# Field Pathogenicity Studies of Four Species of Plant-Pathogenic Nematodes on French-American Hybrid Grapevine Cultivars in Michigan

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## ABSTRACT

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Ten French-American hybrid grapevine cultivars were evaluated for their reactions to four plant-parasitic nematodes: *Criconemella xenoplax, Meloidogyne hapla, Pratylenchus penetrans,* and *Xiphinema americanum.* In the spring of 1987, following soil fumigation, own-rooted vines of the cultivars Couderc 1202, Couderc 1616, Couderc 3309, Kober 5BB, Teleki 5A, Teleki 5C, Foch, Seyval, Vidal, and Vignoles were planted into microplots arranged in a completely randomized design with five replications per treatment. The microplots were inoculated with 2,500 *M. hapla* eggs, 2,500 juveniles and adults of the other three nematode species, or not inoculated. In 1989 and 1990, cane length was measured for each vine, and from 1991 to 1993, vine pruning weights and fruit yields were recorded. The experiment was terminated in the fall of 1993. At least one of the four species of nematodes reduced growth or yield of all the grapevine cultivars tested during 1 year of the study except for Couderc 1202. Yields of cv. Seyval were increased in the presence of all four species of nematodes in at least 1 year of the study, although vine pruning weight was reduced by *M. hapla* in 1993. In general, *M. hapla* was the most virulent of the nematodes studied. *Meloidogyne hapla* reduced fruit yields at least 1 year compared with the control plots in five of the seven cultivars from which yields were collected. *Criconemella xenoplax* only reduced yields of Foch, *P. penetrans* did not reduce yields of any cultivar, and *X. americanum* reduced yields of Vidal and Vignoles. This study should provide viticulturists with valuable information on nematode-grapevine cultivar interactions for management purposes.

Additional keywords: dagger nematode, lesion nematode, ring nematode, root-knot nematode, *Vitis*

Plant-parasitic nematodes are common in soil collected from Michigan vineyards. The ring nematode, *Criconemella xenoplax* (Raski) DeGrisse & Loof, was found in 49 of 50 vineyards in southwestern Michigan surveyed in 1985 (2). Dagger, *Xiphinema americanum* Cobb, and northern root-knot nematodes, *Meloidogyne hapla* Chitwood, were recovered in over 50% of the samples collected. Lesion, *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans-Stekhoven, stubby-root, *Trichodorus/Paratrichodorus* spp., and lance nematodes, *Hoplolaimus galeatus* (Cobb) Thorne, were less frequent. However, although plant-parasitic nematodes are prevalent in Michigan vineyard soils, there is a paucity of information concerning their damage to grapevine (*Vitis* spp.) in the United States east of the Rocky Mountains.

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*Criconemella xenoplax* is prevalent and numerous in Michigan vineyard soils, but its potential as a pathogen of grapevine is unknown. It has been collected around grapevines in poor health but it is often associated with two or more other species of plant-parasitic nematodes. It is known to cause peach tree short life disease (12).

Irrespective of its pathogenicity, *X. americanum* is known to be a vector of peach rosette mosaic virus (PRMV), an economically important virus that causes disease in southwestern Michigan vineyards (4,14,17). In addition, the nematode is also a vector of tomato ringspot virus (TmRSV) and tobacco ringspot virus (TRSV) in the eastern United States (5,6). Although the pathogenicity of *Xiphinema index* Thorne & Allen has been demonstrated on selected cultivars of grapevine in California (10,11,13) and Australia (7), this work has not been done in the eastern United States for *X. americanum* on French-American hybrid grapevines. Harris (7) reported the grapevine rootstocks Couderc 1202 (C1202) and C1616 were susceptible and C3309 was resistant to *X. index.* Because these three rootstocks have potential use in Michigan, they were included in our study.

