8-1982

Nematode community structure in dogwood, maple, and peach nurseries in Tennessee

Terry L. Niblack

To the Graduate Council:

I am submitting herewith a thesis written by Terry L. Niblack entitled "Nematode community structure in dogwood, maple, and peach nurseries in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Ernest C. Bernard, Major Professor

We have read this thesis and recommend its acceptance:

C. J. Southards, L. F. Johnson, W. T. Witte

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Terry L. Niblack entitled "Nematode Community Structure in Dogwood, Maple, and Peach Nurseries in Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Ernest C Bernard

Ernest C. Bernard, Major Professor

We have read this thesis
and recommend its acceptance:

Willard T Witte

Leander F. Johnson

Carroll Southards

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

NEMATODE COMMUNITY STRUCTURE
IN DOGWOOD, MAPLE, AND PEACH NURSERIES
IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Terry L. Niblack

August 1982

DEDICATION

This thesis is dedicated to

Ethel Redding Niblack

and to the memory of her sister

Estelle Redding Lussier

ACKNOWLEDGEMENTS

For uncounted instances of guidance, information, and encouragement, the author wishes to thank the members of her committee: Drs. C. J. Southards, L. F. Johnson, and W. T. Witte, with special thanks to her major professor, Dr. E. C. Bernard.

Thanks are also extended to: Drs. R. Miles, for guidance in conducting the soil analyses; W. L. Sanders, for advice in designing the survey; R. E. Harrison, for information regarding nematodes and the Tennessee nursery industry; D. B. Williams, for information regarding the economic status of the nursery industry; and R. H. Petersen, for advice and encouragement.

The author also wishes to acknowledge, with deepest gratitude, the tireless efforts of Mr. Tim E. Rickard in developing and implementing the computer program WORM, which was instrumental in the completion of this study.

ABSTRACT

Tennessee nurseries are major suppliers of ornamental and fruit trees, but the potential for nematode-induced losses is poorly known. This study was undertaken to i) compare populations of nematode trophic groups in dogwood, maple, and peach nurseries; ii) identify and determine the diversity of of plant parasitic nematodes in these areas; iii) determine the relative importance of tree species and age class, weed cover, and edaphic factors in the distribution of plant parasitic species. Ninety-two nursery blocks were sampled for nematodes in March, July, and October, 1981. Each soil sample was analyzed for pH, bulk density, texture, and organic matter content. Nematodes were extracted from a 200 cm^3 aliquant of each sample and counted. Microbivores, fungivores, predators, and "omnivores" (trophism unknown) were counted as such, but plant parasites were identified to species. Microbivores occurred in the highest numbers for all sampling dates, followed by plant parasites, fungivores, "omnivores" and predators. Fifty-eight plant parasitic species in 25 genera were identified, with one to sixteen species occurring in each site. Diversity was higher in March and Octothan in July, higher in maple than in dogwood and peach blocks, and positively correlated with percent weed ground cover and number of weed species in July. *Paratylenchus projectus* and *Xiphinema americanum* were the two most common species, occurring in 88% and 77% of the sites, respectively. A community ordination technique was employed to determine similarities among sites based on plant parasitic nematode communities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

FIGURE PAGE

CHAPTER I

INTRODUCTION

In 1979, the Tennessee nursery industry ranked ninth in the United States, with over 730 certified nurseries totaling 8900 hectares and generating wholesale sales throughout the nation of over $90 million (Anon., 1982). The southeastern states are particularly dependent on Tennessee nurseries for ornamental, shade, and fruit trees, as the state is ideally situated to supply the market. According to a recent projection, the economic value of nursery and greenhouse crops will rank second only to soybeans in Tennessee agriculture by 1990 (Anon., 1982).

The five-county area of Coffee, DeKalb, Franklin, Grundy, and Warren counties produces over 70% of the state's nursery crop annually (D. B. Williams, pers. comm.). In 1980, these counties produced dogwoods (Cornus florida L.), red maples (Acer rubrum L., hereafter referred to as "maples" unless otherwise specified), and peach trees (Prunus persica

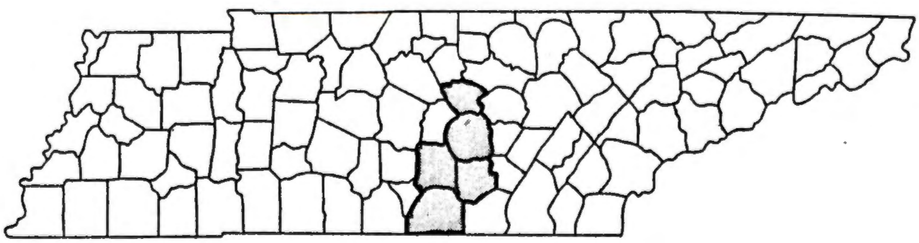

Fig. 1. The five-county area in which 70% of Tennessee's annual nursery crop is produced.

(L.) Batsch) constituting 50%, 25%, and 85%, respectively, of the estimated total sales of these trees in the Southeast, a wholesale value of nearly $12 million (W. T. Witte, pers. comm.).

Nematodes are not considered to be serious problems in tree nurseries, mostly because data are lacking (Ruehle, 1972), and because of the difficulty involved in establishing growth or quality losses in woody perennials. Due to the importance of the nursery industry in Tennessee, however, two questions need to be addressed: first, whether plant parasitic nematode species which could be causing economic loss exist in nurseries in significant populations; second, whether serious nematode pests of crops other than nursery stock exist in nurseries, from which they could be introduced into previously uninfested areas.

Several plant parasitic nematode species are known to cause damage to peaches, either directly or indirectly through disease interactions (Telíz et al., 1967; Hung and Jenkins, 1969; Wehunt and Weaver, 1972; Wehunt and Good, 1974; Lownsbery et al., 1977). Comparatively little is known about the effects of nematode parasitism on either dogwoods or maples; a few host-parasite relationships have been demonstrated (Ruehle, 1971; Lehman and Barnard, 1982), and there have been several reports of potential nematode pests occurring in association with each (Anon., 1960; Springer, 1964; Goodey et al., 1965; Ruehle, 1967). Even with readily recognizable root symptoms, such as galling, aboveground symptoms of nematode parasitism are non-specific. Stunting, chlorosis, and general unthriftiness may not be noticeable without nearby unaffected trees for comparison. Losses attributable to nematode damage are difficult to determine, but have been estimated for woody ornamentals in Florida at 5% of yearly sales (Hague, 1972).

Dogwoods and maples are usually sold balled and burlapped. Because of the transfer of soil with the plants, it is possible that serious nematode pests of other crops may be introduced into previously uninfested areas. Siddiqui *et al*. (1973) sampled balled and burlapped tree shipments entering California from Tennessee and extracted several species of plant parasitic nematodes. There is a potential for economic loss under these circumstances, and tree shipments have been quarantined and/or destroyed as a result of such sampling (R. E. Harrison, pers. comm.). In an analogous transfer of plant plus soil, tomato transplants from Tennessee were reportedly the source of soybean cyst nematode, *Heterodera glycines* Ichinohe, in a previously uninfested area of Ohio (Hammond, 1981). Recently, the trees in an entire nursery block found to be infested with *H. glycines* were destroyed voluntarily by the owner (R. E. Harrison, pers. comm.).

Because peaches are sold bare-root, the same concern over soil transfer does not apply; however, some endoparasitic nematodes of peaches, such as lesion nematodes (*Pratylenchus* spp.), are readily transported on roots in the absence of soil (McElroy, 1972). States with virus-free programs for control of peach viruses are concerned about the occurrence of nematode vectors (*Xiphinema* and *Longidorus* spp.) in peach nurseries. Nurserymen have demonstrated their concern over the actual and potential problems plant parasitic nematodes may cause in nurseries, as evidenced by the sponsorship of two National Nematode Conferences, in 1961 and 1962, by the American Association of Nurserymen (Springer, 1964).

As a starting point from which to address these questions, the primary goal of this investigation was to study the character of nematode populations in Tennessee tree nurseries. Dogwood, maple, and peach were chosen to represent ornamental, shade, and fruit trees, respectively. This goal comprised three objectives:

1) to compare populations of five nematode trophic groups in dogwood, maple, and peach nursery sites;
2) to identify and determine the diversity of plant parasitic nematodes in these areas;
3) to determine the relative importance of tree species and age class, weed cover, and edaphic factors in the distribution of plant parasitic species.

CHAPTER II

LITERATURE REVIEW

I. PLANT PARASITIC NEMATODES IN TENNESSEE

Nematodes, it has often been quoted, are ubiquitous. Many plant parasitic species, including both known and potential pests of nursery crops, occur in Tennessee (Bernard, 1980; Bernard, unpublished results) and have been known to occur at least since 1889, when a root-knot disease of peach was reported (Scribner, 1889). Whittle and Drain (1935) reported severe infestations of several ornamental shrubs and peaches by root-knot nematodes, and further reported that nurserymen discontinued the use of certain fields when surveys revealed the presence of these pests.

Ponchillia (1975) surveyed burley tobacco fields for plant parasitic nematodes, and Klobe (1976) found several genera in seven west Tennessee counties in a survey of other economically important crops. Their results were summarized, and further, more detailed records were reported by Bernard (1980). Aside from Bernard's work, few records of plant parasitic nematodes in Tennessee nurseries exist, despite the economic importance of this industry.

II. PLANT PARASITIC NEMATODES ASSOCIATED WITH DOGWOOD, MAPLE, AND PEACH

Dogwood

The flowering dogwood is a native understory tree throughout the eastern United States. Its economic value today is predicated on its ornamental qualities, and Tennessee nurseries produce over 400 ha annually. Depending on the production system used, nurserymen may invest up to $5.60 per three-year-old salable tree, with the assumption of a 10% field loss (Badenhop and Einert, 1980). No estimates are available of losses attributable to nematode damage, but at least one species is known to be pathogenic to dogwood. Other species known to parasitize woody plants, along with vectors of viruses known to infect dogwood, have been found associated with the tree without direct evidence of a host-parasite relationship.

Root-knot nematodes (*Meloidogyne* spp.) were reported occasionally associated with injury to dogwood in Virginia (Anon., 1960). Severe galling of seedlings, caused by *M. incognita* (Kofoid & White) Chitwood, was reported from Georgia, with concommitant above-ground symptoms of tip burn, leaf drop during periods of moisture stress, and stunting (Johnson *et al.*, 1970), and later reported from Florida (Lehman and Barnard, 1982). Another species of root-knot nematode, *M. hapla Chitwood*, was associated with dogwood in New Jersey nurseries (Springer, 1964). Other parasites of woody plants have likewise been reported (Springer, 1964; Goodey *et al.*, 1965; Ruehle, 1967), but no other host-parasite relationships have been unequivocally demonstrated. One suspected parasite, *Xiphinema americanum* Cobb, is a vector of several viruses that infect dogwood: tobacco ringspot virus (TRSV), cherry leaf roll virus (CLRV), arabis mosaic virus (ArMV), and tomato ringspot virus (TmRSV) (Reddick *et al.*, 1977). The economic importance of this relationship was underscored by the destruction of all ArMV-infected dogwoods in South Carolina in an ArMV eradication program (Reddick *et al*., 1980).

