Population Fluctuation of Three Parasitic Nematodes in Florida Citrus

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Abstract: In Florida, *Tylenchulus semipenetrans* on citrus has two high and two low population levels each year. High levels occur in April-May and November-December, and low levels, in February-March and August-September. Population increases occur about 4-5 weeks after the spring and fall flush of root growth. Populations of *Pratylenchus coffeae* on citrus varied widely, and were not related to season. Populations of *P. brachyurus* showed seasonal variation with a high in June-July and a low in March-May. Males of *T. semipenetrans* and *P. coffeae* were found throughout the year, whereas males of *P. brachyurus* were rare and were found only during November and December. *Key words:* seasonal variation.

Tylenchulus semipenetrans Cobb and *Pratylenchus* spp. are widespread on citrus in Florida (3, 7, 15, 16). Several species of *Pratylenchus* are associated with citrus in Florida, but only *P. brachyurus* and *P. coffeae* are known to be pathogenic (1, 3, 11, 12, 14). *P. coffeae* generally is found in extremely high numbers in comparison with *P. brachyurus* (11). Populations of *T. semipenetrans* fluctuate throughout the year (2, 10, 17, 19, 20) and from season to season (8).

This paper reports our findings of seasonal population variations of *T. semipenetrans, P. coffeae*, and *P. brachyurus* in citrus roots in relation to temperature, moisture and root growth under field conditions.

MATERIALS AND METHODS

T. semipenetrans: Root samples were collected monthly, from January 1966 to January 1967, from 25-year-old 'Valencia' orange [*Citrus sinensis* (L.) Osb.] trees on rough lemon (*C. jambhiri* Lush.) and sour orange (*Citrus aurantium* L.) rootstocks. Highest percentages of citrus feeder roots occur in the top 76 cm of soil (6), and, at each sampling date, twelve sites were sampled at depths of 0-30 and 30-60 cm. To extract nematodes, roots were rinsed in water to remove soil, weighed, and, while moist, incubated in 60-ml vials in the dark at 24-25 C for 6 days (21). Numbers of citrus nematode larvae and males per gram of root were recorded. Although soil samples also were taken and processed, the number of nematodes recovered was typically 800-2000 times fewer than from roots, and thus are not reported.

P. coffeae: Root samples were collected weekly, from August 1969 to September 1970, from two 35-year-old tangelo (*C. paradisi* X *C. reticulata*) seedling trees at each of four sites at depths of 0-15, 15-30, and 30-60 cm. Root samples were washed and incubated moist in 473-ml jars in the dark at 24-25 C for 7 days. Nematodes extracted were counted after 4 and 7 days' incubation. We found earlier that while extended incubation of roots yielded greater numbers of *P. coffeae*, maximum yields occurred in the first 7 days. All life stages of *P. coffeae* were recorded as number per gram of root.

P. brachyurus: Root samples were collected every 2 months from June 1969 to May 1971, from 7-year-old tangerine (*C. reticulata* Blanco) on rough lemon (*C. jambhiri* Lush.) rootstock from 12 sites at depths of 15-30 cm. Nematodes were extracted as for *P. coffeae*, except that roots were incubated 15 days and nematodes were removed and counted at 5-day intervals. All life stages of *P. brachyurus* were recorded as number per gram of root.

All trees from which the above data were collected were growing in Astatula fine sand, typical soil of the "ridge area" of central Florida. These soils contained 94-96% sand, 0.5-1.5% organic matter, and a moisture-holding capacity of 5-8%. All recorded data were subjected to statistical analyses.

RESULTS

T. semipenetrans: Populations varied in relation to depth and month of sampling; however, there were recognizable highs and lows (Fig. 1A). When the data were subjected to statistical analyses, we found no significant difference in numbers of nematodes between depths (0-30 or 30-60 cm) on either rough

Received for publication 7 January 1972.