The effects of *Meloidogyne incognita* (Kofoid & White) Chitwood and *Pratylenchus vulnus* Allen & Jensen on grapevine were investigated under field conditions in California in 1984 (3). The rootstock Couderc 1613, which has potential in Michigan although it is susceptible to infection by PRMV (15), supported population increases of *P. vulnus* and at high inoculum levels C1613 root weights were reduced 15 to 30%. *Meloidogyne incognita* caused no disease on any of the rootstocks tested. In more recent experimental work, Walker et al. (18) reported on field tests done with *M. incognita* and 10 species of *Vitis* plus hybrids. In their study, C1616 was used as a resistant control along with C1613.

Due to the lack of information on the damage caused by *C. xenoplax*, *M. hapla*, and *X. americanum* to grapevine cultivars used in the eastern United States, a field microplot trial was conducted to determine the pathogenicity of these nematodes to 10 French-American grapevine cultivars. A fourth species, *P. penetrans* (Cobb) Filipjev & Schuurmans-Stekhoven, was also included because it is the most frequently recovered plant-parasitic nematode in Michigan. This information should be useful to Michigan viticulturists; it demonstrates the importance of sampling for nematodes for management decisions, and lessening reliance on nematicides.

## MATERIALS AND METHODS

**Microplot preparation.** The research site near Lawton, MI, had been occupied by old *Vitis labrusca* L. 'Concord' vines that were removed 2 years before initiation of the experiment. The site was a deep sandy loam (51% sand, 44% silt, 3% clay; 2% organic matter; pH 6.0). In October 1986, a 0.45-ha area was fumigated with methyl bromide–chloropicrin at 1,010 kg/ha applied by shank injection and covered with a 2 mil polyethylene tarp. In April 1987, no plant-parasitic nematodes were recovered from post-fumigation samples taken at 15.3, 45.7, and 91.4 cm depths.

The microplots were constructed of 0.64-cm-thick fiberglass sheeting installed in a 121.9-cm-diameter circle and 61 cm deep. The centers of the plots were 305 cm apart within rows and 366 cm between rows (Fig. 1). Each circle was dug with a Vermeer tree spade; thus, the microplots were conical (Fig. 2).

**Vine propagation and nematode inoculum.** Twenty-five cuttings of 10 French-American hybrid grapevine cultivars were propagated from the Michigan State University virus-tested grapevine repository located in East Lansing. One-year-old four-bud cane pieces were cut during the dormant season. The cuttings were rooted in moist sand with supplementary bottom heat (30°C). Rooted cuttings were transplanted into a soil-peat-perlite (1:1:1, vol/vol/vol) mixture and the vines grown in a glasshouse for 6 months. Following a dormant period, the vines were planted in the microplots. Of the 10 cultivars utilized, Couderc 1202 (C1202), C1616, C3309, Kober 5BB, Teleki 5A (T5A), and T5C are typically used as rootstocks in Michigan. Foch, Seyval, Vidal, and Vignoles are typically grown as scions. The cultivars were planted in arbitrarily selected microplots in April 1987, for a total of 250 experimental units.

The microplots were inoculated with nematodes in the spring of 1987, a week after the vines were planted. *Criconemella xenoplax* was extracted by a modified centrifugal-flotation technique (9) in a greenhouse from soil in which cherry (*Prunus avium* L.) was growing. *Meloidogyne hapla* eggs were collected by a sodium hypochlorite method (8) from roots of tomato (*Lycopersicon esculentum* Mill. 'Rutgers') grown in the greenhouse. *Pratylenchus penetrans* was obtained on a gyratory shaker and an incubation solution containing mercuric chloride and streptomycin sulfate (1) from a greenhouse culture on corn (*Zea mays* L. 'IO Chief'). *Xiphinema americanum* was extracted by the centrifugal-flotation method (9) from soil collected from a commercial blueberry (*Vaccinium corymbosum* L.) field in southwestern Michigan. Microplot soil was infested at a rate of 2,500 juveniles and adults per vine, except for *M. hapla,* for which eggs were added to the soil. The nematodes were applied to the plots through three pipettes placed equidistantly around a 61 cm circle to a depth of 5 to 10 cm. Soil and root samples were collected in September 1987 for nematode extraction. If nematodes were not detected within infested plots, the plots were reinfested in April 1988.

