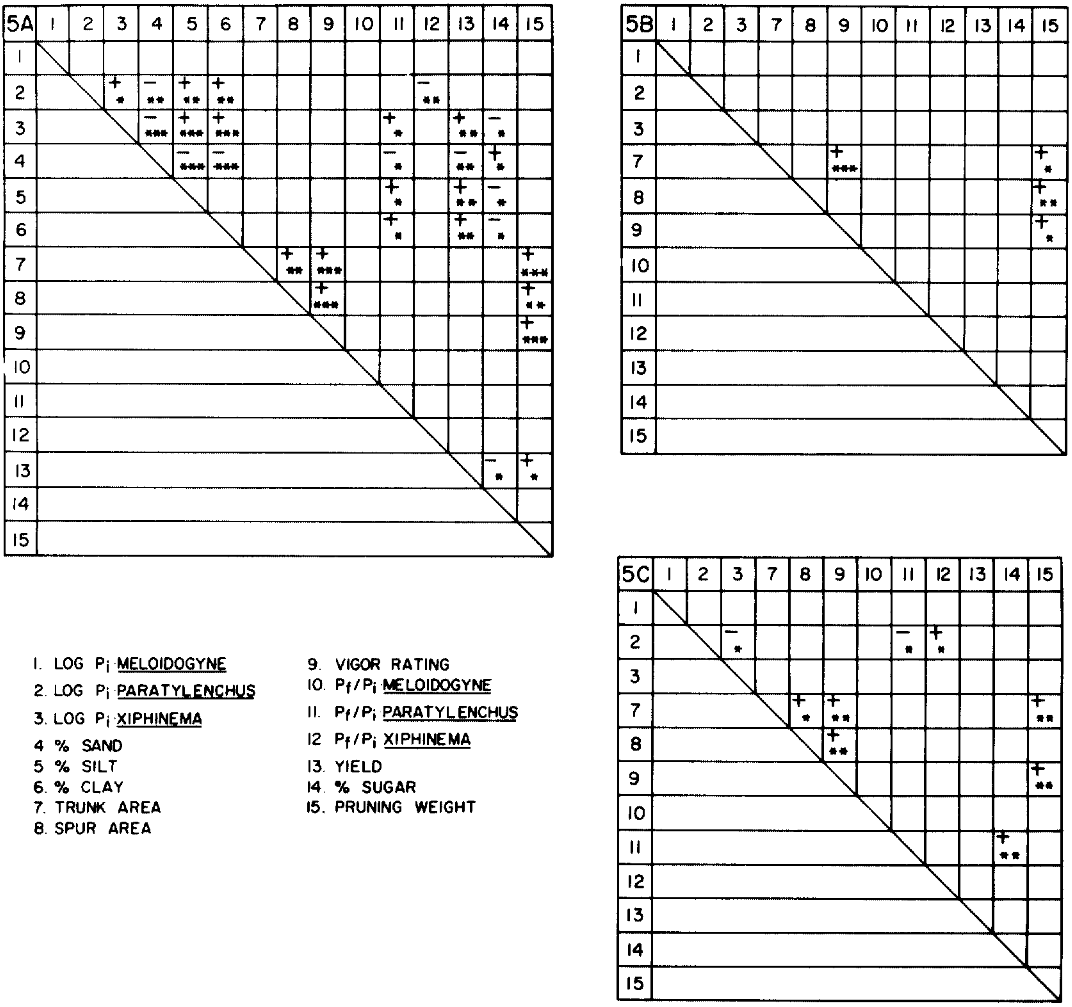


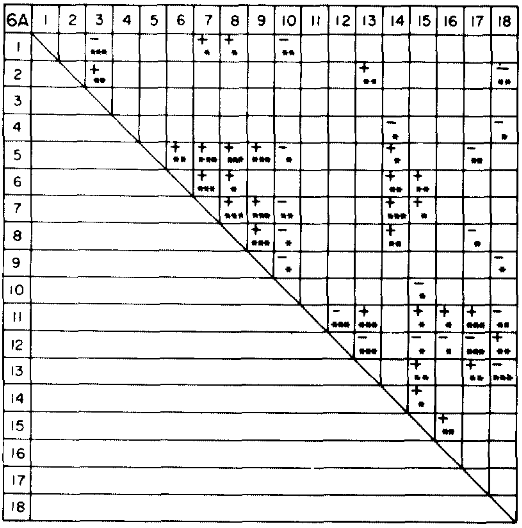
FIG. 5-(A to C). Correlation matrices of nematode densities, vine yield and growth and soil factors at Porter Ave. (site 2) in experiment 2. **A**) Across soil textures. **B**) Sandy soil. C) Loam soil.

