Journal of Nematology 28(4):557–564. 1996.

Population Dynamics of *Pratylenchus penetrans*, *Paratylenchus* sp., and *Criconemella xenoplax* on Western Oregon Peppermint

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Abstract: Endoparasitic nematode populations are usually measured separately for soil and roots without a determination of the quantitative relation between soil and root population components. In this study, *Pratylenchus penetrans* populations in peppermint soil, roots, and rhizomes were expressed as the density within a standardized core consisting of 500 g dry soil plus the roots and rhizomes contained therein. Populations of *Paratylenchus* sp. and *Criconemella xenoplax* in 500 g dry soil were also determined, thus measuring the total plant-parasitic nematode population associated with the plant. Mean wet root weight per standard core peaked in spring and again in late summer and was lowest early in the growing season and in early fall. *Pratylenchus penetrans* populations peaked 4 to 6 weeks after root weight peaks. The percentage of the total population in roots reached 70% to 90% in early April, decreased to 20% to 40% in August, and returned to higher percentages during the winter. Rhizomes never contained more than a minor proportion of the population. Mean *Paratylenchus* sp. populations increased through spring and peaked in late August. Mean *C. xenoplax* populations fluctuated, peaking in August or September. Populations of all parasitic species were lowest during winter. Evaluation using the standard core method permits assessment of the total *P. penetrans* population associated with the plant and of changes in root weight as well as the seasonal distribution of *P. penetrans*.

Key words: population, population dynamics, *Pratylenchus penetrans, Paratylenchus* sp., *Criconemella xenoplax,* peppermint.

Populations of the migratory endoparasite *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans Stekhoven are distributed among soil, root, and rhizome habitats. Analyses of soil and roots for *Pratylenchus* are routinely performed separately, and the weight of roots in a given volume of soil is usually not determined. Rhizome populations are rarely assessed. As a consequence, accurate estimation of the population size is difficult. MacGuidwin (11) demonstrated the importance of determining the relative number of *Pratylenchus* spp. in each habitat. Although several workers (2,7,8,14–16) have examined *P. penetrans* population dynamics in both soil and roots, none have related root and soil populations. However, *P. penetrans* population changes in one habitat may not be indicative of changes in total populations (3). In the present study, after soil containing peppermint roots and rhizomes was collected and the total number of *P. penetrans* in each habitat was determined, nematode numbers were expressed in terms of occurrence in a standard core (SC): 500 g (dry wt) of soil plus the roots and rhizomes contained within that volume of soil. The objective of this research was to monitor seasonal dynamics of the total *P. penetrans* population associated with the plant as well as nematode distribution among soil, roots, and rhizomes. In addition, soil populations of the ectoparasites *Paratylenchus* Micoletzky sp. and *Criconemella xenoplax* (Raski) Luc & Raski were determined for this standardized volume of soil. The SC evaluation reduced variability due to changes in soil moisture, differences in size of cores collected, and seasonal changes in root and rhizome biomass. It also permitted evaluation of changes in root and rhizome growth.

Materials and Methods

Five pairs of 6.1-m by 6.1-m plots were established in each of two fields west of Monroe, Benton County, Oregon. Each field had high *P. penetrans, Paratylenchus* sp., and *C. xenoplax* populations. The *Paratylenchus* sp. appears to be a new species

Received for publication 8 January 1966.
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(Bernard, pers. comm.). Voucher specimens are deposited in both the Oregon State University and University of Tennessee nematode collections. One plot of each pair was treated with 1.1 kg a.i./ha oxamyl, and the other was left untreated. Each plot was sampled biweekly during spring through fall and monthly during the winter from April 1988 to March 1990. Cores approximately 7.5 cm in diameter and 15 cm deep containing peppermint roots and rhizomes were collected using a clam shovel. From April through October 1988, one core per plot was taken on each sample date. For the remainder of the study period, five cores per plot were collected and combined into a single sample.