Maple

Acer spp., both native and introduced species, are produced in ornamental plant nurseries because of their popularity as fast-growing shade trees. Annual production of maples in the five-county area is valued at about $2.5 million (W.T. Witte, pers. comm.). Red maple has been demonstrated in greenhouse tests as a host for *Belonolaimus longicaudatus* Rau, *Macroposthonia xenoplax* (Raski) de Grisse & Loof, *Paratrichodorus minor* (Colbran) Siddiqi (= *Trichodorus christiei* Allen), *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven, *Scutellonema brachyurum* (Steiner) Andrássy, and *Tylenchorhynchus claytoni* Steiner (Ruehle, 1971). These species and other possible parasites have been found associated with red maple (Springer, 1964; Goodey *et al*., 1965; Ruehle, 1967) and other *Acer* spp.. A root-knot nematode, *Meloidogyne ovalis* Riffle, was described from sugar maple (*Acer saccharum* Marshall) and reported on red maple (Riffle, 1963).

From studies on sugar maple, some authors have indicated that nematodes may be involved in certain disease complexes of maple. Urban trees exhibiting nitrogen deficiency symptoms were found to have twice as many nematodes in root-zone soil as were found under symptomless trees in similar sites (Rich and Walton, 1975). Riffle and Kuntz (1966) found the same species of plant parasites inhabiting soil under healthy maple stands as under maple blight and maple dieback areas in Wisconsin, but found they differed in relative abundance, and thought one or more of the species may have contributed to the diseases. Hibben (1964) did not believe that nematodes were the primary cause of maple decline in New

York woodlands, but thought nonetheless that more sampling was necessary to study seasonal population variation. Di Sanzo and Rohde (1969) demonstrated an association between *Xiphinema americanum* populations and maple decline in Massachusetts; it should be noted, however, that the various conditions called "maple decline" may not be the same, but only a range of non-specific symtoms including scorching, chlorosis, partial defoliation, and twig dieback.

Peach

Peach trees have the shortest productive life span of the major woody perennial fruit crops, and last 20 years or less (Lembright, 1976). Tennessee nurseries supply about 85% of the peach trees needed for replanting each year in the Southeast, a wholesale value of over $4 million (W. T. Witte, pers. comm.). Nematode damage and disease complexes involving nematodes, particularly the peach tree short life syndrome, are known limiting factors in peach production.

Wehunt and Good (1974) reviewed the literature on nematode parasitism of peach, and listed the following species as known parasites: *Belonolaimus longicaudatus*, *Criconemoides similis* (Cobb) Chitwood, *Hoplolaimus galeatus* (Cobb) Filipjev & Schuurmans Stekhoven, *Macroposthonia xenoplax*, *M. curvatum* (Raski) de Grisse & Loof, *Meloidogyne incognita*, *M. incognita acrita* Chitwood & Oteifa, *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood, *M. thamesi* Chitwood, *M. hapla*, *Paratylenchus hamatus* Thorne & Allen, *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans Stekhoven, *P. vulnus* Allen & Jensen, *P. brachyurus*, *Tylenchorhynchus claytoni*, *Xiphinema americanum*, *X. basiri* Siddiqi, and *X. indicum* Siddiqi. Many other species have been reported from peach orchards, but without direct evidence of parasitism (Anon., 1960; Goodey et al., 1965; Barker and Clayton, 1969; Wehunt and Good, 1974; Meyer, 1976).

Nematodes have been implicated in several disease complexes of peach. As early as 1949, ring nematodes (Criconemoides spp. sensu lato) were suspected factors in peach tree decline and replant problems (Chitwood, 1949). The etiology of peach tree short life involves physiological, mechanical, and biological causes, including nematodes (Barker and Clayton, 1973). Hung and Jenkins (1969) associated Macroposthonia curvatum with a peach tree decline problem. Lownsbery et al. (1973) demonstrated a relationship between M. xenoplax and Pseudomonas syringae van Hall in the development of bacterial canker of peach, and later proved (Lownsbery et al, 1977) that the development of the canker was affected by soil moisture but unaffected by either 'Nemaguard' or 'Lovell' rootstock. Wehunt and Weaver (1972) found a synergistic interaction between Hoplolaimus galeatus and Fusarium oxysporum on peach. Dhanavantari et al. (1975) found that infestations of either Pratylenchus penetrans or Meloidogyne hapla predisposed peaches to crown gall caused by Agrobacterium tumefaciens under certain conditions. Of great concern to orchardists and plant inspection agencies is that several viruses that infect peach are transmitted by Xiphinema and Longidorus spp. (Dropkin, 1980). Certification of a nursery for production of virus-free stock requires, among other things, assays for the presence of these vectors regardless of the presence of a virus (R. E. Harrison, pers. comm.).

III. FACTORS AFFECTING NEMATODE POPULATIONS

The factor having the greatest effect on the occurrence and density of soil-inhabiting nematodes is unarguably the presence of a suitable food source, which in turn is directly and indirectly affected along with nematode populations by a multitude of environmental conditions. Soil characteristics are among the important influences in specific nematode occurrences and their population dynamics (Norton, 1978). Laboratory experimental results on these factors are not reliably applicable to field conditions because the complex interactions among factors in the field may mitigate the influence of any given factor (Norton *et al.*, 1971).

pH

Whether soil pH has any direct effect on nematodes is a matter still at issue, and the sometimes contradictory results of studies on the matter were summarized by Norton (1978). Very few studies have been made of pH effects on nematodes associated with woody plants (Lownsbery *et al.*, 1961; Van Gundy and Martin, 1962; Van Gundy *et al*, 1964). Burns (1971) suggested that pH-induced differences in mineral availability and uptake in soybeans resulted in morphological changes in root epidermal cells, thus indirectly affecting populations of *Pratylenchus penetrans*. Norton *et al.* (1971) suggested that soil pH, having an effect on cation exchange capacity, might affect nematodes directly through their chemoreceptive organs.

Organic matter

Much attention has been given to the use of organic amendments in biological control of plant parasitic nematodes, but relatively little to the relationships between naturally occurring organic matter and nematodes. Positive correlations between organic matter content and total nematodes were found in Manitoba soils (Marchant, 1934), and with members of the Tylenchinae, Psilenchinae, and non-stylet bearing nematodes in a normal rainfall year in Iowa, but only with dorylaimids in a dry year (Norton *et al.*, 1971). Jenkins *et al.* (1957) noted larger populations of *Aphelenchoides* spp. and greater frequency of *Psilenchus* spp. in soils with higher organic matter content; soil-dwelling species in both genera are fungivorous. The plant parasites *Hemicycliophora parvana* Tarjan, *Hemicriconemoides wessoni* Chitwood & Birchfield, and *Macroposthonia curvatum* were observed to occur in Florida citrus grove soils with relatively higher organic matter (Brzeski, 1965). Norton *et al.* (1971) found a significant correlation between organic matter and the plant parasite *Helicotylenchus pseudorobustus* (Steiner) Golden.

Soil texture and bulk density

There are many publications dealing with the effect of soil texture on nematode populations (Norton, 1978). Few authors regard soil texture itself as having a major effect on nematode occurrence. Norton *et al.* (1971) found significant correlations between clay and silt content with populations of *H. pseudorobustus*. Cohn (1969) found a clear relationship between nematode volume, population size, and soil texture in a study of the distribution of *Xiphinema* and *Longidorus* species in

Israel. The smallest species were predominant in clayey soils, decreasing as percent sand increased, and the larger species predominated in sandy soils. Texture influences pore space in soils, which in turn influences nematodes directly through size relationships and indirectly through effects on soil aeration and moisture content (Norton, 1978). An accepted method of estimating soil porosity is through determination of bulk density, the ratio of soil mass to volume (Baver et al., 1972; Jones and Thomasson, 1976).

Though seemingly clear relationships may be found between various soil factors and nematode populations, the complex interactions among soil microorganisms and their environment make a causal relationship difficult to prove. However, there is undoubtedly an effect, and continued investigations into such relationships are warranted (Norton, 1978).

IV. COMMUNITY STRUCTURE ANALYSIS

Trophic groups

Nematodes occupy a wide range of ecological niches. Soil-dwelling nematodes have often been classified according to trophic groups for community analysis on the assumption that competitive interactions are minimal among groups using different food sources. A commonly used classification scheme is: microbivores, or bacterial feeders; fungivores; plant parasites; predators; and "omnivores," meaning those feeding on a variety of substrates to account for dorylaims of unknown trophism (some of which may be true omnivores) for semantic purposes. Community structure studies based on trophic group comparisons were reviewed by Ferris and Ferris (1974) and Yeates (1979). These have mostly been confined to studies of non-agricultural habitats.

Plant parasitic nematode communities

The degree of community structure is dependent on the degree of interaction among the members of a community. In studies of agricultural situations, the interaction of interest is that of host-parasite and the factors affecting that relationship. Surveys provide useful information, but surveys combined with community structure analyses are more relevant to eventual modeling of plant parasitic nematode communities, and thus relevant to control decisions (Wallace, 1973).

Community structure analyses applied to plant parasitic nematode communities in agricultural sites have been few, and none if only woody perennials are considered. Norton and Oard (1980) used the Shannon-Weiner diversity index to study plant parasitic nematodes in corn plantings in loess toposequences. Norton *et al.* (1971) correlated various soil properties with nematodes in soybean fields. Ferris *et al.* (1971) used a cluster analysis and a three dimensional ordination technique to show relationships between nematodes and soil types in soybeans. In non-agricultural sites, similar techniques were used. Schmitt and Norton (1971) used a cluster analysis based on presence-absence and population size data for nematodes in native prairies. Kimpinski and Welch (1971) correlated nematode populations and soil factors in Manitoba soils, and Johnson *et al.* (1972, 1973, 1974) used the techniques applied by Ferris *et al.* (1971) for analysis of communities in forest woodlots. These last two were not limited to plant parasitic nematodes. Knobloch and Bird (1978) used prominence and importance values to analyze Criconematinae habitats. Such measures are useful because abundance data are modified by frequency data, with some emphasis given to rarely occurring species not given with presence-absence data (Beals, 1960).

Community ordination

The analytical techniques used in nematological studies have all been borrowed from other disciplines, primarily plant ecology (Johnson et al., 1973). Community ordination is a method for determining relationships among nematode communities based strictly on species composition, and non-linear relationships can be determined between communities and various factors that might be missed by other analytical methods such as correlations. A relatively simple two-dimensional ordination method was applied to animal communities by Beals (1960), with prominence values, rather than presence-absence data, used to compare habitats. This technique provides a quantitative basis for predicting where one is more likely to find a given species within the limits of the variables studied; such analyses can be very valuable in developing models of nematode communities.

CHAPTER III

MATERIALS AND METHODS

I. DATA COLLECTION

Site selection

In October, 1980, 25 nurserymen growing one or more blocks of dogwood, maple, or peach trees were contacted as potential cooperators for this study. The nurseries were distributed among Coffee, DeKalb, Franklin, Grundy, and Warren Counties. From the sites surveyed, 100 were chosen according to the following additional criteria: the block had contained the same tree species for the previous five years, the trees would remain in the block for the duration of the study, and the site would be accessible by car in adverse weather. Eight of the sites were abandoned between the first and last sampling dates because the trees were rogued, but the remaining 92 comprised 48 dogwood and 27 maple blocks, each in three age classes, and 17 peach blocks (Table 1).

Table 1. Tree species and age classes of sites sampled in Tennessee nurseries.