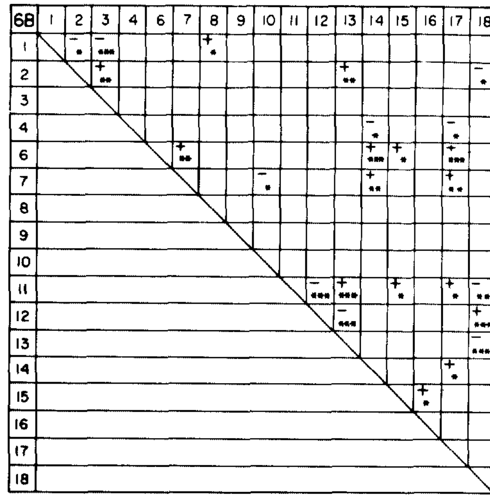
confounded in the nematode distribution effect. Multiplication of the nematode (P_f/P_i) was also correlated negatively with the electrical conductivity below 30 cm (Fig. 6-A).

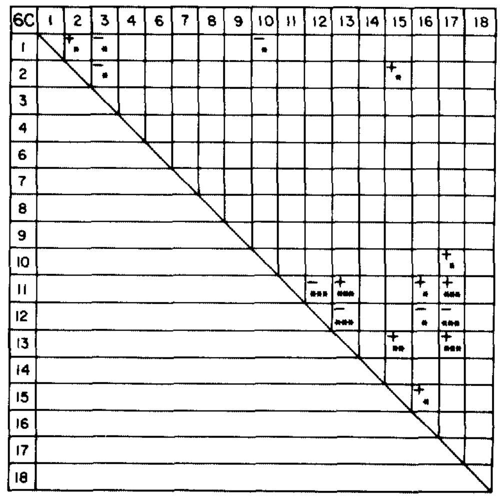
At sites 1a, 1b and 2, *Paratylenchus hamatus* densities were greater on the finer textured soils (Tables 1, 2 and 3) and were correlated with lower sand content (Fig. 3-A, 5-A). Multiplication (P_f/P_i) of the nematode was higher on the coarser-textured soil, and positively correlated with % sand at site 1a (Table 1, Fig. 3-A), but lower on the coarse-textured soil and negatively related to % sand at site 2 (Table 3, Fig. 5-A).

—2) *Effects of soil physical factors on vine yields and vigor.*—Vine yields were lower on the coarse-textured soil at site 1a (Table 1). The yields of low-vigor vines on the sandy loam soil were lower than those of low-vigor vines on fine sandy loam soil at site 1b (Table 2). However, the correlations were not significant (Fig. 3-A). Yield was negatively correlated with sand percentage at site 2 (Table 3, Fig. 5-A). At site 3, yield measurements (berry wt.) were positively related to sand content, but the sandy areas had lower salt concentrations (electrical conductivity) below 30 cm (Table 4, Fig. 6-A).

—3) *Relationship between parasitic nematodes and vine yield and vigor.*—To remove the effects of known causes of growth differences, we divided our data according to

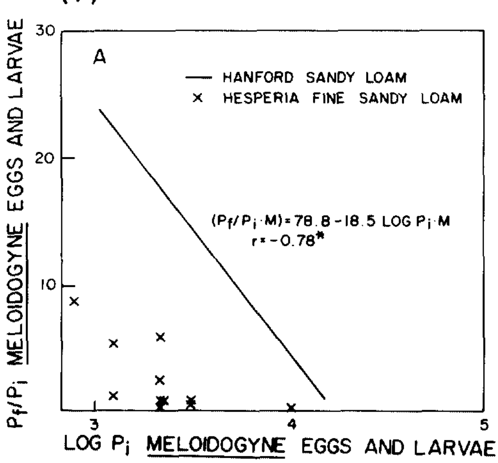






1 P_i MELOIDOGYNE
2 P_i LONGIDORUS
3 P_f/P_i MELOIDOGYNE
4 P_f/P_i LONGIDORUS
5 VIGOR RATING
6 TRUNK AREA
7 CANE AREA
8 VIGOR IN ROW
9 NO. OF BUDS
10 % BUD BREAK
11 % SAND
12 % SILT
13 % CLAY
14 NO. OF BUNCHES
15 BERRY WEIGHT
16 % SUGAR
17 E C 0-30cm
18 E C 30-60cm