Cores from each plot on each sampling date were passed through a 5-mm sieve to separate mint roots and rhizomes from soil. Remaining soil and debris were washed from roots and rhizomes. Roots were picked from rhizomes, which were then cut into approximately 5-mm segments. Roots and rhizomes from each sample were weighed separately and placed in an intermittent misting chamber, and nematodes were collected after 7 days for counting. Nematodes were extracted from 100 g soil using a wet-sieving centrifugal flotation technique (4). Nematodes in each soil, root, and rhizome sample were counted using a dissecting microscope.

Nematode numbers and the weight of roots and rhizomes were expressed in terms of a 500-g SC. Nematode counts from 100 g wet soil were corrected for soil moisture to obtain nematodes per 100 g dry soil and were then multiplied by 5 to obtain nematodes per 500 g dry soil. Total fresh weight of roots and rhizomes within the soil sample was divided by the weight of the total dry weight of the soil in the sample and multiplied by 500 to obtain the fresh root and rhizome weight proportional to 500 g dry soil. *Pratylenchus penetrans* per gram fresh root and per gram fresh rhizome were multiplied by the weight of roots or rhizomes contained in 500 g dry soil to estimate the total *P. penetrans* in roots and rhizomes contained in each SC. Fresh weight was used in calculations because dry root samples were too small to weigh accurately. *Pratylenchus penetrans* in soil, root, and rhizome components were summed to determine total population in each SC. Percentages of the total population in soil, roots, and rhizomes were calculated based on this sum.

Results

Because nematode populations rarely differed significantly between treatments (13), data from treated and untreated plots were pooled. Root weight in field 1 peaked in April 1988 and 1989 at 1.1 and 2.1 g/SC, respectively, and then decreased to approximately 0.5 g/SC in late May to early June of each year (Fig. 1). A second root weight peak occurred in August 1988 and 1989 at 2.1 and 2.5 g/SC, respectively, and then decreased to fall and winter levels. Root weight trends in field 2 followed the same pattern, with peaks between 1.4 and 1.6 g/SC in April and August 1988 and 1989 and minima of 0.3 to 0.6 g/SC in late May to early June and in the fall of both years. Decreases in root weight followed spring flaming for rust control and fall harvest and flaming for *Verticillium* control. Root weight was lower in field 2 than in field 1 during most of the study period, but the difference between these fields was more pronounced during the 1988 growing season and the following winter. Rhizome weight followed the same pattern as root weight, although late summer peaks of 4.0 to 8.3 g/SC were usually less pronounced and often occurred earlier than root weight peaks.

Population dynamics of total *P. penetrans* per SC (soil, root, and rhizome habitat populations combined) were synchronized with root weight changes, with population peaks usually following root weight peaks by 2 to 4 weeks (Figs. 1,2). Total populations in both fields were relatively large (690 to 3,441 nematodes/SC) in early May during both years. Populations declined in summer to less than 500 nematodes/SC in 1988 and 1,000 nematodes/SC in 1989, in-