Tree species	Tree age class: 1-2 yrs.	3-5 yrs.	10+ yrs.	Totals
Dogwood	29[1]	7	12	48
Maple	6	14	7	27
Peach	17	0	0	17

[1]Numbers refer to number of sites in each age class.

Peach cultivar and fumigation history information was collected.

Sampling and nematode assay

Sampling sites of approximately 30 m^2 were marked at or near the center of each block, from which soil samples were taken in March, July, and October, 1981. Each sample consisted of 20 soil cores (1000 cm^3) collected from within the rows about the roots of the trees to a depth of 20-30 cm (Johnson, *et al.*, 1972; Barker *et al.*, 1978). Samples were transported to the laboratory in coolers and kept at 12 C until processed. Nematodes were extracted by a sugar-flotation centrifugation method (Jenkins, 1964).

Nematodes identified as microbivores, fungivores, predators, and omnivores were counted as such. Plant parasitic individuals were identified to genus and counted, then hand-picked from the extracts, killed and fixed in hot 4% formalin, processed to glycerin (Seinhorst, 1959), mounted, and labeled for identification to species. Each sample containing root-knot (*Meloidogyne* spp.) juveniles was potted with a tomato plant (*Lycopersicon esculentum* L. 'Rutgers') to obtain adult females for identification (Taylor and Sasser, 1978). Soil from samples containing cyst (*Heterodera* spp.) juveniles was processed for extraction of cysts. Identification of all plant parasitic species was accomplished through the use of recent keys and descriptions.

Weed and soil analyses

During the July sampling, a determination was made of the percentage weed ground cover within sample sites. In sites with weeds, the number of weed species present were counted. During the October sampling, extra soil cores were taken for soil analyses. Cores for determination of bulk density (g/cm^3 soil) were measured on-site and stored in jars to be oven dried and weighed (Baver et al., 1972). Air-dried soil was passed through a 40 mesh (420 μm openings) sieve and ground with a ceramic mortar and pestle for the remaining analyses.

Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1936), and soil texture designation was given according to the U.S. system (Norton, 1978). Percent organic matter content was determined as percent organic carbon by a chromic acid titration method (Walkley and Black, 1934; Walkley, 1946) multiplied by 1.72 as a conversion factor to obtain percent organic matter, with the assumption that organic matter is 58% C (R. Miles, pers. comm.). Soil pH was determined for 10 g samples mixed with 20 ml de-ionized distilled water. All of the procedures were duplicated for each sample; soil characteristics given in Table 2 are mean values.

II. DATA ANALYSIS

All calculations and statistical analyses were accomplished through a computer program, entitled WORM, written by Tim E. Rickard. Species diversity (H') was computed for each site per sampling date with the Shannon-Weiner formula as modified by Lloyd, Zar, and Karr (1968):

$$H' = \frac{c}{N} (N\log_{10}N - \sum n_i \log_{10} n_i)$$

where c = log base conversion factor (= 1); N = total number of individuals; and n_i = number of individuals per species. Species dominance (d) was calculated for each site per sampling date by Simpson's formula,

Table 2. Soil characteristics of sample sites in dogwood, maple, and peach nurseries in Tennessee.

Site no.	Bulk density (g/cm^3)	pH	Organic matter (%)	Soil texture Sand (%)	Silt (%)	Clay (%)	Textural class
0201	1.71	5.1	1.28	5	64	31	silty clay loam
0202	1.53	5.2	1.75	1	82	17	silt loam
1001	1.07	5.7	0.87	25	50	25	loam
1002	1.72	4.5	1.11	23	54	23	silt loam
1003	1.38	5.0	2.35	15	64	21	silt loam
1201	1.41	5.2	2.49	35	58	7	silt loam
1202	1.62	4.9	1.61	31	54	15	silt loam
1203	1.59	7.3	0.64	33	52	15	silt loam
1204	1.51	6.2	0.96	33	50	17	silt loam
1501	1.84	5.6	1.02	21	62	17	silt loam
1502	1.62	5.4	0.90	19	58	23	silt loam
1503	1.37	4.6	1.88	17	68	15	silt loam
1504	1.31	4.9	1.65	31	56	13	silt loam
1505	1.51	4.7	2.07	23	56	21	silt loam
1506	1.55	5.1	0.95	27	54	19	silt loam
1507	1.42	5.6	1.99	31	56	13	silt loam
1508	1.42	5.7	1.66	31	52	17	silt loam
2001	1.52	6.1	1.32	33	50	17	silt loam
2002	1.52	4.8	1.73	13	72	15	silt loam
2003	1.31	6.8	1.58	5	76	19	silt loam
2004	1.28	5.5	1.53	27	62	11	silt loam
2005	1.53	5.7	1.59	19	62	19	silt loam
2007	1.70	7.2	1.82	25	58	17	silt loam
2008	1.72	5.1	0.78	21	64	15	silt loam
2009	1.63	7.3	1.80	29	58	13	silt loam
2010	1.53	6.3	1.52	31	56	13	silt loam
2011	1.53	6.5	1.45	25	62	13	silt loam
2201	1.45	4.5	1.44	33	56	11	silt loam

Table 2. (continued)

Site no.	Bulk density (g/cm3)	pH	Organic matter (%)	Soil texture Sand (%)	Silt (%)	Clay (%)	Textural class
2202	1.43	4.7	1.19	19	56	25	silt loam
2203	1.44	4.6	1.74	27	56	17	silt loam
2204	1.48	6.2	1.83	29	56	15	silt loam
2205	1.28	5.3	1.43	23	58	19	silt loam
2206	1.41	5.4	1.07	13	70	17	silt loam
3001	1.93	4.7	1.33	35	44	21	loam
3002	1.26	4.3	0.86	31	48	21	loam
4201	2.07	4.5	0.64	17	56	27	silty clay loam
4202	1.61	4.3	1.28	21	56	23	silt loam
4204	1.62	4.4	1.66	15	60	25	silt loam
4205	1.57	4.8	2.15	29	42	29	clay loam
4401	1.50	6.0	1.72	19	72	9	silt loam
4402	1.38	5.6	0.96	21	60	19	silt loam
4701	1.57	7.1	0.85	31	46	23	loam
4702	1.71	4.4	0.71	27	50	23	loam
4703	1.43	5.9	1.69	37	52	11	silt loam
4704	1.66	6.1	1.00	47	28	25	loam
4705	1.72	6.4	1.80	41	44	15	loam
4706	1.47	7.4	1.66	23	50	27	silty clay loam
5501	1.67	5.2	1.86	43	36	21	loam
5502	1.55	5.0	2.57	35	44	21	loam
5503	1.57	5.5	1.63	19	50	31	silty clay loam
5504	1.53	4.7	0.70	23	50	27	silty clay loam
5801	1.48	5.0	1.08	3	76	21	clay loam
5802	1.80	4.8	1.14	33	40	27	clay loam
5803	1.66	5.1	0.18	37	40	23	loam
5804	1.65	4.8	0.88	33	48	19	loam
6501	1.56	4.8	2.05	33	46	21	loam
6502	1.56	5.1	2.03	51	28	21	sandy clay loam
6503	1.52	4.9	1.40	61	28	11	sandy loam

Table 2. (continued)

Site no.	Bulk density (g/cm3)	pH	Organic matter (%)	Soil texture Sand (%)	Silt (%)	Clay (%)	Textural class
6504	1.44	4.4	0.89	57	24	19	sandy loam
6505	1.32	4.4	1.01	31	48	21	loam
6901	1.36	5.0	2.13	17	62	21	silt loam
6902	1.54	5.2	2.11	25	50	25	loam
6903	1.24	5.1	2.15	17	64	19	silt loam
6904	1.44	5.1	2.43	3	80	17	silt loam
6905	1.25	6.9	1.50	21	60	19	silt loam
6906	1.31	5.7	2.79	27	56	17	silt loam
7301	1.54	4.9	1.53	9	70	21	silt loam
7401	1.39	5.5	2.07	19	60	21	silt loam
7402	1.68	4.5	1.84	5	76	19	silt loam
7403	1.48	4.7	1.96	1	76	23	silt loam
7405	1.32	4.4	0.90	13	66	21	silt loam
7601	1.14	4.6	1.44	23	52	25	silt loam
7602	1.22	5.0	2.20	35	42	23	loam
7603	1.54	6.0	1.96	21	56	23	silt loam
7604	1.52	5.2	2.10	7	62	31	silty clay loam
7605	1.59	5.3	1.81	21	52	27	clay loam
7606	1.63	5.1	1.92	25	54	21	silt loam
7607	1.60	5.1	2.74	19	48	33	silty clay loam
7701	1.50	5.3	1.96	5	60	35	silty clay loam
7702	1.69	5.1	1.97	25	52	23	silt loam
7703	1.80	4.9	2.02	19	58	23	silt loam
7704	1.46	5.6	2.76	13	68	19	silt loam
7705	1.39	5.6	2.03	27	54	19	silt loam
7706	1.48	5.9	2.22	25	50	25	loam
7801	1.28	6.0	2.29	17	60	23	silt loam
7802	1.64	5.3	2.17	11	60	29	silty clay loam
7803	1.52	6.1	0.62	25	50	25	loam
7804	1.58	5.2	2.33	5	68	27	silty clay loam
7901	1.43	5.1	1.85	19	72	9	silt loam

Table 2. (continued)

Site no.	Bulk density (g/cm^3)	pH	Organic matter (%)	Soil texture Sand (%)	Silt (%)	Clay (%)	Textural class
7902	1.08	5.0	1.81	19	58	23	silt loam
7903	1.47	4.8	1.82	27	56	17	silt loam
7904	1.42	5.9	1.18	21	62	17	silt loam

as applied by Metz and Dindal (1975):

$$d = \sum \left(\frac{n_i}{N}\right)^2 .$$

Correlation coefficients among diversity, dominance, and the data collected as described in Part I, this chapter, were calculated by product moment correlation (Huntsberger and Billingsley, 1977). Both numbers of nematodes and the percentages of the totals each group represented of the totals for each site were sorted by date, tree species, and/or both for analysis. Sorted data and unsorted data were used in correlations with tree age class (dogwood and maple sites only; see Table 1), edaphic factors (Table 2), and weed information (data not given). Correlations between weed data and other data were based on July data only, since weed information was not collected in March or October. Percent weed cover and number of weed species were correlated with a coefficient of +0.810. Correlations for species in the Tylenchidae were also based on July data only. These species were counted together on all three sampling dates, and one-fourth of the total individuals per sample were extracted and identified to species in July. The proportion represented by fungivorous genera was subtracted from the total, and the remaining plant parasitic species were separated based on the proportions they represented. Correlation coefficients reported herein were those significant at $p \leq 0.05$.

Comparisons of plant parasitic communities were made using Beals' (1960) two-dimensional community ordination technique.

CHAPTER IV

RESULTS

I. TROPHIC GROUP STRUCTURE OF NEMATODE COMMUNITIES IN DOGWOOD, MAPLE, AND PEACH NURSERIES

Table 3 contains mean data for counts of nematode totals and for those in each of the five trophic groups. These data are also given as mean percent of total nematodes, and listed according to tree species and sampling date.