(7)



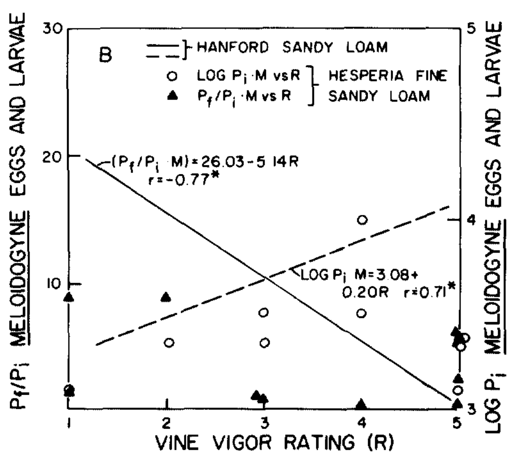


FIG. 6-7. **6)** Correlation matrices of nematode densities, vine yield and growth and soil factors at Mecca (site 3) in experiment 2. **6-A)** Across vine-vigor ratings. **6-B)** Low-vigor vines. **6-C)** High-vigor vines. **7)** Experiment 2, site 1a. **7-A)** Relationship of *Meloidogyne* multiplication (P_f/P_i) to spring nematode densities on two soil types. **7-B)** Relationship of *Meloidogyne* multiplication and spring population densities to vine vigor on two soil types. Lines represent significant correlations, points represent nonsignificantly correlated relationships.

TABLE 2. Means and ranges of factors considered in correlations determined for the vineyard at site 1b (McCall Ave., Selma, California).

	Hanford sandy loam				Hesperia fine sandy loam			
	Low-vigor vines		High-vigor vines		Low-vigor vines		High-vigor vines	
Factor	Mean	Range	Mean	Range	Mean	Range	Mean	Range
1. P_i *Meloidogyne*[a]	1.78	0.40-5.59	3.24	1.30-6.13	0.29	0.14-1.18	0.62	0.21-1.78
2. P_i *Xiphinema*[a]	0.20	0.02-1.88	0.32	0.12-0.68	0.02	0.00-0.34	0.04	0.00-0.66
3. P_i *Paratylenchus*[a]	0.01	0.00-0.06	0.01	0.00-0.04	0.24	0.06-1.78	0.36	0.18-0.70
4. Trunk area (cm^2)	43.0	21.7-81.5	102.9	55.9-187.1	92.8	74.0-124.0	97.1	76.4-127.2
5. Cane area (cm^2)	1.5	0.8-2.3	4.0	3.3-5.5	2.2	0.03-2.9	5.1	4.3-5.5
6. % Bud break	75.5	64.0-85.0	83.6	80.0-88.0	78.4	68.0-89.0	86.1	80.0-94.0
7. Yield/vine (kg)	7.5	0.8-18.3	26.4	19.5-35.5	12.3	4.6-20.1	25.7	18.6-30.5
8. % Sugar	20.0	18.0-23.0	17.7	16.0-19.7	18.0	14.0-19.5	17.5	15.8-18.8

[a]($\times 10^3$). Based on numbers of nematodes in four 500-cc samples of soil taken from each vine. Log_{10} transformations of these numbers were used in correlations.

TABLE 3. Means and ranges of factors considered in correlations determined for the vineyard at site 2 (Porter Ave., Dinuba, California).