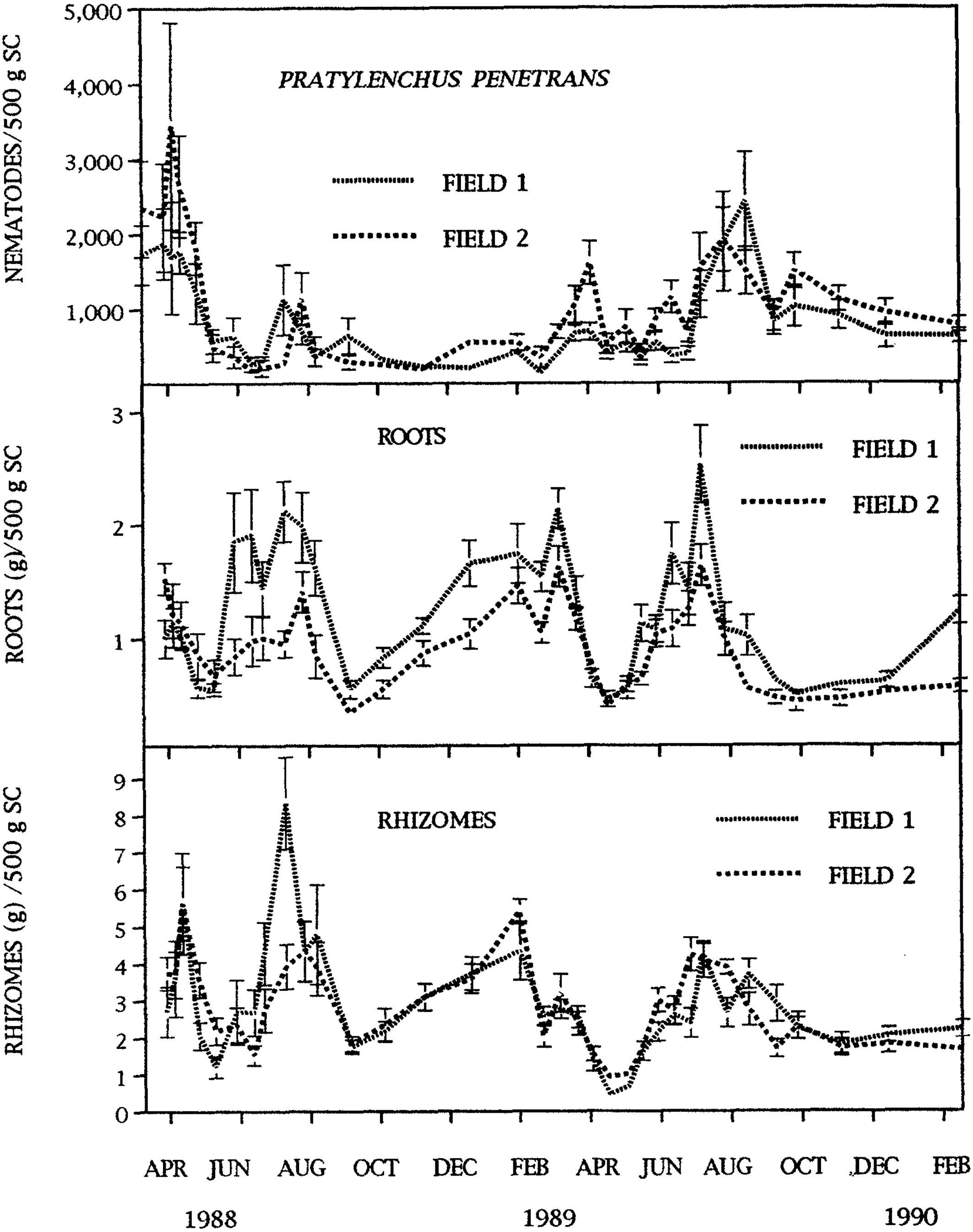

FIG. 1. *Pratylenchus penetrans,* root weight, and rhizome weight per 500 g standard core (SC), Fields 1 and 2. Bars represent standard errors.

creased in late August to early September to between 1,100 and 2,500 nematodes, and declined to a winter plateau of below 500 nematodes in 1988 and usually below 1,000/SC in 1989. Populations were lower during the harsh winter of 1988–89 (sustained temperatures below 0°C for more than 1 week) than during the mild winter of 1989–90. A population minimum in late March 1989 occurred 8 weeks after a