Total nematodes

Total nematodes per 200 cm^3 soil ranged from 52 to 9166, with a grand mean of 1785.2 (standard deviation = 1420.9). The highest mean total for March was in maple sites, followed closely by that for dogwood sites. Standard deviations of the means were similar, though the range was more extreme for dogwood sites. The mean total for peach sites was only about 60% of that for the others, with a standard deviation close to the mean. Totals were lower in July for all three tree species, but only slightly so for peach. The most extreme range again occurred in dogwood sites, in which the standard deviation was greater than the mean. Totals increased for all tree species in October, nearly doubled in maple and nearly tripled in peach sites, but only just above the March level in dogwood sites. Both the standard deviation of the mean and the range were most extreme for peach sites. In most sites in which all five trophic groups were represented, ranking of groups expressed as the percentage of total nematodes remained the same, in the order: micro-

Table 3. Total nematodes and constituencies of five trophic groups in dogwood, maple, and peach nursery soils on three sampling dates.

Tree species	Sample date	Trophic groups: Microbivores	Plant parasites	Fungivores	Omnivores	Predators	Total nematodes/200 cm^3: Mean	Range	S.D.
		Mean densities/200 cm^3							
Dogwood n=48	March	1019.6	433.5	253.4	76.8	20.1	1803.2	162-7212	1284.8
	July	642.9	635.4	161.8	70.6	8.5	1519.2	76-9166	1678.1
	October	1134.4	473.4	173.8	70.6	9.3	1861.5	66-5216	1358.0
Maple n=27	March	975.6	576.7	226.8	90.9	42.1	1912.1	272-5194	1294.8
	July	487.9	632.6	125.2	58.4	7.5	1311.6	138-3112	751.6
	October	1352.4	879.5	165.7	115.5	18.7	2531.7	158-5928	1248.2
Peach n=17	March	597.3	269.9	182.4	47.2	10.4	1107.2	52-4178	1004.3
	July	625.5	289.5	144.3	34.8	6.8	1100.9	226-3178	787.4
	October	2122.5	401.1	430.1	35.3	9.3	2998.3	226-6884	2058.5
		Mean percentages of totals							
Dogwood	March	55.6	23.4	15.8	3.9	1.3			
	July	51.3	30.8	13.2	4.3	0.4			
	October	62.8	23.2	10.2	3.4	0.4			
Maple	March	47.4	31.6	13.1	5.5	2.4			
	July	42.0	41.1	10.6	5.7	0.6			
	October	54.0	33.4	7.1	4.7	0.8			
Peach	March	61.3	15.2	18.8	3.6	1.1			
	July	58.4	21.0	16.8	3.1	0.7			
	October	69.3	17.0	11.6	1.7	0.4			

bivores, plant parasites, fungivores, omnivores, and predators (Fig. 2).

Nematode totals were correlated significantly with three of the variables measured. Correlation coefficients between totals in all sites (n=92) with percent weed groud cover and with number of weed species were +0.371 and +0.458, respectively. A positive correlation was found between totals and tree age, but further analysis showed this relationship to be significant only in dogwood sites (n=48), r=+0.358 (Fig. 3).

Microbivores

In most sites, numbers of microbivorous nematodes exceeded those of other groups. Both mean numbers and their percent constituency of total nematodes were lower in July than in March in dogwood and maple sites. The highest means of both numbers and percentages of microbivores were found in October for all tree species. Their mean density in peach sites was more than three times higher, so that microbivores accounted for 69.3% of the total.

In dogwood and maple sites (n=75), but not in peach sites, positive correlations were found between numbers of microbivores and percent weed cover, r=+0.310 and +0.376, respectively. The correlations between these variables and percent microbivores were negative, r=-0.250 and -0.287, respectively. A negative correlation was also found between percent microbivores and dogwood tree age (n=48), r=-0.289 (Fig. 4).

Plant parasites

Mean densities and percentages of plant parasitic nematodes were higher in July than in March for all sites. Plant parasites were

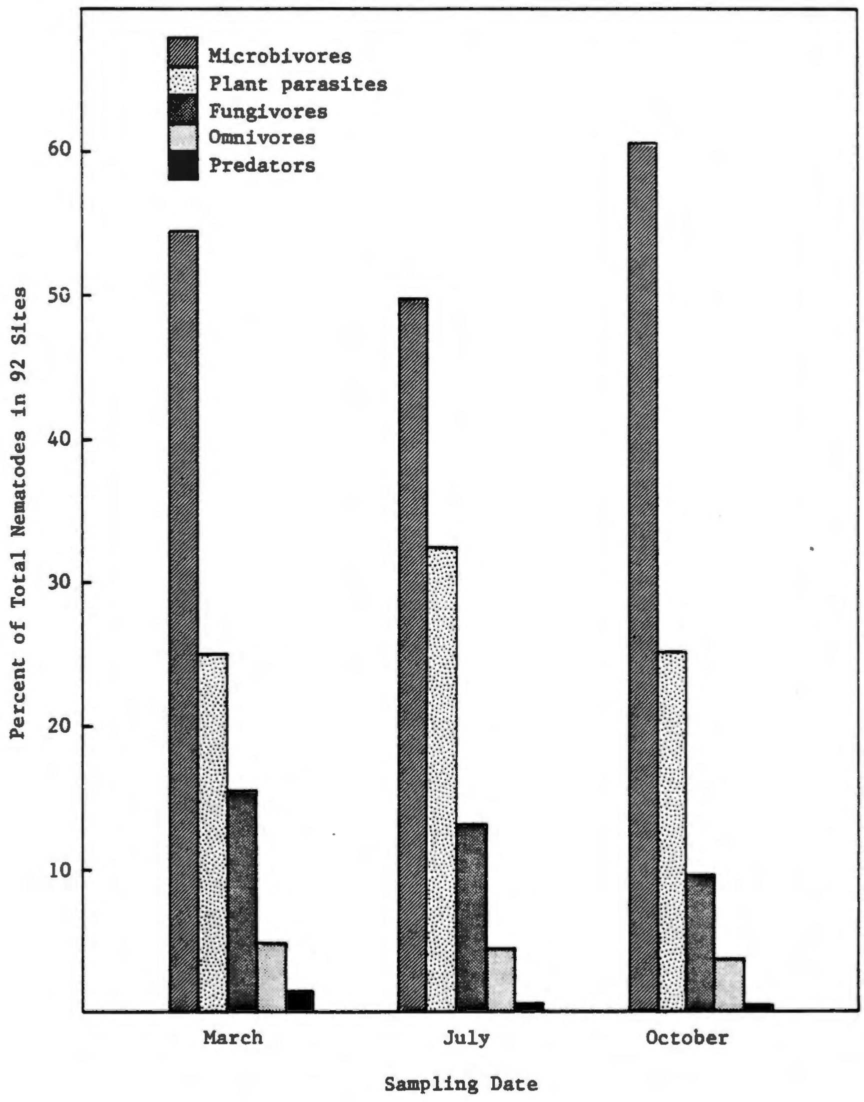

Fig. 2. Population sizes of nematode trophic groups in soil samples from Tennessee nursery sites.

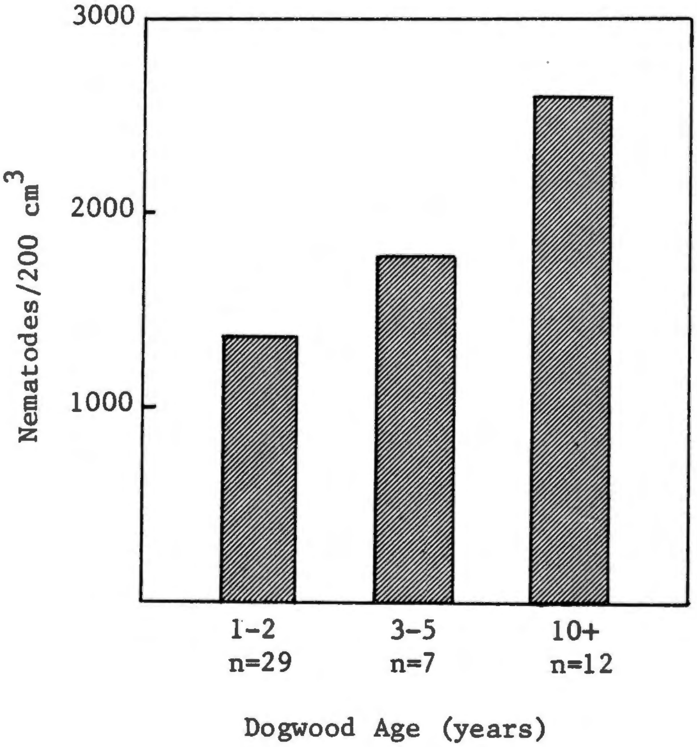

Fig. 3. Densities of nematodes in soil samples from sites of three dogwood age classes.

the only group for which the percentage of the total count was higher in July for all three tree species. Percent plant parasites for October was lower than for March in dogwood and maple, and only slightly higher than for March in peach sites. Mean numbers, however, were lower in October than in July in dogwood sites, and higher in maple and peach sites.

Numbers and percentages of plant parasites were positively correlated with tree age in dogwood (n=48) and maple (n=27) sites, r=+0.380 and +0.385, respectively (Fig. 4). Correlations of numbers of plant parasites with percent weed cover and number of weed species were +0.408 and +0.448, respectively, for dogwood sites, but were not significant for maple or peach sites. The plant parasitic group is discussed in more detail in another section.

Fungivores

Numbers of fungivores were highest in March in dogwood and maple sites, lowest in July, and intermediate in October. In all sites, mean percentages of fungivores were lower in July and lowest in October. However, the percentage of fungivores in peach sites in March was higher than the percentage of plant parasites. Also contrary to the results for dogwood and maple sites, numbers of fungivores in peach sites were highest in October, triple the numbers found in July. A negative correlation was found between percent fungivores and tree age in dogwood sites only, r=-0.350 (Fig. 4).

Omnivores

Numbers of omnivores were highest in dogwood and peach sites

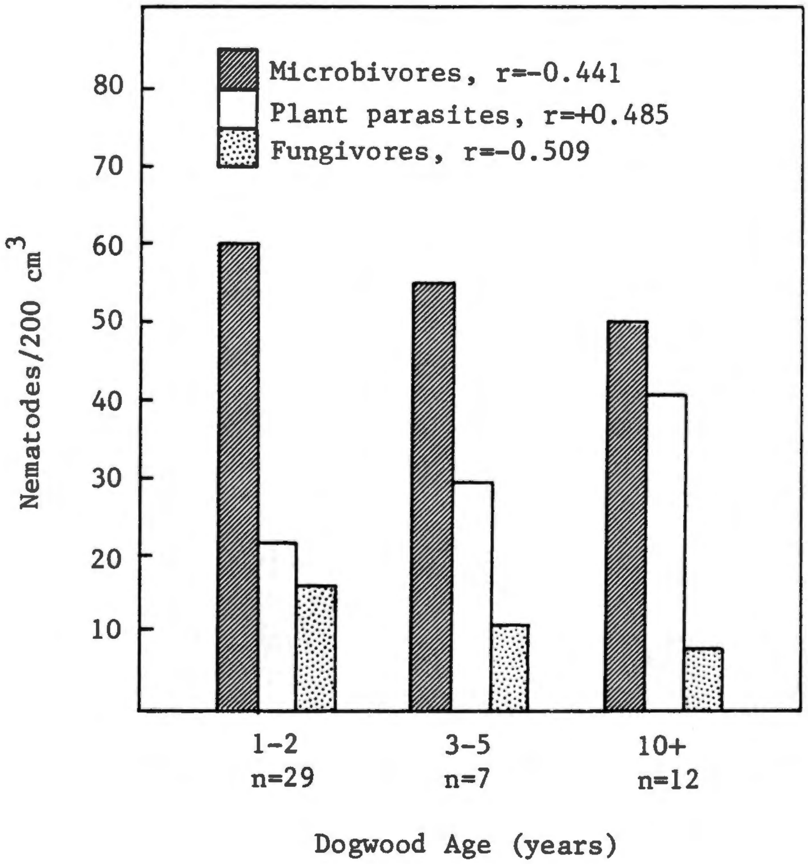

Fig. 4. Occurrence of three nematode trophic groups in soil samples from dogwood sites of three age classes.

in March, and highest in maple sites in October. The mean percentages these numbers constituted were higher in July than in March in dogwood and maple sites, and lower in peach sites. These percentages were higher than March levels in dogwood and maple sites in October, and much lower in peach sites.