A drip irrigation system was installed within 1 month of planting to provide water during the summer months. The plots were fertilized with nitrogen (approximately 100 kg/ha) annually. Weeds were controlled manually the first 2 years, then with Simazine Caliber 90 (Ciba Agric. Chemicals, Greensboro, NC) applied at 1.68 kg a.i./ha in a band 122 cm wide centered on the row. After the first 2 years of vine establishment, the vines were balanced pruned to a 30+10 formula to establish plant uniformity (16 ).

**Nematode sampling and vine growth and yield measurements.** Soil and root samples were collected for nematodes annually in the spring (usually in May). Approximately 500 $cm^3$ of soil and 1 to 2 g of root tissue were collected from each microplot to a depth of approximately 20 cm. A final destructive sample was taken in September 1993, when the vines were removed. Nematodes were extracted from the soil by a modified centrifugal-flotation method (9) with nested 1,000-µm- and 38-µm-pore sieves. Nematodes were extracted from 1-g subsamples of root tissue by the shaker method (1). After being shaken for 48 to 72 h, nematodes were removed from the incubation solution with nested 150-µm- and 38-µm-pore sieves.

Beginning in November 1989, grapevine cane length was measured on the 10 longest canes per vine. This was repeated the following year. In February of 1991 through 1993, vine pruning weights were taken for each vine as a more accurate measure of vegetative growth. Fruit was harvested in September 1991 through 1993. Some of the cultivars (C1616, C3309, and T5C) did not produce fruit; they are typically utilized as rootstocks (Table 1). All data were analyzed for analysis of variance and Duncan's multiple range test was used for means separation.

## RESULTS AND DISCUSSION

Vine cane length, vine pruning weight, or marketable yield was significantly reduced compared with the controls by at least one of the four species of nematodes tested in at least 1 year of the study of all the grapevine cultivars except for Couderc 1202 (Table 1). Fruit yields were not re-

**Fig. 1.** View of test plot area showing the use of fiberglass microplots to compartmentalize nematodes used to infest soil around test vines.

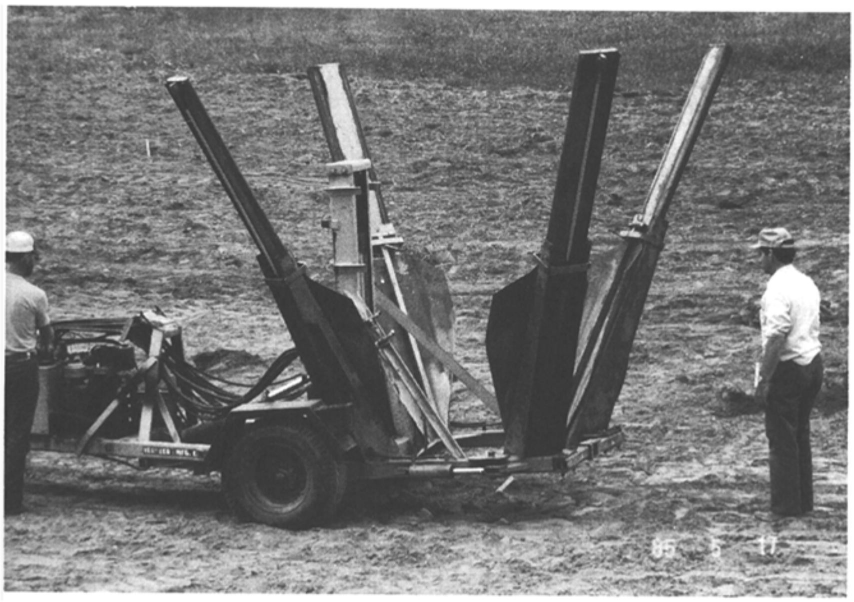

**Fig. 2.** Use of Vermeer tree spade to lift up a cone of soil at each vine site, to facilitate fitting the cone-shaped fiberglass barrier around each vine.

duced by any of the nematodes for C1202, Kober 5BB, and Seyval. In 1991 and 1992, yields of Seyval were higher in the inoculated plots than in the control plots.