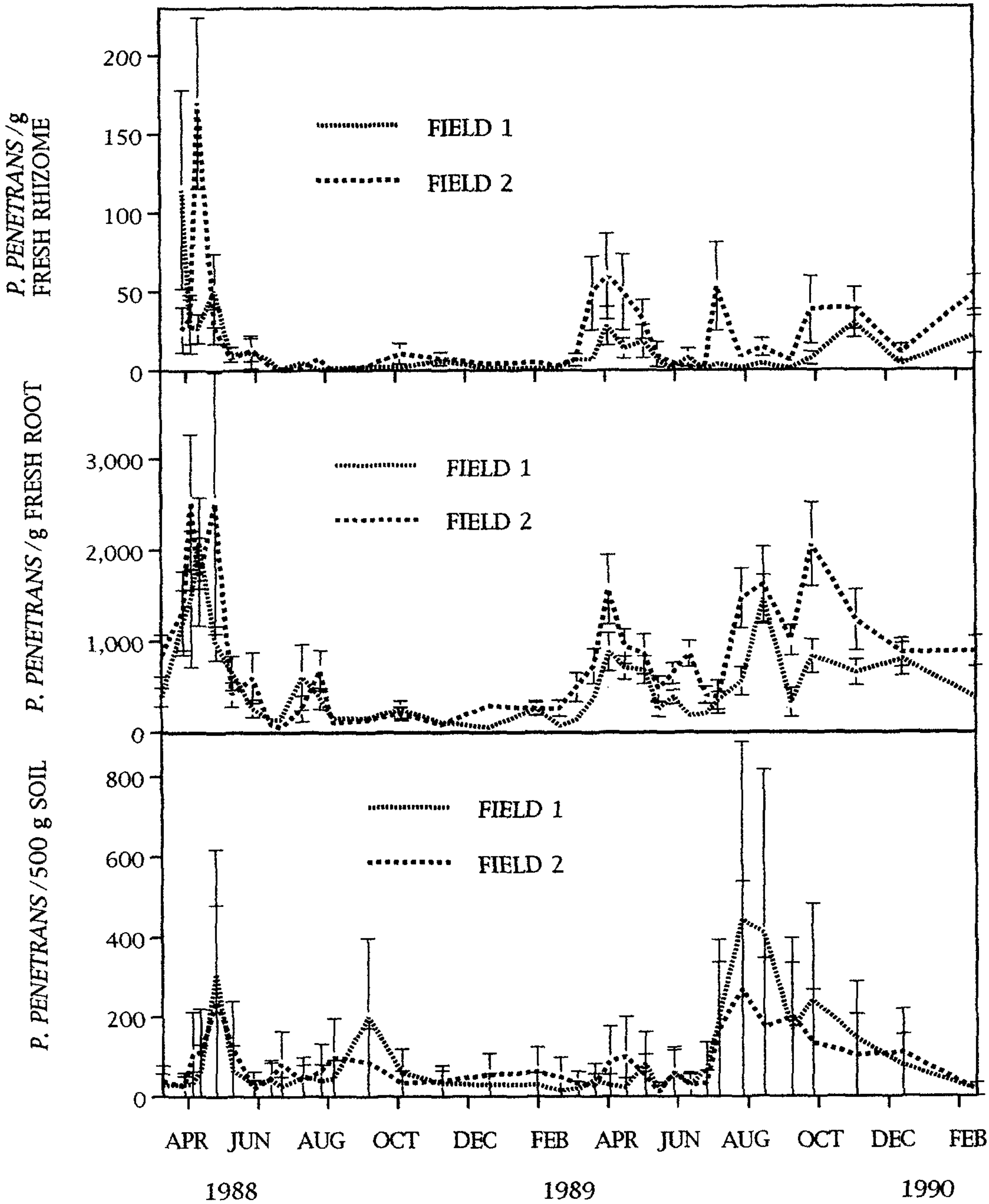

FIG. 2. *Pratylenchus penetrans* per 500 g soil and per g fresh root and rhizome, Fields 1 and 2. Bars represent standard errors.

freeze in early February. Population peaks in late August and early September were higher following the 1989 growing season than in 1988. Root population peaks usually preceded soil population peaks during spring, whereas August soil, root, and rhizome population peaks were usually simultaneous.

Between 70% to 90% of the total *P. penetrans* population was in the root habitat in early April (Fig. 3). This decreased to between 40% and 50% by the end of June