Numbers and percentages of omnivores were correlated with dogwood and maple tree ages, r=+0.450 and +0.317, respectively. Numbers of omnivores were also correlated with percent weed cover and number of weed species in all sites (n=92), r=+0.360 and +0.420, respectively. Correlation coefficients of +0.137 and +0.140 were found between numbers of omnivores and percent sand and bulk density, respectively, in all sites.

Predators

Predaceous nematodes occurred in the lowest numbers among the five trophic groups. Predator numbers and percentages were lower in July than in March, and higher in October than in July. The highest numbers occurred in March in all sites, and in July were less than half the March counts in dogwood sites and less than one-fourth in maple sites. There was a positive correlation between numbers of predators and percent soil organic matter, r=+0.191 (Fig. 5).

II. PLANT PARASITIC NEMATODE COMMUNITY STRUCTURE

Occurrence of plant parasitic nematodes

Plant parasitic nematodes occurred in every site sampled. Fifty-eight species in 25 genera were identified, with one to 16 species occurring in a given site. Three of the species found were new United

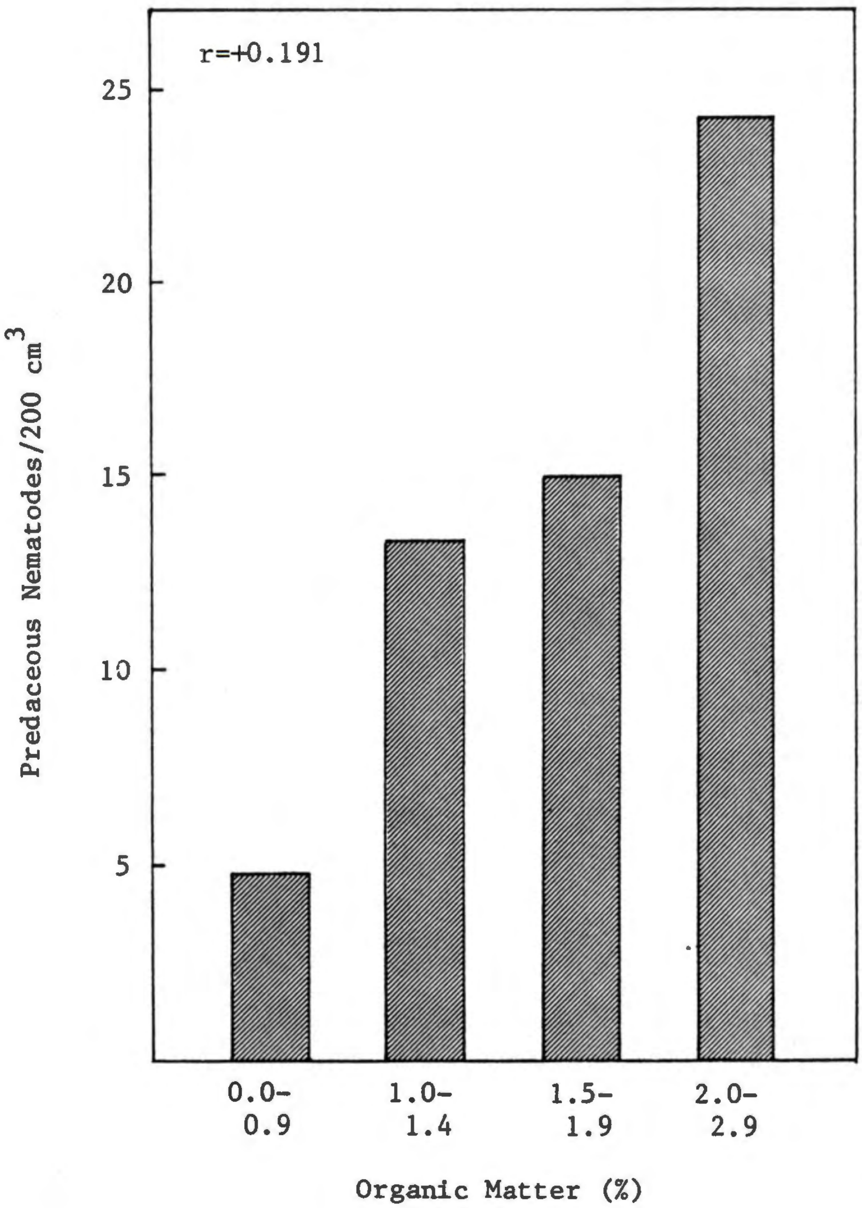

Fig. 5. Relationship between predaceous nematodes and organic matter in Tennessee nursery soils.

States records and 11 were new Tennessee records. Identified species are listed in Table 4. Five Filenchus and two Tylenchus species were not named but were separated into numbered taxa according to certain morphological characteristics. One Gracilacus species, one Paratylenchus species, and two Hemicycliophora species were found to be undescribed taxa, and were also designated by numbers. The number of occurrences (frequency), mean density per sampling date, and standard deviations of the means, are given in Table 5. Thirteen of the species were found in only one site each, 22 were found in more than 10% of the sites, and only five species were found in more than 25% of the sites sampled. The most commonly found species were Paratylenchus projectus (88% of the sites), Xiphinema americanum (78%), Helicotylenchus pseudorobustus (53%), Filenchus cylindricus (46%), and Tylenchus davainei (36%). The 22 species found in more than 10% of the sites were generally equally distributed among dogwood, maple, and peach sites. The only species occurring in three or more sites which was limited in distribution to association with one tree species was Aorolaimus helicus, which was found in four dogwood sites. Seven of the 13 species found only once were found in maple sites.

Genera occurring in more than 10% of the sites

Coslenchus. C. costatus constituted a new state record, and was found in 19 sites. Mean populations were highest in dogwood sites, 164/200 cm^3 compared to 87 for maple and 55 for peach sites. The species was found in sites with a pH between 4.5 and 6.0; it occurred in 49% of sites with a pH between5.0 and 5.4, but attained its highest densities between

Table 4. New records of plant parasitic nematodes from dogwood, maple, and peach nurseries in Tennessee.

Species	New records U.S.	New records Tenn.	New records County	Counties[1]	Plant association[2]
Aglenchus agricola (de Man, 1884) Meyl, 1961		x	x	C D G W	D M
Aorolaimus helicus Sher, 1963			x	F	D
Basiria sp. Siddiqi, 1959					D M P
Cephalenchus sp.					M
Coslenchus costatus (de Man, 1921) Siddiqi, 1978		x	x	C D F G W	D M P
Filenchus cylindricus (Thorne & Malek, 1968)[3]					D M P
F. parvissimus (Thorne & Malek, 1968)[3]					D M P
F. plattensis (Thorne & Malek, 1968)[3]					D M P
Gracilacus aculenta (Brown, 1959) Raski, 1962		x	x	C F G W	D M
Helicotylenchus canadensis Waseem, 1961	x	x	x	W	M
H. crassatus Anderson, 1974		x	x	W	D
H. dihystera (Cobb, 1893) Sher, 1961			x	C F G W	D P
H. paraplatyurus Siddiqi, 1972	x	x	x	C D F G W	D M P
H. platyurus Perry in Perry, Darling, and Thorne, 1959			x	F	D
H. pseudorobustus (Steiner, 1914) Golden, 1956			x	C F G W	D M P
H. vulgaris Yuen, 1964	x	x	x	W	M
Heterodera glycines Ichinohe, 1952			x	G	D
H. lespedezae Golden & Cobb, 1963			x	W	D M
H. schachtii Schmidt, 1871		x	x	G	D

Table 4. (continued)

Species	New records U.S.	Tenn.	County	Counties[1]	Plant association[2]
H. trifolii Goffart, 1944			x	C W	D M P
Hoplolaimus galeatus (Cobb, 1913) Filipjev & Schuurmans Stekhoven			x	D F W	D M P
Macroposthonia xenoplax (Raski, 1952) de Grisse & Loof, 1965			x	C F G	D M P
Malenchus sp. Andrassy, 1968					D M P
Meloidogyne hapla Chitwood, 1949			x	C F G W	D M P
M. incognita (Kofoid & White, 1919) Chitwood, 1949					D
Merlinius brevidens (Allen, 1955) Siddiqi, 1970			x	F W	D M
Nothocriconema demani (Micoletzky, 1925) de Grisse & Loof, 1965			x	C	M
N. mutabile (Taylor, 1936) de Grisse & Loof, 1965			x	C G W	M P
Paratrichodorus minor (Colbran, 1956) Siddiqi, 1973			x	C F G W	D M
Paratylenchus projectus Jenkins, 1956			x	C D G W	D M P
P. tenuicaudatus Wu, 1961		x	x	C F W	D M P
Pratylenchus crenatus Loof, 1960			x	C D	D P
P. hexincisus Taylor & Jenkins, 1957		x	x	D	M
P. neglectus (Rensch, 1924) Filipjev & Schuurmans Stekhoven, 1941			x	W	D M

Table 4. (continued)

Species	New records U.S.	Tenn.	County	Counties[1]	Plant association[2]		
P. scribneri Steiner in Sherbakoff & Stanley, 1943			x	D F W	D	M	P
P. vulnus Allen & Jensen, 1951			x	F G W	D	M	
P. zeae Graham, 1951			x	F W	D	M	P
Pseudhalenchus sp. Tarjan, 1958					D	M	P
Quinisulcius curvus (Williams, 1960) Siddiqi, 1971		x	x	F W	D	M	
Tylenchorhynchus claytoni Steiner, 1937			x	D F G W	D	M	P
T. maximus Allen, 1955			x	C F W	D	M	P
Tylenchus arcuatus Siddiqi, 1963					D	M	P
T. davainei Bastian, 1865					D	M	P
Xenocriconemella macrodora Taylor, 1936			x		D		
Xiphinema americanum Cobb, 1913			x	C F G	D	M	P

[1] C = Coffee; D = DeKalb; F = Franklin; G = Grundy; W = Warren.

[2] D = dogwood; M = maple; P = peach.

[3] These species fit the generic circumscription of Filenchus (=Lelenchus) as proposed by Andrássy (1976).

Table 5. Occurrence of plant parasitic nematode species in selected dogwood, maple, and peach nurseries in Tennessee.