	Across soils		Sand		Loam	
Factor	Mean	Range	Mean	Range	Mean	Range
1. P_i *Meloidogyne*[a]	5.37	0.14-29.02	10.00	2.86-19.36	2.89	0.14-29.02
2. P_i *Paratylenchus*[a]	0.06	0.00-0.30	0.02	0.00-0.18	0.19	0.06-0.30
3. P_i *Xiphinema*[a]	0.03	0.00-1.56	0.002	0.00-0.04	0.50	0.24-1.56
4. % Sand	53.9	45.1-62.6				
5. % Silt	22.7	17.8-27.6				
6. % Clay	22.8	18.4-27.2				
7. Trunk area (cm^2)	22.5	10.2-38.5	22.1	10.2-35.1	23.0	12.2-38.5
8. Spur area (cm^2)	5.3	2.7-8.8	5.2	3.2-8.8	5.4	2.7-7.3
9. Vigor rating	3.0	1-5	2.6	1-5	3.4	2-5
10. P_f/P_i *Meloidogyne*	1.9	0.02-6.8	2.6	0.6-6.8	1.1	0.02-5.7
11. P_f/P_i *Paratylenchus*	2.0	0.05-9.9	0.8	0.05-2.2	3.1	1.1-9.9
12. P_f/P_i *Xiphinema*	63.8	0.5-661.0	126.0	1.0-661.0	1.6	0.5-3.1
13. Yield vine (kg)	14.4	0.7-25.9	10.0	0.7-15.6	18.7	14.5-25.9
14. % Sugar	22.6	19.6-25.5	23.7	20.7-25.5	21.6	19.6-24.8
15. Pruning wt. (kg)	1.4	0.5-2.6	1.1	0.5-2.6	1.7	1.1-2.4

[a]($\times 10^3$). Based on numbers of nematodes in eight 500-cc samples of soil taken from each vine. Log_{10} transformations of these numbers were used in correlations.

TABLE 4. Means and ranges of factors considered in correlations at site 3 (Mecca, California).

	All vines		Low vigor		High vigor	
Factor	Mean	Range	Mean	Range	Mean	Range
1. P_i *Meloidogyne*[a]	8.52	1.50-67.18	6.03	1.88-44.55	11.50	1.50-67.18
2. P_i *Longidorus*[a]	0.11	0.00-0.60	0.09	0.00-0.26	0.14	0.04-0.60
3. P_f/P_i *Meloidogyne*	1.0	0.01-20.0	1.6	0.02-20.0	0.4	0.01-4.8
4. P_f/P_i *Longidorus*	0.5	0.01-75.0	0.5	0.01-75.0	0.5	0.01-1.4
5. Vigor rating	1.5	1-2				
6. Trunk area (cm^2)	112.7	49.7-191.0	96.4	49.7-168.3	128.1	92.0-191.0
7. Cane area (cm^2)	4.3	0.5-8.1	2.8	0.5-5.8	5.8	4.7-8.1
8. Vigor in row	4.4	1-8	2.5	1-4	6.5	5-8
9. No. of buds	67.1	12-115	54.9	12-81	78.6	53-115
10. % Bud break	49.8	13.0-77.0	55.5	30.0-75.0	44.5	13.0-77.0
11. % Sand	56.4	42.0-67.0	56.7	42.0-67.0	56.0	42.0-67.0
12. % Silt	24.9	13.0-43.0	24.5	13.0-43.0	25.4	13.0-43.0
13. % Clay	18.7	15.0-21.0	18.8	15.0-21.0	18.6	15.0-21.0
14. No. of bunches	22.4	3-47	18.5	7-35	26.2	3-47
15. Berry weight (g)	2.2	1.4-3.1	2.1	1.4-3.1	2.4	1.7-3.1
16. % Sugar	13.3	8.8-17.0	13.5	9.4-17.0	13.0	8.8-15.6
17. E.C. 0-30 cm	5.7	3.2-8.0	6.4	5.3-8.0	5.3	3.2-6.3
18. E.C. 30-60 cm	2.9	2.1-5.5	3.1	2.1-5.5	2.7	2.2-3.0

[a]($\times 10^3$). Based on numbers of nematodes in four 500-cc samples of soil taken from each vine. Log_{10} transformations of these numbers were used in correlations.

soil texture and/or plant vigor (Fig. 3-B, C; 4; 5-B, C; 6-B, C; 7-A, B).

Spring densities of *Meloidogyne* spp. (P_i) were positively correlated with plant yield and vigor on the coarse-textured soil of the Hanford series at site 1a (Fig. 3-B, 7-B), but not on the Hesperia fine sandy loam soil (Fig. 3-C, 7-B). Densities were lower on the finer soil and multiplication (P_f/P_i) lower (Table 1, Fig. 3-A; 7-A, B). On the coarse-textured soil at site 1a, initial densities (P_i) were high on the high-vigor vines but remained stable (P_f/P_i low), whereas densities on the low-vigor vines were low initially, but went through greater seasonal increase (Fig. 7-B). At site 1b there was no correlation between *Meloidogyne* densities and plant growth on either soil with the low-vigor vines, but yield was negatively correlated with densities on the high-vigor vines on the coarser-textured soil (Fig. 4). At site 3 on the low-vigor vines, *Meloidogyne* densities were positively correlated with the vigor rating of vines in each area of the field. (Fig. 6-B).