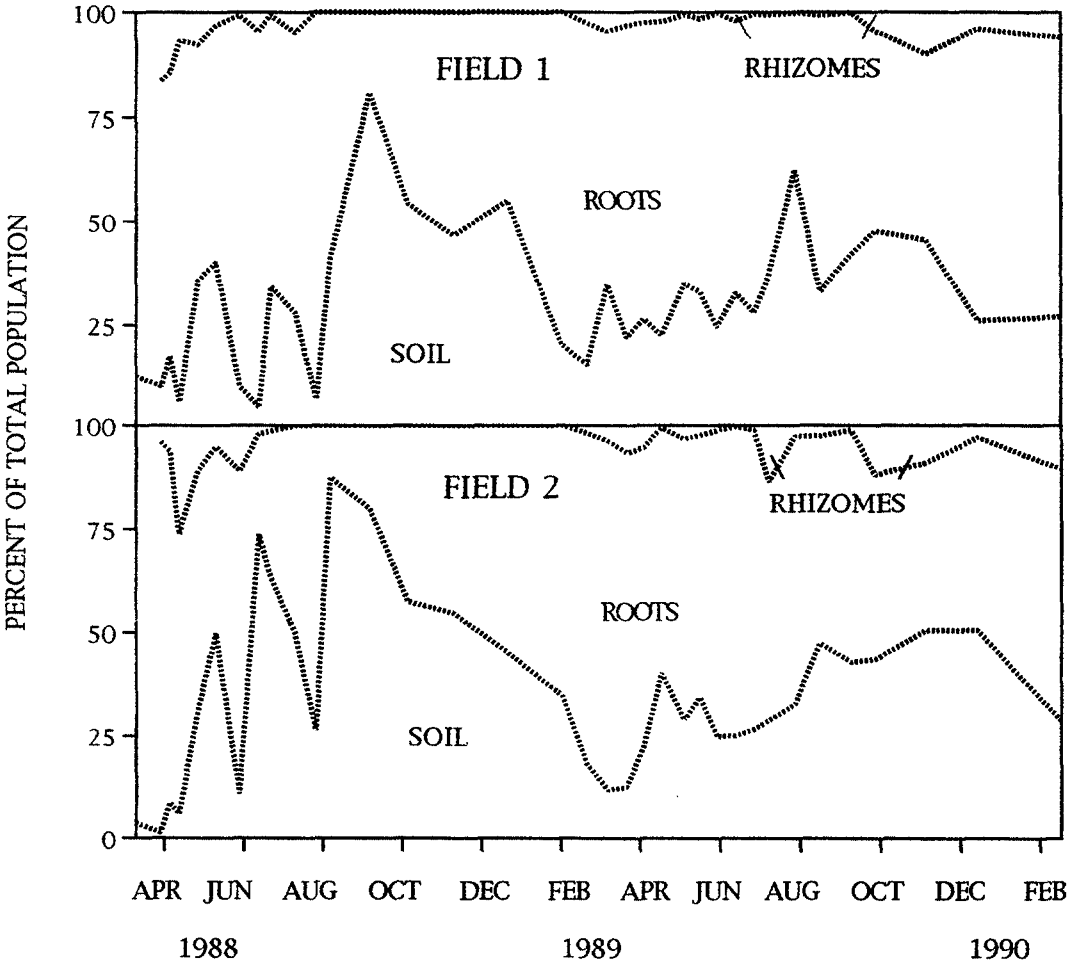

FIG. 3. Percentages of *Pratylenchus penetrans* in soil, roots, and rhizomes, Fields 1 and 2. Soil line represents percentage of *P. penetrans* per 500 g standard core (SC) recovered from soil. Distance between soil line and rhizome line represents percentage recovered from roots. Distance between rhizome line and top of graph represents percentage recovered from rhizomes.

and to between 20% and 40% at harvest. The percentage of the population in roots increased through the winter, again approaching 70% to 90% in the spring of 1990. Throughout the study, the majority of the total *P. penetrans* population was recovered from roots except in late September and early October. *Pratylenchus penetrans* in rhizomes usually comprised less than 11% of the population in both fields during the 1988 growing season, but after a late summer decrease, it was not detected during the winter of 1988–89. Up to 7% of the population was recovered from rhizomes throughout the 1989 growing season. The percentage decreased in late summer and increased to a maximum of 12% of the population during the following winter.

Paratylenchus sp. populations were low in winter, increased steadily through spring and summer, and peaked during late August (Fig. 4). The August peaks coincided with root weight peaks. Populations were lower during the severe winter of 1988–89 than during the milder winter of 1989–90.