Species	Number of occurrences	Mean density / 200 cm^3			Standard deviation / 200 cm^3		
		March	July	October	March	July	October
Aglenchus agricola	4	45.8	50.0	33.8	56.4	14.9	14.2
Aorolaimus helicus	4	15.3	7.6	10.0	13.9	11.4	13.8
Basiria sp.	4	21.3	27.8	36.0	15.1	33.5	43.6
Cephalenchus sp.	1	226.0	896.0	874.0	0.0	0.0	0.0
Coslenchus costatus	19	77.1	168.9	89.6	53.8	353.4	80.3
Filenchus cylindricus	46		121.2			161.8	
F. parvissimus	11		87.4			117.8	
F. plattensis	8		51.4			28.8	
F. sp. 1	27		136.7			99.5	
F. sp. 2	7		61.9			49.8	
F. sp. 3	13		127.2			101.7	
F. sp. 4	8		48.3			38.5	
F. sp. 5	6		83.3			49.9	
Gracilacus aculenta	13	26.8	86.2	64.5	43.1	305.8	215.3
G. sp. 2	1	104.0	36.0	44.0	0.0	0.0	0.0
Helicotylenchus canadensis	1	6.0	0.0	2.0	0.0	0.0	0.0
H. crassatus	1	4.0	4.0	0.0	0.0	0.0	0.0
H. dihystera	17	22.5	25.1	92.5	48.1	67.6	329.5
H. paraplatyurus	14	15.4	9.5	12.4	40.9	18.8	34.3
H. ?platyurus	1	2.0	0.0	0.0	0.0	0.0	0.0

Table 5. (continued)

Species	Number of occurrences	Mean density / 200 cm^3			Standard deviation / 200 cm^3		
		March	July	October	March	July	October
H. pseudorobustus	49	36.2	33.8	14.9	141.7	16.49	26.8
H. vulgaris	1	0.0	5.0	13.0	0.0	0.0	0.0
Hemicycliophora sp. 1	1	10.0	49.0	10.0	0.0	0.0	0.0
H. sp. 2	1	0.0	3.0	0.0	0.0	0.0	0.0
Heterodera glycines	1	0.0	2.0	0.0	0.0	0.0	0.0
H. lespedezae	2	2.0	3.0	0.0	2.8	1.4	0.0
H. schachtii	1	2.0	0.0	0.0	0.0	0.0	0.0
H. trifolii	4	7.0	4.0	0.5	10.1	6.7	1.0
Hoplolaimus galeatus	13	10.0	4.1	3.4	10.3	6.7	4.3
Macroposthonia xenoplax	11	3.3	2.6	13.1	4.8	4.5	30.5
Malenchus sp.	28	67.7	63.5	70.1	87.7	63.4	55.9
Meloidogyne hapla	21	20.1	6.6	45.2	50.5	24.3	117.3
M. incognita	1	0.0	0.0	92.0	0.0	0.0	0.0
Merlinius brevidens	10	19.5	7.9	13.8	19.7	10.2	11.9
Nothocriconema demani	1	0.0	3.0	10.0	0.0	0.0	0.0
N. mutabile	4	7.3	4.5	24.0	5.9	4.1	40.1
Paratylenchus projectus	81	135.54	185.2	165.4	320.3	599.4	287.9
P. tenuicaudatus	8	156.8	130.9	211.8	208.5	109.6	238.9
P. sp. 3	18	90.4	333.3	342.2	110.8	531.2	523.3

Table 5. (continued)

Species	Number of occurrences	Mean density / 200 cm^3			Standard deviation / 200 cm^3		
		March	July	October	March	July	October
Pratylenchus crenatus	2	9.0	9.0	3.0	7.1	9.9	1.4
P. hexincisus	1	10.0	0.0	14.0	0.0	0.0	0.0
P. neglectus	2	10.0	2.0	9.0	0.0	0.0	12.7
P. penetrans	5	13.8	8.0	13.2	11.9	7.9	16.0
P. scribneri	10	16.4	3.4	5.7	26.9	4.5	8.7
P. vulnus	8	20.5	14.0	29.0	46.9	32.8	39.3
P. zeae	6	16.5	3.0	3.2	24.9	3.7	3.1
Pseudhalenchus sp.	11	30.0	57.5	81.0	31.9	65.9	130.0
Paratrichodorus minor	7	0.3	8.3	20.3	0.8	7.8	30.2
Quinisulcius curvus	4	23.8	17.0	57.5	40.2	31.4	101.7
Tylenchorhynchus claytoni	14	59.1	93.5	89.4	78.7	169.6	283.3
T. maximus	5	36.8	35.6	14.4	66.9	77.4	24.7
Tylenchus arcuatus	10		52.0			35.9	
T. davainei	33		80.3			76.5	
T. sp. 1	4		58.0			20.1	
T. sp. 2	9		37.7			26.4	
Xenocriconemella macrodora	2	2.0	0.0	0.0	0.0	0.0	0.0
Xiphinema americanum	72	26.5	8.6	33.4	44.8	18.4	84.1

4.5 and 4.9 (Fig. 6). Densities of *C. costatus* were negatively correlated with pH, r=-0.314 (n=19).

Filenchus and *Tylenchus*. *F. cylindricus*, *F. parvissimus*, *F.* sp. 1, *F.* sp. 3, *T. arcuatus*, and *T. davainei* were all found in more than 10% of the sites sampled. *F. cylindricus* and *T. davainei* were two of the five found in more than 25% of the sites. All species in this group were proportionally equally distributed among dogwood, maple, and peach sites.

Mean densities of *F. cylindricus* (n=46), *F. parvissimus* (n=11), and *T. davainei* (n=33) were correlated with percent sand, r=+0.260, -0.632, and -0.237, respectively (Fig. 7). *F.* sp. 1 (n=27) was negatively correlated with bulk density, r=-0.260; pH was positively correlated with densities of *F.* sp. 1 and *F.* sp. 3 (n=13), r=+0.348 and +0.408, respectively. Densities of *F.* sp. 3 and *T. arcuatus* (n=10) were both positively correlated with percent weed cover, r=+0.653 and +0.686, respectively. *T. arcuatus* was also correlated, along with *Filenchus parvissimus* with tree age, r=+0.523 and +0.420, respectively (Fig. 8).

Gracilacus. The occurrence of *G. aculenta* was a new record for the state. It occurred in eight dogwood and five maple sites, and was not found in peach sites. Another species was found once, in a peach site, and was not found in other sites. Densities of *G. aculenta* (n=13) were positively correlated with tree age, r=+0.356 (Fig. 9).

Helicotylenchus. Seven species of *Helicotylenchus* were extracted, four of which were found in only one site each. Two of these, *H. canadensis* and *H. vulgaris*, were found to be new U.S. records; both were found in

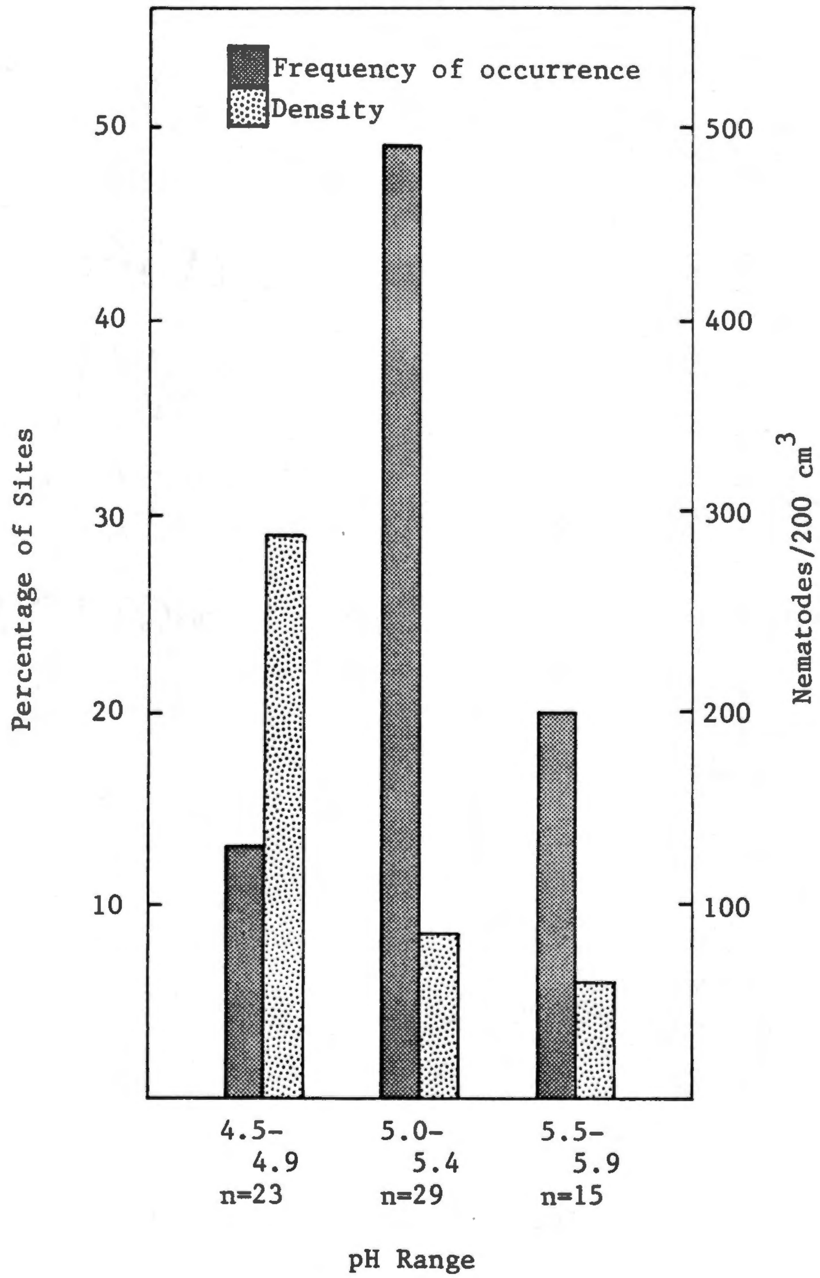

Fig. 6. Relationship of pH to frequency of occurrence and density of Coslenchus costatus in Tennessee nursery soils.