In general, nematode numbers did not differ greatly among cultivars (Table 2). Counts were variable from year to year, but the population densities of all four nematodes were lower in 1993 than in the previous 3 years. Based on nematode population densities, the only cultivar resistant to any of the four species tested was C1616. *Meloidogyne hapla* second-stage juveniles were never recovered from roots of C1616 from 1990 to 1993, although statistically this response was not different from those of the other cultivars.

The summary of nematode effects on growth and yield of the 10 French-American grapevine cultivars is presented in Table 3. In general, the three Couderc rootstocks (C1202, C1616, and C3309) would be good choices for growers in Michigan and the eastern United States, based on our results. Although cane lengths and vine weights of C1616 and C3309 were reduced by *M. hapla*, yields were not affected. C1616 and C1613 were also shown to be resistant to *M. incognita* in a study conducted in California (18). It is possible that Couderc rootstocks have resistance to *M. hapla*.

The Couderc rootstocks were not af-

**Table 1.** Mean vine growth, pruning weights, and fruit yields of grapevine culitvars exposed to four species of plant parasitic nematodes in microplots located near Lawton, MI[x]

| | | 1989[y] | 1990[y] | 1991[y] | | 1992[y] | | 1993[y] | |
|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Nematode spp. | Vine cane length | Vine cane length | Vine pruning wt. | Fruit yield | Vine pruning wt. | Fruit yield | Vine pruning wt. | Fruit yield |
| Couderc 1202 | None | 80 c | 141 c | 238 c | 4,100 c | 289 c | 3,463 c | 394 c | 1,700 c |
| C1202 | *C. xenoplax* | 92 c | 148 c | 202 c | 3,420 c | 196 c | 1,545 c | 472 c | 1,705 c |
| C1202 | *X. americanum* | 90 c | 128 c | 269 c | 3,460 c | 154 c | 3,238 c | 971 c | 1,852 c |
| C1202 | *P. penetrans* | 76 c | 113 c | 228 c | 4,000 c | 251 c | 2,193 c | 746 c | 2,225 c |
| C1202 | *M. hapla* | 67 c | 126 c | 96 c | 2,360 c | 141 c | 2,063 c | 365 c | 1,707 c |
| Couderc 1616 | None | 170 b | 232 bc | 681 c | ...[z] | 1,867 b | ... | 1,108 b | ... |
| C1616 | *C. xenoplax* | 100 b | 137 c | 363 c | ... | 1,092 b | ... | 1,271 b | ... |
| C1616 | *X. americanum* | 260 a | 299 b | 407 c | ... | 2,220 b | ... | 1,916 b | ... |
| C1616 | *P. penetrans* | 180 b | 159 c | 475 c | ... | 898 c | ... | 1,544 b | ... |
| C1616 | *M. hapla* | 70 c | 119 c | 746 c | ... | 479 c | ... | 512 c | ... |
| Couderc 3309 | None | 125 b | 164 b | 332 bc | ... | 877 bc | ... | 1,589 b | ... |
| C3309 | *C. xenoplax* | 138 b | 158 b | 209 c | ... | 1,298 a | ... | 1,253 bc | ... |
| C3309 | *X. americanum* | 160 b | 184 b | 582 b | ... | 1,487 a | ... | 1,374 b | ... |
| C3309 | *P. penetrans* | 120 b | 121 bc | 336 bc | ... | 1,020 a | ... | 900 bc | ... |
| C3309 | *M. hapla* | 60 c | 83 c | 15 c | ... | 101 c | ... | 295 c | ... |
| Teleki 5A | None | 160 b | 286 c | 445 bc | ... | 1,260 c | 778 c | 962 b | 237 b |