Large but variable numbers of *C. xenoplax* were recovered from field 1 throughout the study period (Fig. 4). In field 2, *C. xenoplax* numbers were small during 1988 and increased during 1989. The population in field 1 peaked between May and

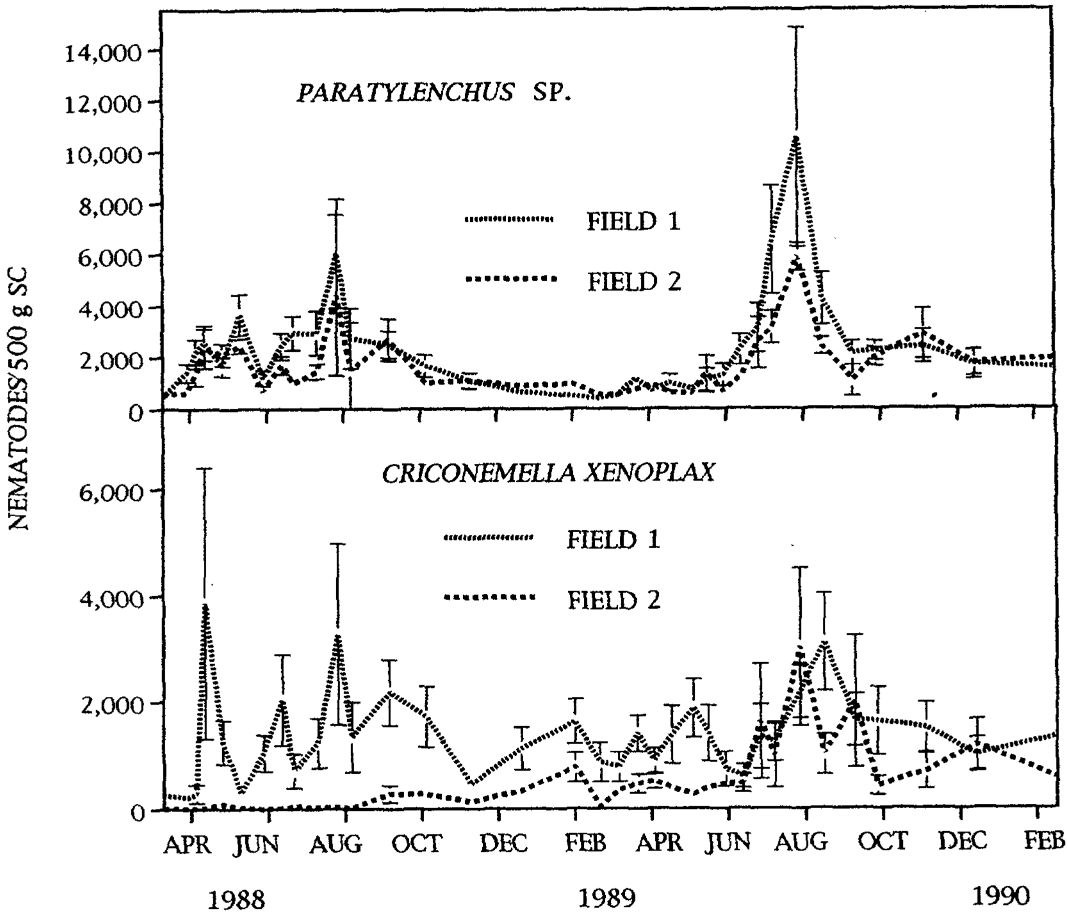

FIG. 4. *Paratylenchus* sp. and *Criconemella xenoplax* per 500 g standard core (SC), Fields 1 and 2. Bars represent standard errors.

June and between August and September of both years. The increasing population in field 2 began to follow the pattern exhibited by the field 1 population beginning in about December 1988.

Discussion

Proportions of the total *P. penetrans* population components in soil, root, and rhizome habitats can change rapidly during the year. Thus, the accuracy of an assessment of only one component will vary according to the time of year the field is sampled. This may result in an inaccurate estimation of the total population, which may affect management decisions. The relationship between population components may have additional implications because nematicides may perform differently in roots and soil. Because rhizomes in this study contained a consistently low percentage of the total *P. penetrans* population, rhizome assays are probably not critical for accurate population assessment.