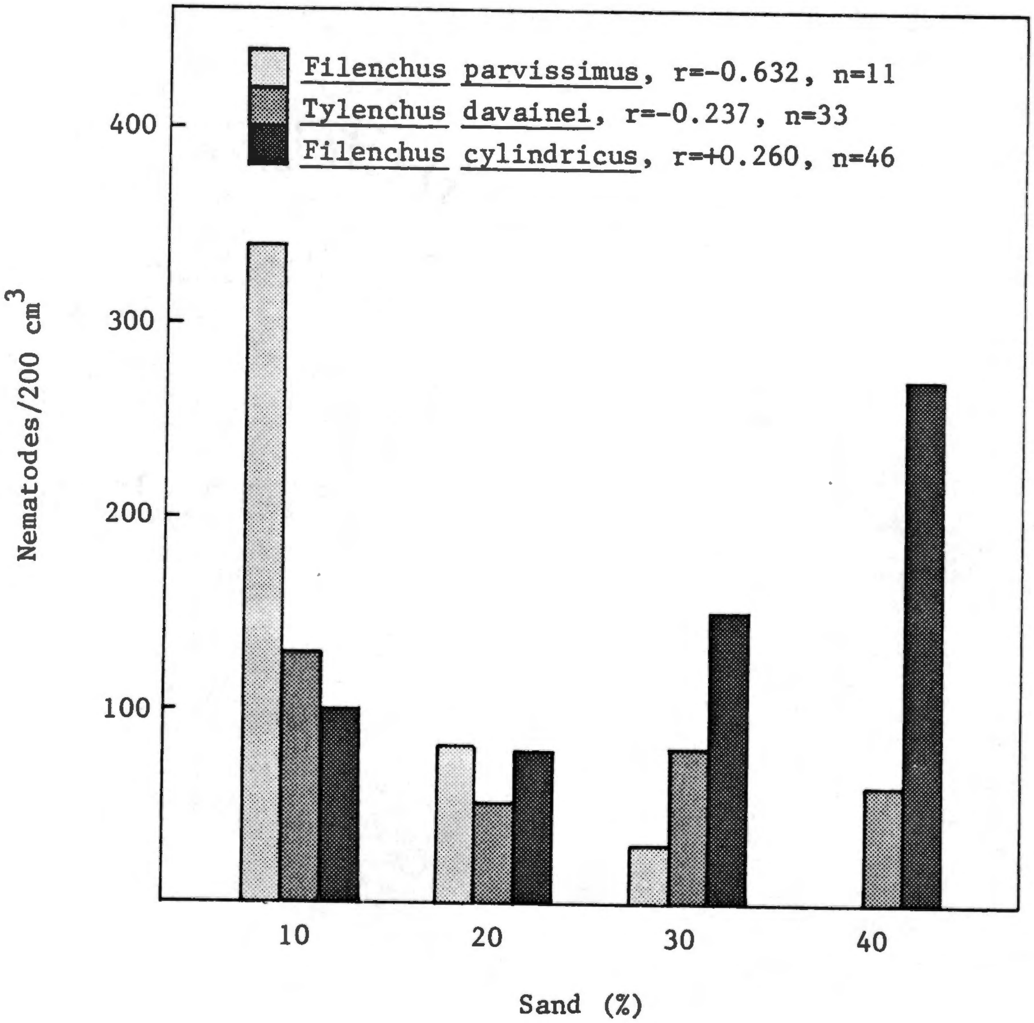

Fig. 7. Relationship between sand content of soils and densities of Filenchus parvissimus, Tylenchus davainei, and Filenchus cylindricus in Tennessee nursery soils.

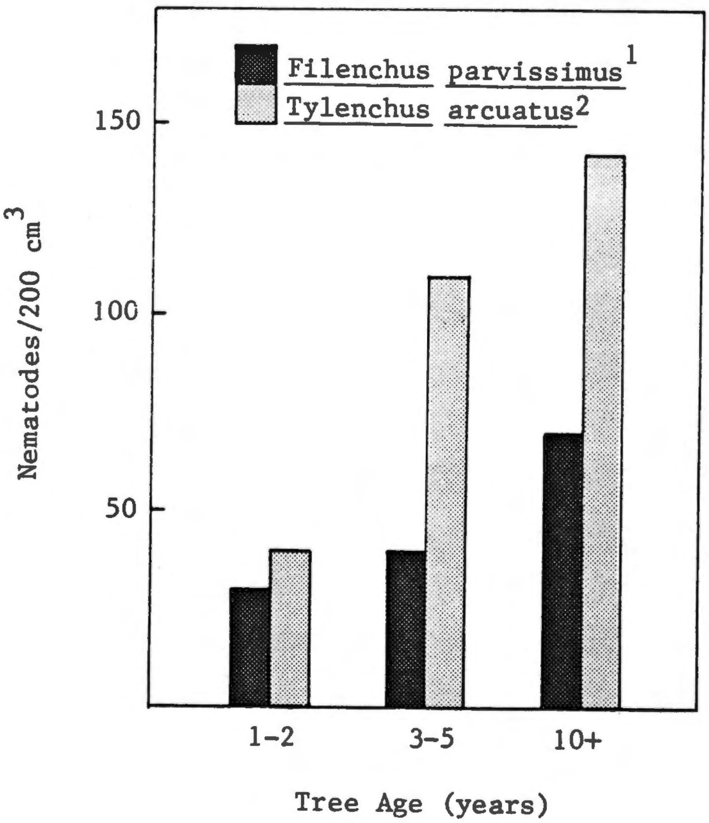

Fig. 8. Densities of _Filenchus parvissimus_ and _Tylenchus arcuatus_ in soil samples from dogwood and maple sites of three age classes.

[1] r=+0.420, n=11

[2] r=+0.523, n=10

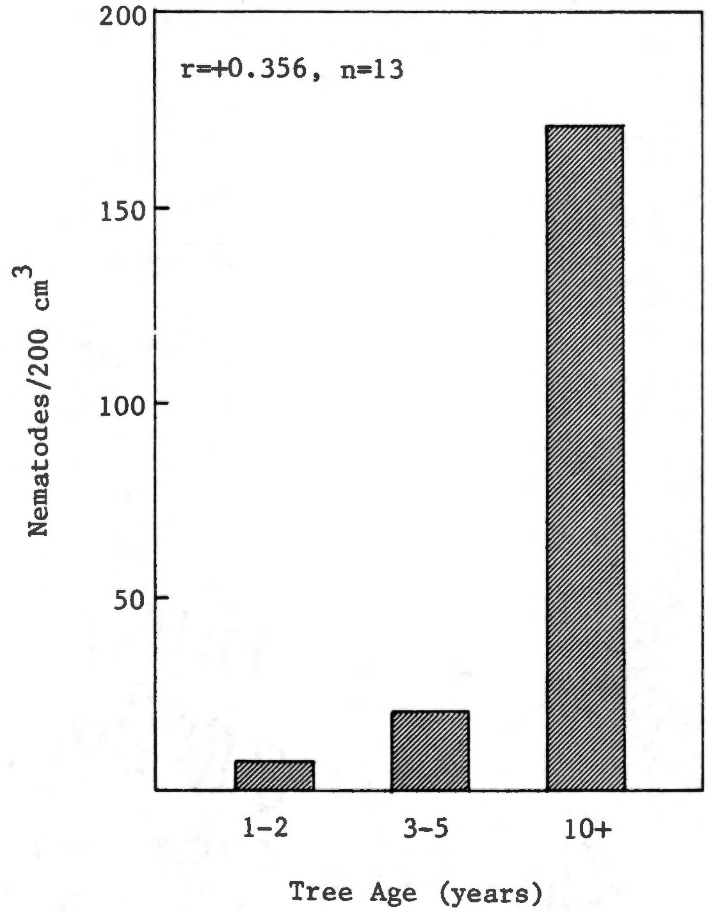

Fig. 9. Densities of Gracilacus aculenta in soil samples from dogwood and maple sites of three age classes.

maple sites. The other two were H. crassatus, a new state record found in a dogwood site, and H. ?platyurus, also found in a dogwood site and found previously in Tennessee associated with woody ornamentals, turf, and commercial vegetables (Bernard, 1980); only one specimen was found in this survey, and thus identification is tentative. A third U. S. record was made when H. paraplatyurus was found; it occurred in 14 sites equally distributed among all three tree species. H. dihystera was found in 17 sites and H. pseudorobustus in 49, the former only in dogwood and maple, and the latter in peach as well. Two or more Helicotylenchus species commonly occurred in the same site.

In this study, the name H. pseudorobustus was applied to populations which were highly variable morphologically. Several collections clearly were named correctly according to Sher's (1966) redescription, while other collections made early in this study could be separated from this species by one or more morphological characters, especially tail shape and stylet length. However, as more collections were made, clines became apparent in each character among the collections. Sher noted morphological variation among and within populations, but considered it best not to describe even a distinct population from Nigeria as a new species before further studies could be made. The variants observed in this study were therefore considered to be variants of H. pseudorobustus as they generally fit the species circumscription.

Correlations were found between H. dihystera densities and bulk density, r=+0.379 (n=17), and between H. pseudorobustus and tree age in dogwood sites, r=+0.324 (n=23) (Fig. 10). Both species were distributed among several soil pH classes, and both attained their high-

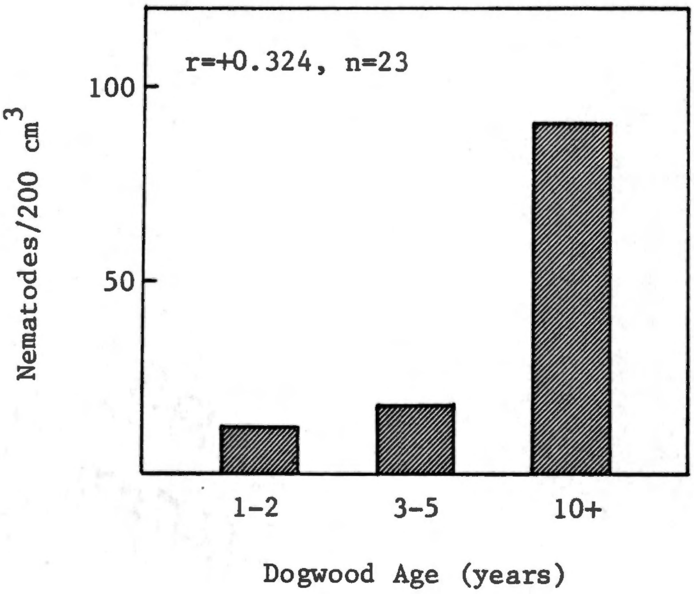

Fig. 10. Densities of Helicotylenchus pseudorobustus in soil samples from dogwood sites of three age classes.

est densities in sites with a pH between 4.5 and 4.9 (Figs. 11 and 12).

Hoplolaimus. H. galeatus was found in 13 sites, in blocks of each tree species. Densities were generally low, from two to 100/200 cm^3 soil, with a mean density of less than ten. Densities were higher in sites with a pH between 4.5 and 6.0 than in those with a higher pH (Fig. 13). Densities were correlated with percent organic matter, r=+0.326 (Fig. 14).

Macroposthonia. M. xenoplax is a known peach parasite, but was found often in dogwood sites, for a total of 11 collections. Densities were very low in all sites (Table 5), and were not found to correlate with any of the variables studied.

Meloidogyne. M. hapla, also a peach parasite, was found proportionally less often in peach blocks (2 sites) than in dogwood or maple blocks (19 sites). Furthermore, juvenile densities per 200 cm^3 were higher in dogwood (18.9) and maple (42.2) than in peach sites (3.6). In all sites, however, at least three times as many juveniles were extracted in March and October than in July (Table 5). The same was found for M. incognita, which was collected in one dogwood site, and which is the only known nematode parasite of dogwood.

Densities of M. hapla were correlated with tree age in maple sites, r=+0.615 (n=8). Densities of this species were highest in soils with a pH in the range 5.0 to 5.4, but it was found more frequently in sites with a lower pH (Fig. 15).