| T5A | *C. xenoplax* | 190 b | 227 c | 247 bc | ... | 1,002 c | 288 c | 754 bc | 282 b |
| T5A | *X. americanum* | 225 a | 311 c | 630 b | ... | 1,486 c | 818 c | 1,571 b | 145 bc |
| T5A | *P. penetrans* | 230 b | 289 c | 481 bc | ... | 1,014 c | 350 c | 572 c | 182 bc |
| T5A | *M. hapla* | 98 b | 108 c | 25 c | ... | 1,141 c | 417 c | 1,063 b | 36 c |
| Teleki 5C | None | 106 c | 164 b | 342 b | ... | 1,838 a | ... | 1,089 bc | ... |
| T5C | *C. xenoplax* | 170 b | 158 b | 414 b | ... | 1,152 ab | ... | 858 c | ... |
| T5C | *X. americanum* | 180 b | 184 b | 459 b | ... | 1,209 ab | ... | 1,175 bc | ... |
| T5C | *P. penetrans* | 210 b | 121 bc | 355 b | ... | 1,070 b | ... | 2,170 b | ... |
| T5C | *M. hapla* | 115 bc | 83 c | 32 c | ... | 502 c | ... | 772 c | ... |
| Kober 5BB | None | 217 b | 298 b | 460 c | ... | 1,838 b | 327 c | 1,807 b | ... |
| K5BB | *C. xenoplax* | 138 bc | 239 bc | 85 c | ... | 829 c | 500 c | 654 c | ... |
| K5BB | *X. americanum* | 243 b | 297 b | 546 c | ... | 1,050 bc | 448 c | 1,253 b | ... |
| K5BB | *P. penetrans* | 154 bc | 239 bc | 207 c | ... | 681 c | 270 c | 602 c | ... |
| K5BB | *M. hapla* | 77 c | 178 c | 128 c | ... | 605 c | 433 c | 828 c | ... |
| Foch | None | 85 b | 107 c | 180 c | 1,080 b | 323 c | 4,525 b | 591 c | 2,315 c |
| Foch | *C. xenoplax* | 115 b | 86 c | 70 c | 300 c | 165 c | 4,175 b | 267 c | 3,223 c |
| Foch | *X. americanum* | 135 a | 66 c | 88 c | 600 bc | 79 c | 1,278 ab | 433 c | 2,379 c |
| Foch | *P. penetrans* | 85 b | 70 c | 61 c | 560 bc | 148 c | 1,320 ab | 182 c | 1,889 c |
| Foch | *M. hapla* | 65 b | 56 c | 22 c | 200 c | 147 c | 483 c | 327 c | 3,096 c |
| Seyval | None | 70 c | 114 c | 51 c | 2,360 c | 147 c | 1,128 c | 227 bc | 1,725 c |
| Seyval | *C. xenoplax* | 90 b | 136 c | 181 c | 8,280 b | 695 c | 828 c | 719 a | 1,725 c |
| Seyval | *X. americanum* | 148 b | 193 c | 248 c | 9,860 b | 272 c | 3,635 b | 191 bc | 1,598 c |
| Seyval | *P. penetrans* | 94 b | 135 c | 210 c | 5,740 bc | 160 c | 1,513 b | 300 b | 2,733 c |
| Seyval | *M. hapla* | 150 b | 124 c | 89 c | 5,000 bc | 116 c | 2,267 b | 123 c | 1,289 c |
| Vidal | None | 75 c | 122 c | 146 c | 4,740 c | 210 c | 2,473 b | 300 b | 1,074 c |
| Vidal | *C. xenoplax* | 150 c | 173 c | 242 c | 5,780 c | 1,152 c | 3,955 b | 306 b | 2,197 c |
| Vidal | *X. americanum* | 120 c | 169 c | 226 c | 6,240 c | 290 c | 723 c | 167 bc | 2,397 c |
| Vidal | *P. penetrans* | 110 c | 158 c | 62 c | 4,600 c | 261 c | 2,788 b | 572 b | 2,007 c |
| Vidal | *M. hapla* | 70 c | 97 c | 29 c | 5,260 c | 164 c | 2,105 b | 124 c | 1,371 c |
| Vignoles | None | 120 b | 125 b | 110 c | 900 bc | 230 c | 1,660 b | 454 b | 690 b |
| Vignoles | *C. xenoplax* | 55 c | 88 bc | 16 c | 1,200 bc | 65 c | 1,450 b | 65 c | 372 bc |
| Vignoles | *X. americanum* | 100 b | 139 b | 146 c | 1,980 b | 183 c | 920 c | 228 bc | 518 bc |
| Vignoles | *P. penetrans* | 118 b | 139 b | 145 c | 1,800 b | 170 c | 1,183 b | 647 b | 454 bc |
| Vignoles | *M. hapla* | 44 c | 49 c | 18 c | 180 c | 60 c | 368 c | 49 c | 236 c |