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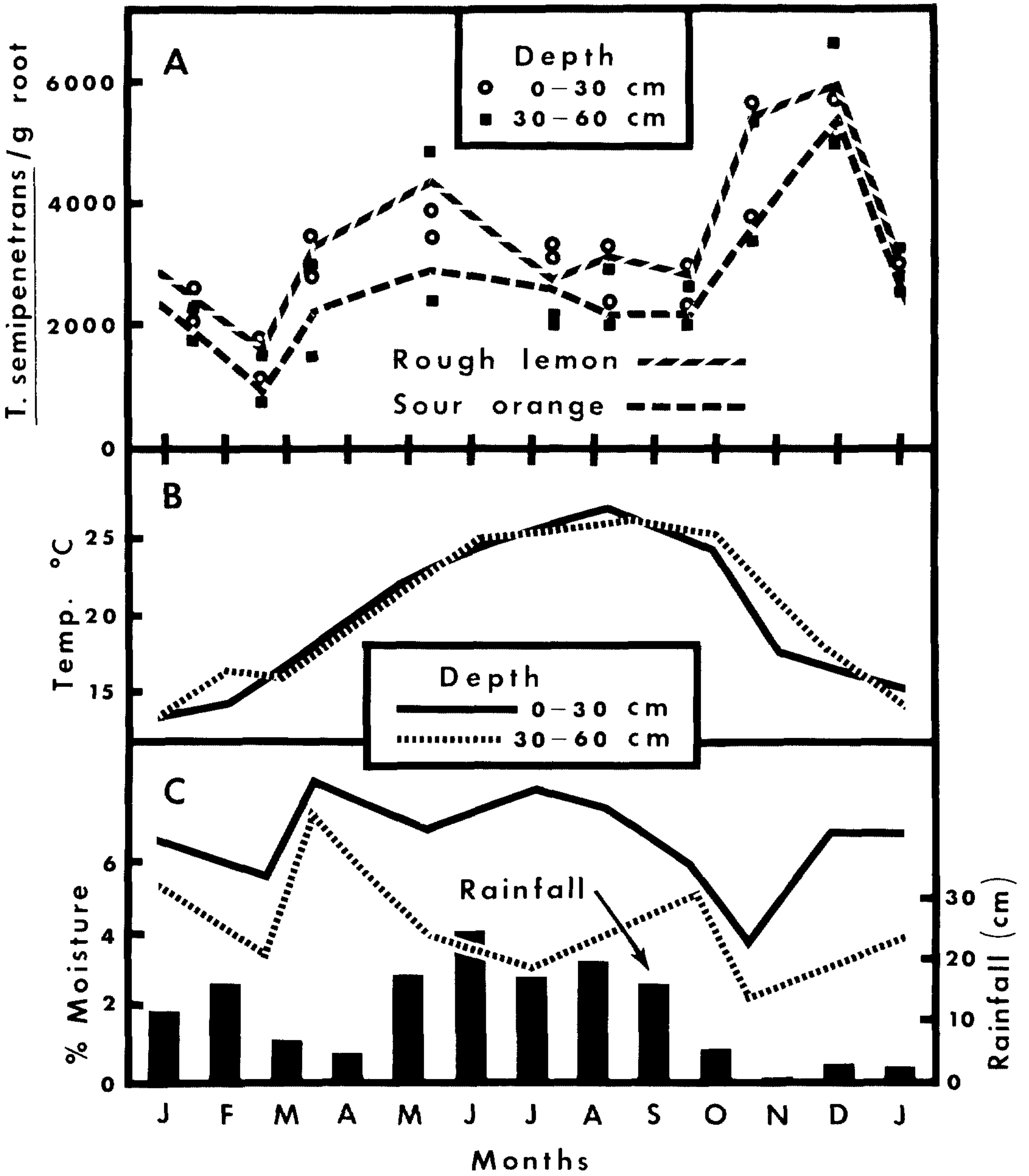