At site 1a there was no correlation between *X. americanum* densities and vine yield and growth (Fig. 3). However, at site 1b there was a negative relationship in the high-vigor vines (Fig. 4). At site 2 there was a positive correlation between vine yield and *X. americanum* densities (Fig. 5-A). Higher-vigor vines were on the loam soil where most of the *X. americanum* occurred (Table 3). The relationship did not hold amongst samples from the loam soil (Fig. 5-C).

On the low-vigor vines at site 3, multiplication (P_f/P_i ratio) of *L. africanus* was negatively correlated with number of bunches (Fig. 6-B), whereas spring densities were positively correlated with berry wt. on the high-vigor vines (Fig. 6-C).

Spring densities of *P. hamatus* at site 1a were positively correlated with trunk cross-sectional area and pruning weight, indicators of plant vigor (Fig. 3-A). They were positively correlated with yield of low-vigor vines at site 1b on the finer soil (Fig. 4) where larger numbers of nematodes occurred (Table 2). There was no correlation between *P. hamatus* and vine yield and growth at site 2 (Fig. 5).

DISCUSSION

After 2 years of examining several thousand soil samples and making several hundred measurements of vine yield and growth, we have found relatively few clear relationships between nematode density and plant growth. Some interesting data on nematode/soil-factor relationships have been obtained. We are unable to rationalize some of the correlations found in these studies; some may be meaningless, whereas others will require further studies to elucidate relationships. Perhaps in most cases studied, nematode densities in vineyards were below economic threshold levels. The pathogenic effects of nematodes became apparent when the vines were under stress, as in the coarser-textured soil at McCall Avenue. In these cases, high-vigor vines could tolerate the nematode-induced stress, whereas low-vigor vines could not.

Meloidogyne spp. were generally in greater numbers and apparently more likely to influence plant yield and vigor on sandier soil. *P. hamatus* were more numerous on finer-textured soils, positively correlated with yield and vine vigor and, perhaps, even indicative of it. *X. americanum* densities were usually greater in coarser-textured soils except where prior chemical treatment may have had a long-term effect.

Our demonstration of lower yield and vigor associated with *X. americanum* on the marginal soil situation at McCall Ave. seemed valid, although based on a covariance model which might be disputed. In some vineyards, we found that the nematode multiplication factor P_f/P_i decreased with increasing initial densities. This was not the case, however, in the field and the soil type to which we applied the model; hence, we feel that its use is valid. Higher correlations with yield and vigor were obtained when the soil sample set used corresponded to the distribution of the nematodes in the soil. Correlations with *X. americanum* were highest when samples were drawn from the upper 60 cm of soil where the majority of the population occurs and with samples down to 120 cm for the more generally distributed *P. hamatus* (5, 6).

To our knowledge, retarded growth of grapevines due to *X. americanum* has been demonstrated directly in greenhouse tests (3, 9), but only by implication in the field (11). Unfortunately, our regression equations have too great a standard error to have predictive usefulness in relating nematode numbers to potential loss in grapevine yield and growth. We are also unable to establish threshold densities at which damage occurs under particular situations. The data show, however, significant negative relationships between densities of *X. americanum* and vine yield and growth, and emphasize the importance of this nematode on low-vigor vines and in marginal situations.

Nematode pest management problems are especially difficult when, as at McCall Ave., most of the field is of one soil type with a small area of a different soil type. Management practices are suited to the major part of the field and may only compound the stresses in the marginal area. If each area of a field could be managed in accordance with its needs, we feel that many nematode problems in perennial crops could be alleviated. Unfortunately, patchwork management is difficult in modern agriculture with current mechanization and irrigation practices. Some possibilities which should be considered in these situations include smaller field divisions with closer individual management, and drip irrigation or sprinkler irrigation with varying emitter or nozzle capacities for differential water supply according to the requirements of the area. Another solution would be to vary plant spacing according to moisture or nutrient-holding capacities of different areas of a vineyard.

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