[x] Means followed by letters in common in columns within each cultivar do not differ significantly according to Duncan's multiple range test, $P = 0.05$.
[y] Cane length in centimeters. Other values in grams.
[z] Data not taken due to fruitlessness by the cultivar indicated.

fected by *X. americanum* or *P. penetrans* in our study. Harris (7) found that *X. index* caused slight root damage to C1616 and moderate to severe damage to C3309. Root growth was not quantified in our study, but severe root damage would probably have resulted in reduced growth or fruit yields. These effects were not observed. Chitambar and Raski (3) demonstrated that root weight of C1613 was reduced by high levels of *P. vulnus*. C1613 was not grown in this trial, but *P. penetrans* was not pathogenic on C1202, C1616, or C3309 at the population density used in our investigation.

The other three cultivars known as rootstocks, Teleki 5A, T5C, and Kober 5BB, should be avoided in the presence of certain nematodes. Yields of T5A were greatly reduced by *M. hapla* in 1993 at very low nematode population densities. No yields were obtained for the other two cultivars in 1993, but vine pruning weights of T5C were reduced by *C. xenoplax* and *M. hapla* and of Kober 5BB by *C. xenoplax*, *P. penetrans*, and *M. hapla*. *Xiphinema americanum* was not pathogenic to these three cultivars at the population density utilized.

Of the four cultivars generally known as scions, Seyval appears to be the best choice for sites with nematode infestations. In 1993, although vine pruning weights were reduced by *C. xenoplax* and *M. hapla*, yields were not reduced by the nematodes. In 1991 and 1992, yields of Seyval were often higher in the nematode-treated plots than in the control plots. Seyval is a white wine cultivar often grown on its own roots.

Vidal and Vignoles were the only two cultivars used in this study whose yields were reduced by *X. americanum*. These yield reductions occurred in 1992 but not in 1993. Population densities of this species were also higher in 1992 than in 1993, possibly explaining the yield results. Yields of Vignoles were also reduced by *M. hapla* in 1992 and 1993. Although these two cultivars are regarded as excellent white wine grapes, grown on their own roots, they may be of limited utility in Michigan and the eastern United States.

Our study demonstrated the importance of sampling potential sites for plant-parasitic nematodes prior to vineyard establishment. The 10 French-American hybrid grapevine cultivars differed in their reactions to the four species of nematodes used in our investigation. Proper nematode

**Table 2.** Population densities of plant-parasitic nematodes in artificially infested French-American hybrid grapevine microplots located near Lawton, MI