FIG. 1. Seasonal variation of *Tylenchulus semipenetrans* extracted from roots of two citrus rootstocks during 1966. A. Nematode populations extracted from two rootstocks at two depths. B. Temperature at two depths. C. Soil moisture and rainfall record.

lemon or sour orange rootstock. When the monthly sampling data were analyzed for either rough lemon or sour orange populations, statistically significant differences were found. With the nematode population from rough lemon, two high population periods occurred: April-May (P = .05) and November-December (P = .01). Lowest nematode populations were found during February (P = .01). Population levels during the summer (July, August, September) were intermediate and were significantly lower (P = .05) than the fall (November-December) populations. Although the nematode populations from sour orange roots followed a similar trend, with a February low and a December high (P = .01), the intervening populations (April-October) were not significantly different.

Rough lemon roots generally supported higher populations of citrus nematodes than did sour orange roots, corroborating a previous report (9). Mean populations were never lower than 800 nematodes/g of root (February) on either rootstock, and males were present throughout the year. During the peak population periods, soil temperatures were suitable for nematode infectivity and reproduction, but reached lower limits for nematode activity during January and February (Fig. 1B). The soil was a deep, well-drained sand, and generally soil moisture was not a limiting factor as shown by rainfall records

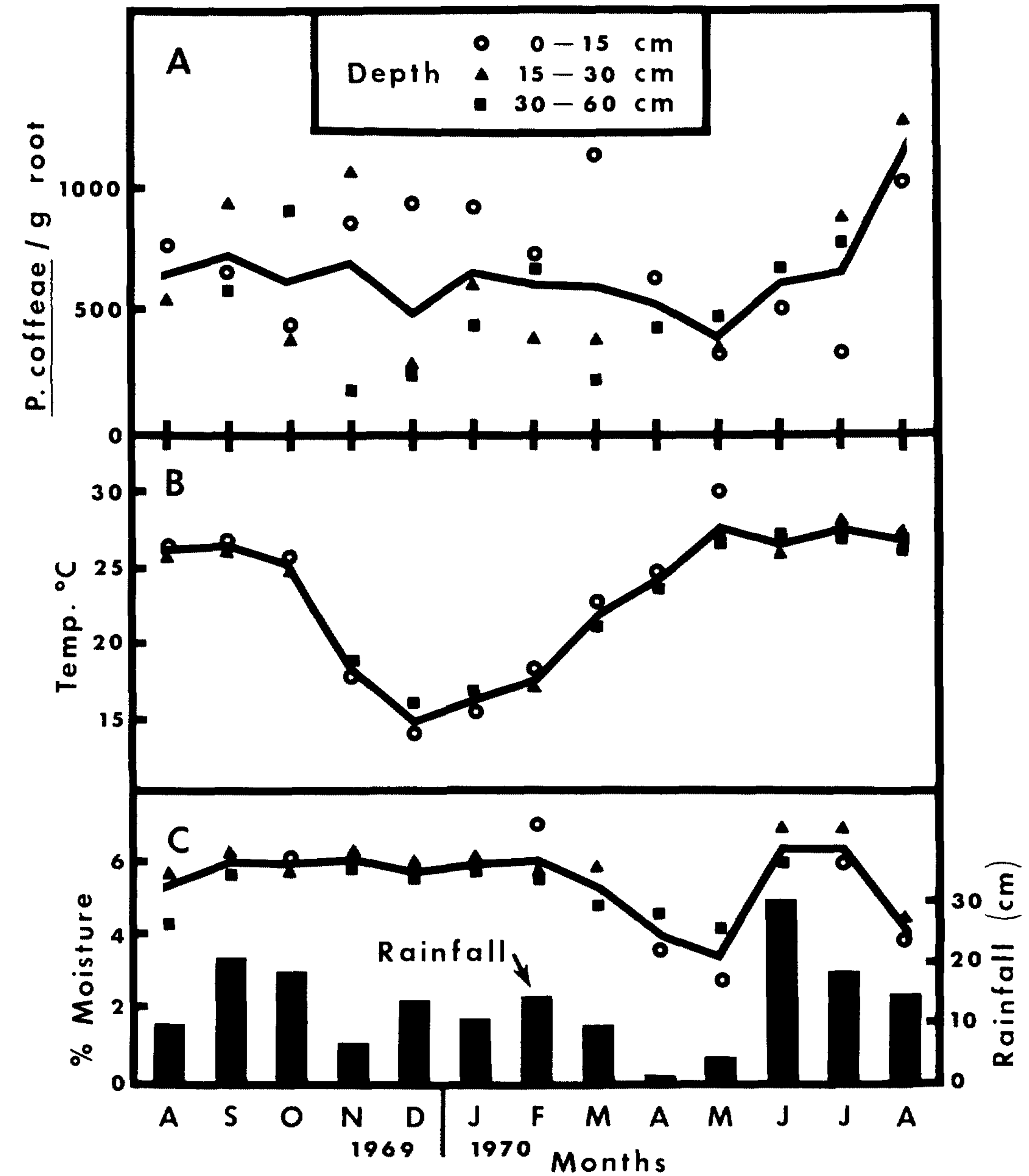

FIG. 2. Seasonal variation of *Pratylenchus coffeae* extracted from citrus roots 1969-1970: A. Nematode populations extracted from tangelo seedling rootstock at three depths. B. Temperature at three depths. C. Soil moisture and rainfall record.

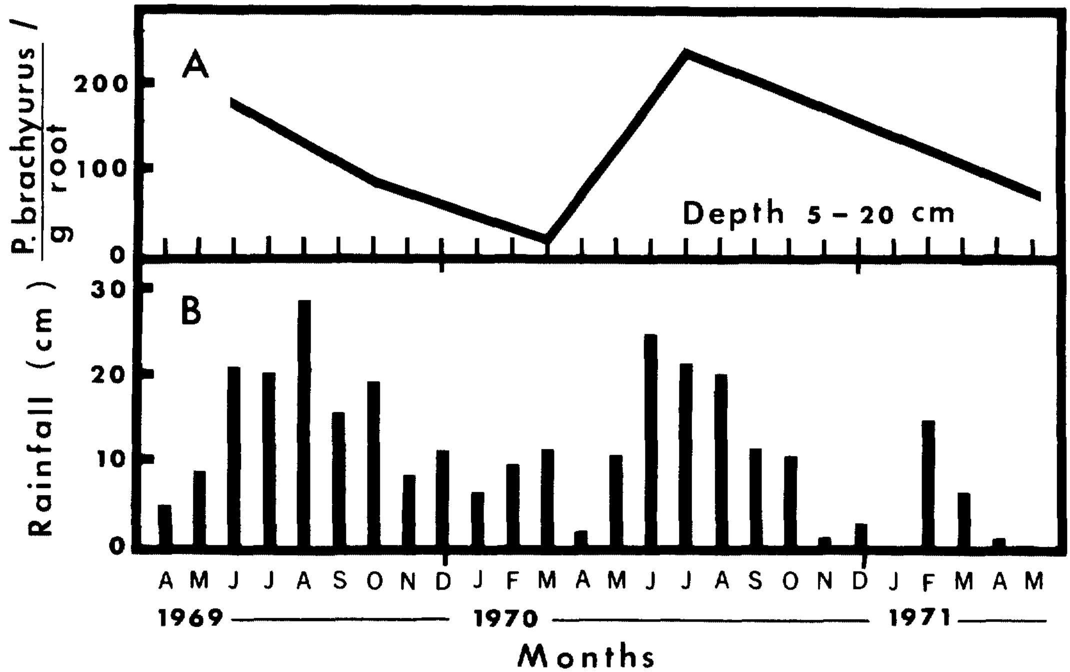

FIG. 3. Seasonal variation of *Pratylenchus brachyurus* extracted from citrus roots 1969, 70, 71: A. Nematode populations extracted from rough lemon rootstock. B. Rainfall record.