Environmental conditions and cultural practices may cause differences in population trends between years and fields. Root and rhizome weight per SC was less in field 2 than in field 1 during the 1988 growing season, possibly resulting from severe flaming of field 2 in the spring of 1988. However, *P. penetrans* populations per SC were similar in fields 1 and 2 through late winter and spring of 1989, suggesting that any flaming injury to plants did not affect nematode population levels. Except for the May 1988 *P. penetrans* peak in field 2, populations in fields 1 and 2 were lower during 1988 than in 1989 and early 1990.

Although the severe winter of 1988–89 may have kept the nematode populations at lower levels than in the following year, the abnormally cold weather may also have stressed the peppermint plants, making them more susceptible to parasitism and resulting in higher nematode populations in 1989. Alternatively, cold weather could have suppressed natural nematode controls. Greater *P. penetrans* survival in the spring of 1990 followed the milder winter of 1989–90.

Population dynamics observed in this study resemble patterns noted in previous *P. penetrans* studies. Spring and fall peaks have previously been reported on peppermint (15,16), although soil populations peaked before those in roots. Central and western Oregon populations of *P. penetrans* on peppermint were also similar, with nematode population peaks following root weight peaks by 4 to 6 weeks (5). On strawberry, soil populations of *P. penetrans* peaked in spring, while root populations peaked in summer (2). *Pratylenchus penetrans* populations on raspberry peaked in spring and(or) fall and were inconsistent between years (9,10,18). Populations under rye-tobacco rotation peaked in fall (14).

Population fluctuations of *P. penetrans* in this study may represent generations. The life-cycle duration of *P. penetrans* is 86 days at 15°C, 42 to 44 days at 20°C, and 30 to 31 days at 30°C (12). Times between population peaks in field 2 during the 1989 growing season were 56 days (4 May to 13 July), 40 days (13 July to 28 August), and 62 days (28 August to 16 November)—all plausible egg-to-egg generation times. Comparable *P. penetrans* fluctuations have occurred on clover (8) and potato (1). The decline in *P. penetrans* populations in late spring and late summer is probably a response to a decline in root biomass, which is probably a result of carbohydrate allocation toward stems and leaves during rapid growth in the spring and after harvest.

Populations of *Paratylenchus* sp. in both fields, like those of *P. penetrans,* were higher during 1989 and 1990 than during the previous growing season and winter. As with *P. penetrans,* although the severe winter may have repressed the winter nematode population, it also may have stressed the peppermint plants or suppressed natural controls of the nematodes.

Fluctuations of the lower *C. xenoplax* populations in field 2 during 1988 often paralleled the higher populations in field 1, and the 28 August 1989 peak of more than 3,000/500 g soil was nearly as high as the 15 September peak in field 1. The 12 May 1988 and 4 June 1989 *C. xenoplax* peaks in field 1 suggest a predictable spring population peak as well as one in the fall. Fluctuations in the *C. xenoplax* population may also represent generation times. The *C. xenoplax* life cycle takes 25 to 35 days (6,17). Population peaks in field 1 occurred regularly from 41 to 61 days apart. Although longer than the documented generation time, they are shorter during summer than during winter, suggesting temperature-affected reproduction and development.

Pratylenchus penetrans, Paratylenchus sp., and *C. xenoplax* all exhibited a late-August to mid-September population peak in both years, except for the nearly absent *C. xenoplax* in field 2 in 1988. These peaks followed the early August root weight peak by 3 to 5 weeks. *Pratylenchus penetrans* population peaks and possible *C. xenoplax* population peaks followed the spring root weight peak by about the same time period, approximating generation times for these nematodes. Thus, the delay between root growth and nematode population growth may represent the time necessary for the development of a new generation.

Evaluation of the relationships between endo- and ectoparasitic nematode populations and root and rhizome weight would be impossible without analysis of all relevant population components. Their comparison is facilitated by the SC approach to data analysis.

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