| | Mean no. nematodes recovered | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *C. xenoplax* | | *X. americanum* | | *P. penetrans* | | *M. hapla* | |
| **Year/cultivar** | **g root** | **100 cc soil** | **g root** | **100 cc soil** | **g root** | **100 cc soil** | **g root** | **100 cc soil** |
| 1990[y] | | | | | | | | |
| Couderc 1202 | ...[z] | 516 c | ...[z] | 72 c | 33 c | 1 bc | 161 c | 306 b |
| Couderc 1616 | ... | 158 c | ... | 87 c | 73 c | 2 bc | 0 c | 1 c |
| Couderc 3309 | ... | 225 c | ... | 17 c | 1 c | 0 c | 36 c | 26 bc |
| Teleki 5A | ... | 765 c | ... | 34 c | 52 c | 1 c | 3 c | 1 c |
| Teleki 5C | ... | 205 c | ... | 58 c | 5 c | 0 c | 77 c | 38 bc |
| Kober 5BB | ... | 373 c | ... | 19 c | 211 c | 4 bc | 2 c | 7 c |
| Foch | ... | 1,860 b | ... | 46 c | 2 c | 0 c | 1 c | 16 bc |
| Seyval | ... | 752 c | ... | 46 c | 26 c | 2 bc | 167 c | 291 ab |
| Vidal | ... | 352 c | ... | 51 c | 227 c | 1 c | 2 c | 15 bc |
| Vignoles | ... | 197 c | ... | 6 c | 81 c | 7 b | 30 c | 96 abc |
| 1991[y] | | | | | | | | |
| Couderc 1202 | ... | 55 bc | ... | 3 c | 22 c | 1 c | 56 c | 174 bc |
| Couderc 1616 | ... | 9 c | ... | 296 b | 620 c | 1 c | 0 c | 2 c |
| Couderc 3309 | ... | 31 bc | ... | 84 bc | 112 c | 1 c | 0 c | 2 c |
| Teleki 5A | ... | 201 abc | ... | 136 bc | 0 c | 249 bc | 1 c | 17 c |
| Teleki 5C | ... | 30 bc | ... | 197 bc | 50 c | 1 c | 1 c | 0 c |
| Kober 5BB | ... | 41 bc | ... | 42 c | 323 c | 849 b | 0 c | 26 c |
| Foch | ... | 339 ab | ... | 78 bc | 0 c | 672 b | 0 c | 1 c |
| Seyval | ... | 204 abc | ... | 87 bc | 347 c | 1 c | 46 c | 80 bc |
| Vidal | ... | 419 a | ... | 103 bc | 365 c | 2 c | 45 c | 270 b |
| Vignoles | ... | 47 bc | ... | 30 c | 21 c | 3 c | 2 c | 0 c |
| 1992[y] | | | | | | | | |
| Couderc 1202 | ... | 313 c | ... | 41 c | 183 c | 19 c | 13 c | 240 b |
| Couderc 1616 | ... | 240 c | ... | 102 c | 440 bc | 48 c | 0 c | 2 c |
| Couderc 3309 | ... | 155 c | ... | 14 c | 14 c | 14 c | 2 c | 5 c |
| Teleki 5A | ... | 444 c | ... | 54 c | 732 b | 55 c | 1 c | 5 c |
| Teleki 5C | ... | 17 c | ... | 19 c | 5 c | 0 c | 0 c | 3 c |
| Kober 5BB | ... | 380 c | ... | 29 c | 128 c | 22 c | 109 b | 0 c |
| Foch | ... | 548 c | ... | 8 c | 51 c | 0 c | 2 c | 5 c |
| Seyval | ... | 743 c | ... | 0 c | 126 c | 5 c | 12 c | 291 b |
| Vidal | ... | 145 c | ... | 85 c | 321 c | 32 c | 43 c | 187 b |
| Vignoles | ... | 332 c | ... | 19 c | 24 c | 1 c | 39 c | 159 b |
| 1993[y] | | | | | | | | |
| Couderc 1202 | ... | 40 c | ... | 2 c | 87 c | 0 c | 40 c | 68 b |
| Couderc 1616 | ... | 5 c | ... | 5 c | 2 c | 15 c | 0 c | 0 c |
| Couderc 3309 | ... | 23 c | ... | 52 b | 7 c | 0 c | 32 c | 0 c |
| Teleki 5A | ... | 48 c | ... | 8 c | 86 c | 4 c | 1 c | 0 c |
| Teleki 5C | ... | 13 c | ... | 6 c | 51 c | 0 c | 0 c | 0 c |
| Kober 5BB | ... | 5 c | ... | 4 c | 51 c | 2 c | 3 c | 0 c |
| Foch | ... | 150 c | ... | 1 c | 4 c | 0 c | 8 c | 0 c |
| Seyval | ... | 88 c | ... | 3 c | 123 c | 1 c | 48 c | 0 c |
| Vidal | ... | 29 c | ... | 6 c | 41 c | 10 c | 13 c | 0 c |
| Vignoles | ... | 17 c | ... | 1 c | 45 c | 28 c | 17 c | 47 bc |

[y] Means followed by letters in common in columns do not differ significantly according to Duncan's multiple range test, $P = 0.05$.
[z] No root analysis because these nemas are ectoparastic.