(Fig. 1C). During periods of low rainfall, supplemental irrigation was usually applied, which aided in maintaining adequate soil moisture, particularly in the upper 30 cm.

P. coffeae: There was considerable variation between numbers of *P. coffeae* per gram of root at each depth (Fig. 2A) and from month to month. When subjected to statistical analyses, there were no significant differences between nematode populations in roots at the three depths sampled, nor was population variation significant from month to month (Fig. 2A).

From December to April, more nematodes were extracted from roots collected at 0-15 cm than from 15-30 or 30-60 cm, but the reverse occurred from May to August. Nematode populations in roots in the upper 15 cm dropped during this time from a March high of 1190 to a May low of 300. This coincided with drought conditions and increased temperatures, particularly evident in the 0 to 15-cm zone (Fig. 2B, C). Previous work demonstrated the influence of drought on populations of *P. coffeae* in excised roots, particularly at 27 and 32 C (11). Populations increased rapidly immediately after summer rains began, and in mid-August, high populations were recorded at all depths. Males were found during all seasons and accounted for 20-30% of the population.

P. brachyurus: Populations varied between samples and months, and there was a recognizable high and low seasonal pattern (Fig. 3A). Highest mean populations occurred during June 1969 (P = .05) and July 1970 (P = .01). Minimal populations were recorded during March 1970 and May 1971 (P = .05). Numbers ranged from a mean of 3.2 to 375 nematodes/g of root. Males of *P. brachyurus* were found only in samples obtained in November and December, and comprised less than 0.5% of the population.

DISCUSSION

In Florida, *T. semipenetrans* population infecting citrus will vary from year to year, depending upon the condition of the host, as was reported by Reynolds and O'Bannon (13). Superimposed on this are the two annual high and low population levels. Fall populations (November-December) are generally higher than spring populations (April-May). The two peak populations develop during the periods of increased root growth, which occurs in citrus in Florida in spring and early fall. Fall populations are higher than spring populations because of the higher numbers of nematodes found in late

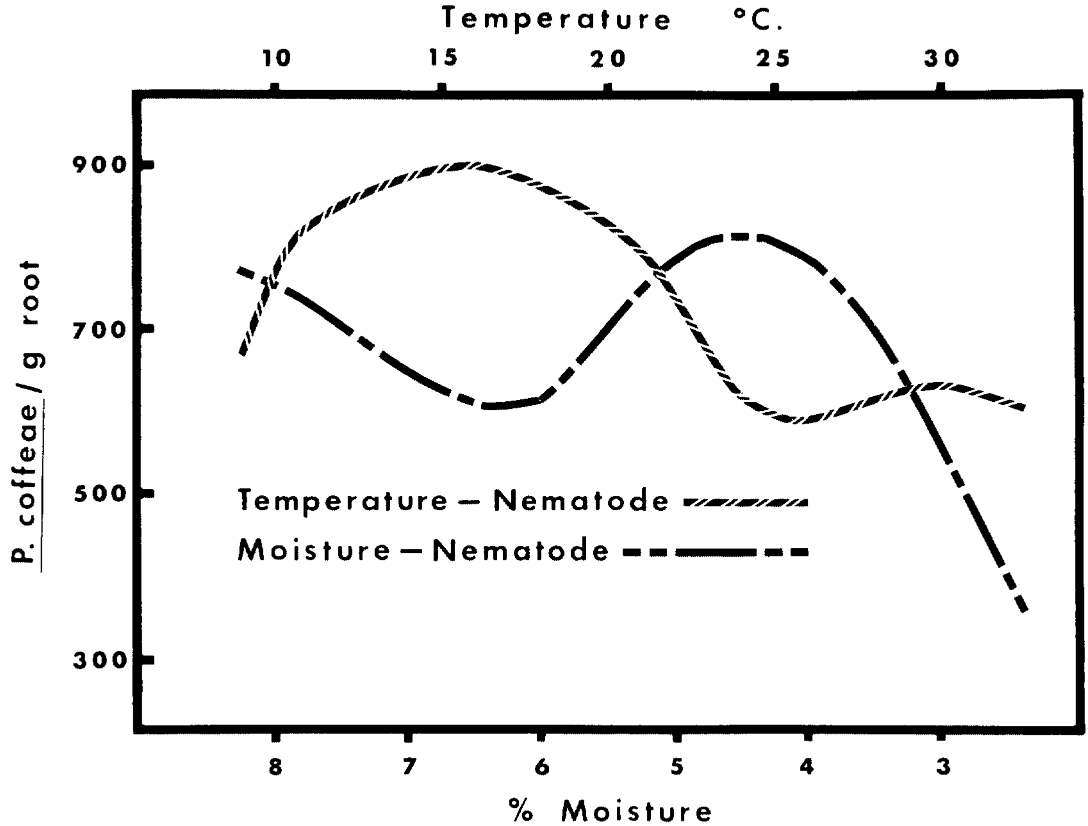

FIG. 4. The relationship of soil temperature and moisture to *Pratylenchus coffeae* extracted from roots in 1969 and 1970.

summer, than in late winter resulting in a greater reproductive potential for the fall population. Infection and subsequent population cycles are restricted to primary roots because citrus nematodes feed only in the cortex of primary roots (18). Vilardebo (19) also recognized two high and low population periods which he relates to temperature and moisture. Several investigators observed highest populations in the summer (10, 17, 19), but in Japan, Yokoo (20) noted a slight increase in autumn. Although temperature and moisture could influence seasonal fluctuations, most investigators report that other adverse environmental conditions may affect population changes (2, 10, 17, 20).

Monthly variation in *P. coffeae* populations were not related to seasonal changes. Populations increased and decreased rapidly, and did not reach an equilibrium. *P. coffeae* is capable of multiplying rapidly, and is generally associated with root deterioration (11, 12) which would result in a rapid decrease in populations. The lowest population observed coincided with lowest soil moisture and highest soil temperature. While population differences were not significant, these environmental extremes together did affect the population (Fig. 4). Roots in the upper 16 cm of soil were subjected to greatest environmental stress, which was most evident during dry periods when soil moisture approached the permanent wilting point (<3%) and temperatures reached a maximum of 34 C. Radewald, et al. (11), working under controlled conditions, showed that moisture was a greater limiting factor for survival of *P. coffeae* than temperature; the data from field conditions reported here generally agree with their findings.

Populations of *P. brachyurus* showed an annual high and a low level seasonal variation. The population began increasing in April or May, and reached its peak in June or July. *P. brachyurus* in Florida seems to reach its population peak during the hot summer months, and our unpublished data indicate that optimum temperature for reproduction is comparatively high. *P. brachyurus* was reported to withstand temperatures in excess of 43 C for short durations (4). This ability to survive high temperatures probably accounts for high populations extracted from infected citrus roots during the summer, when maximum temperatures under trees will reach 34 C for short durations in the upper soil horizon. *P. brachyurus*, the most common *Pratylenchus* spp. in citrus in Florida (15), does not cause as serious root debilitation as *P. coffeae*. Fliegel (5) found, on another perennial host [*Prunus persica* (L.) Batsch], that *P. brachyurus* was the most common species encountered and that it was not associated with severe damage to roots. *P. brachyurus* reproduces slowly and does not increase to high numbers as does *P. coffeae*.

Nematode populations, as reported here, should not be considered the maximum numbers which could be extracted; in practice, these nematodes will vacate roots for several weeks. For the time intervals used in these studies, we feel that proportional recoveries were obtained and are representative of the total nematode populations.

Environmental influences of climate, soil, food supply, and competition are principal factors regulating nematode activity; however, our study indicates that inherent behavioral dynamics also influence population variation on *Citrus* of *T. semipenetrans*, *P. coffeae*, and *P. brachyurus*.

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