**Table 3.** Summary of nematode effects on growth and yield of 10 French-American grapevine cultivars in Michigan

| Cultivar | Cane length | Vine pruning weight | Fruit yield | Susceptibility, tolerance, or resistance |
|---|---|---|---|---|
| Couderc 1202 | No effect | No effect | No effect | Tolerant to at least *C. xenoplax, P. penetrans,* and *M. hapla* and possibly resistant to *X. americanum* |
| Couderc 1616 | Reduced 1989 by *M. hapla;* increased 1989 by *X. americanum* | Reduced 1992, 1993 by *M. hapla* and 1992 by *P. penetrans* | Not measured (no crop) | Resistant to *C. xenoplax,* probably tolerant to *X. americanum,* tolerant to *P. penetrans,* susceptible to *M. hapla* |
| Couderc 3309 | Reduced 1989, 1990 by *M. hapla* | Reduced 1992, 1993 by *M. hapla;* increased 1992 by *C. xenoplax, X. americanum,* and *P. pentrans* | Not measured (no crop) | Resistant to *C. xenoplax* and *X. americanum,* tolerant to *P. penetrans,* and susceptible to *M. hapla* |
| Kober 5BB | Reduced 1989, 1990 by *M. hapla* | Reduced 1992, 1993 by *C. xenoplax, P. penetrans,* and *M. hapla* | No effect 1992; not measured 1993 (no crop) | Susceptible to *C. xenoplax* and *P. penetrans,* resistant to *X. americanum,* susceptible to *M. hapla* |
| Teleki 5A | Increased 1989 by *X. americanum* | Reduced 1991 by *M. hapla;* reduced 1993 by *P. penetrans* | Reduced 1993 by *M. hapla* | Susceptible to *P. penetrans* and *M. hapla;* tolerant to *C. xenoplax* and *X. americanum* |
| Teleki 5C | Reduced 1990 by *M. hapla* | Reduced 1991, 1992 by *M. hapla* and 1992 by *P. penetrans* | Not measured (no crop) | Susceptible to *M. hapla*; resistant/tolerant to *P. penetrans;* tolerant to *X. americanum;* resistant to *C. xenoplax* |
| Foch | Increased 1989 by *X. americanum* | No effect | Reduced 1991, 1992 by *M. hapla* and 1991 by *C. xenoplax* | Susceptible to *M. hapla*; tolerant to *C. xenoplax, X. americanum,* and *P. penetrans* |
| Seyval | Increased 1989 by *C. xenoplax, X. americanum, P. penetrans,* and *M. hapla* | Increased 1993 by *C. xenoplax;* reduced 1993 by *M. hapla* | Increased 1991, 1992 by *X. americanum,*1991 by *C. xenoplax,* 1992 by *P. penetrans* and *M. hapla* | Susceptible to *C. xenoplax;* tolerant to *M. hapla, P. penetrans,* and *X. americanum* |
| Vidal | No effect | Reduced 1993 by *M. hapla* | Reduced 1992 by *X. americanum* | Susceptible to *M. hapla;* tolerant to *C. xenoplax, X. americanum,* and *P. penetrans* |
| Vignoles | Reduced 1989, 1990 by *M. hapla* and 1989 by *C. xenoplax* | Reduced 1993 by *C. xenoplax* and *M. hapla* | Reduced 1992, 1993 by *M. hapla,* and 1992 by *X. americanum* | Very susceptible to *M. hapla;* tolerant to *C. xenoplax* and *P. penetrans;* possibly resistant to *X. americanum* |

identifications coupled with cultivar responses to various nematodes should facilitate cultivar selections and lessen dependence on nematicides.


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