Merlinius. M. brevidens was found in 10 sites: six dogwood and four maple. It was found in only three nurseries, however, none of which

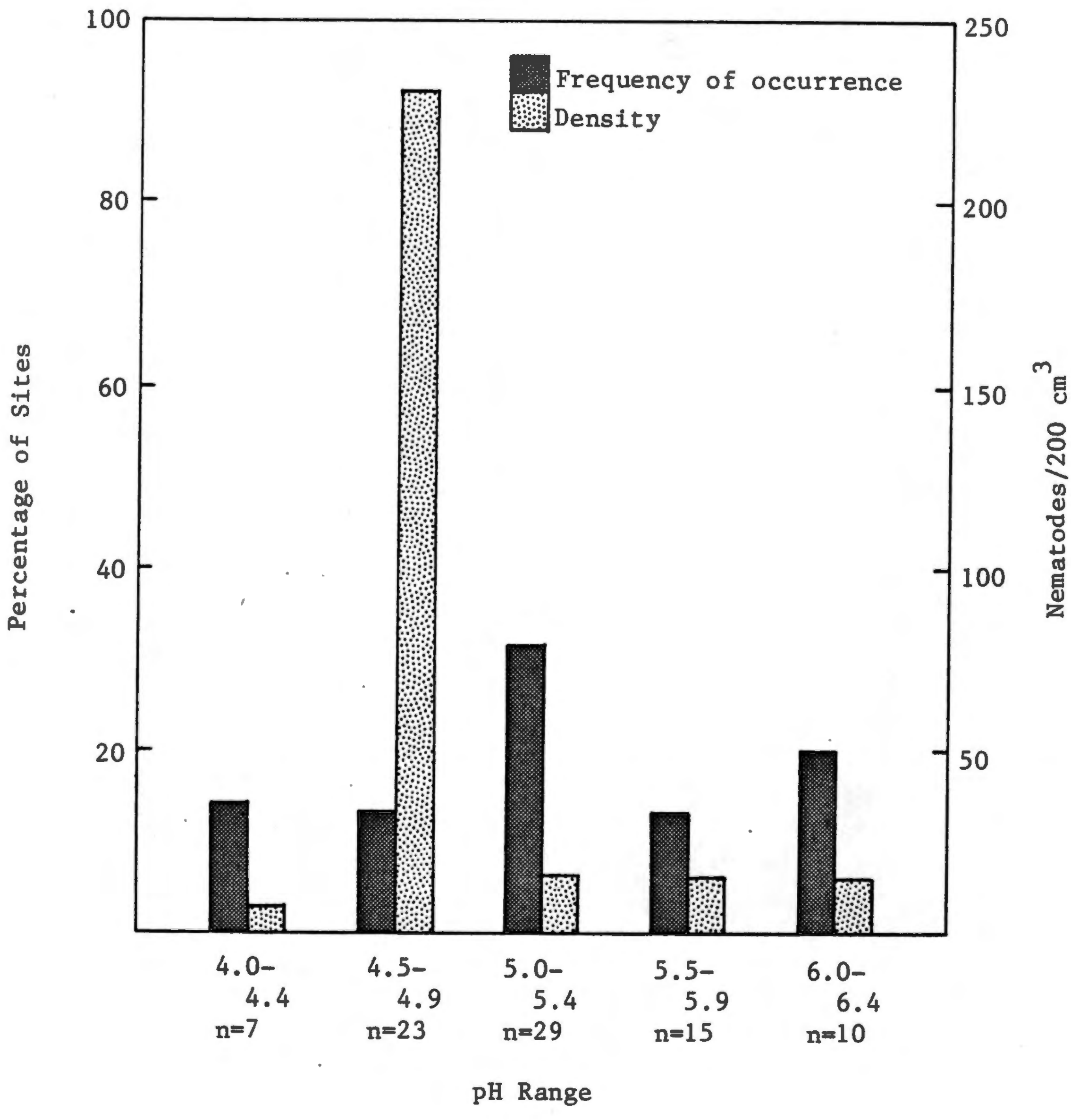

Fig. 11. Relationship of pH to frequency of occurrence and density of Helicotylenchus dihystera in Tennessee nursery soils.

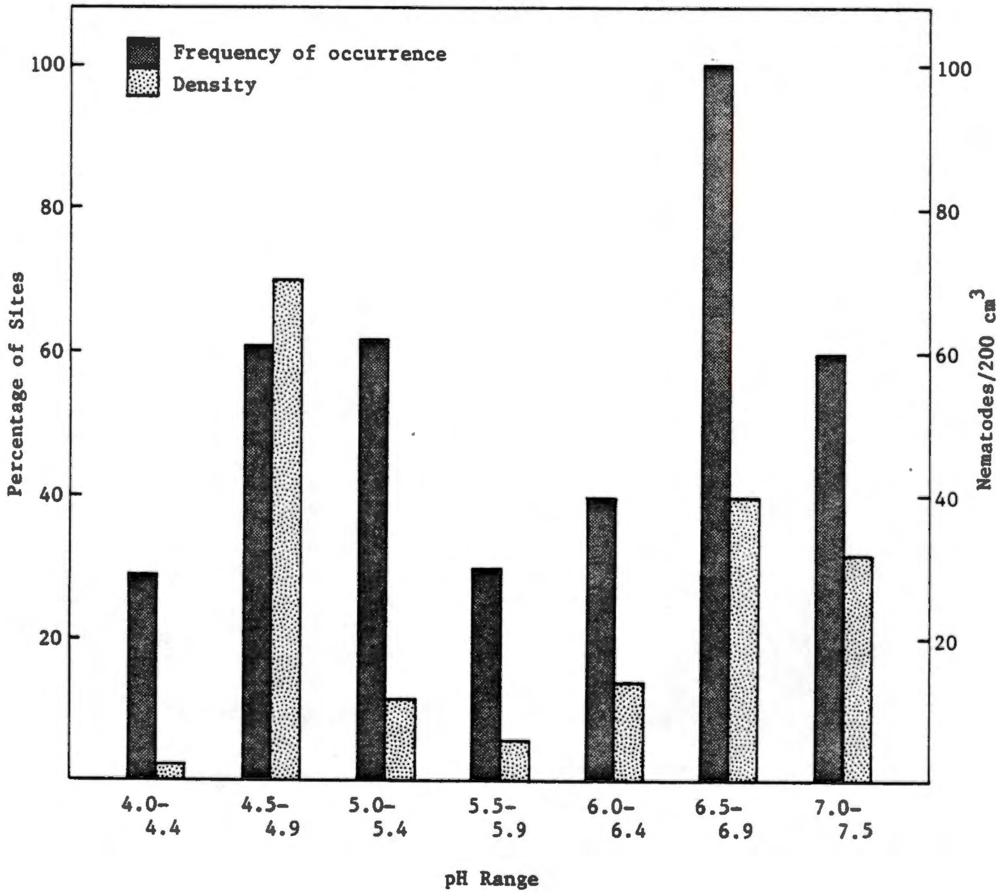

Fig. 12. Relationship of pH to frequency of occurrence and density of Helicotylenchus pseudorobustus in Tennessee nursery soils.

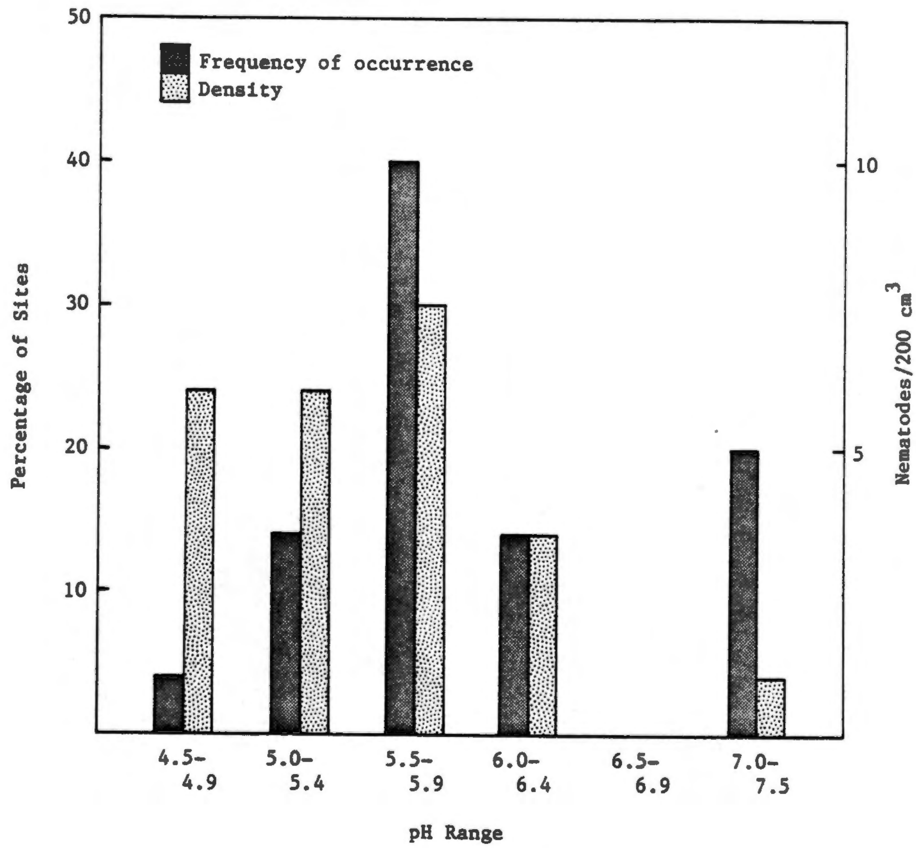

Fig. 13. Relationship of pH to frequency of occurrence and density of *Hoplolaimus galeatus* in Tennessee nursery soils.

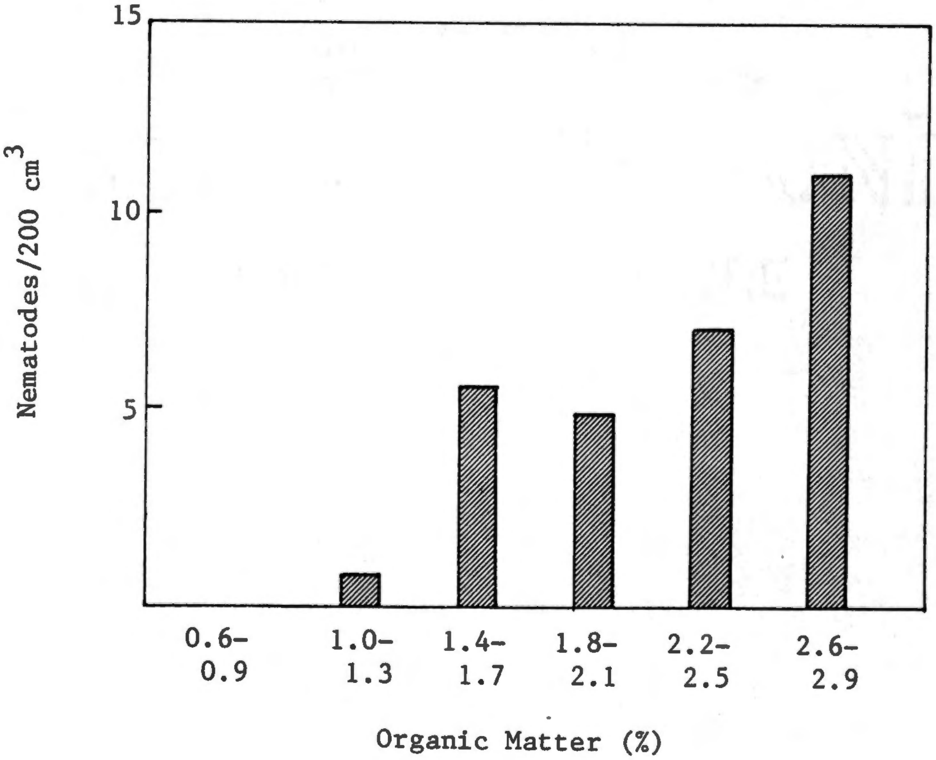

Fig. 14. Relationship between organic matter and *Hoplolaimus galeatus* in Tennessee nursery soils.

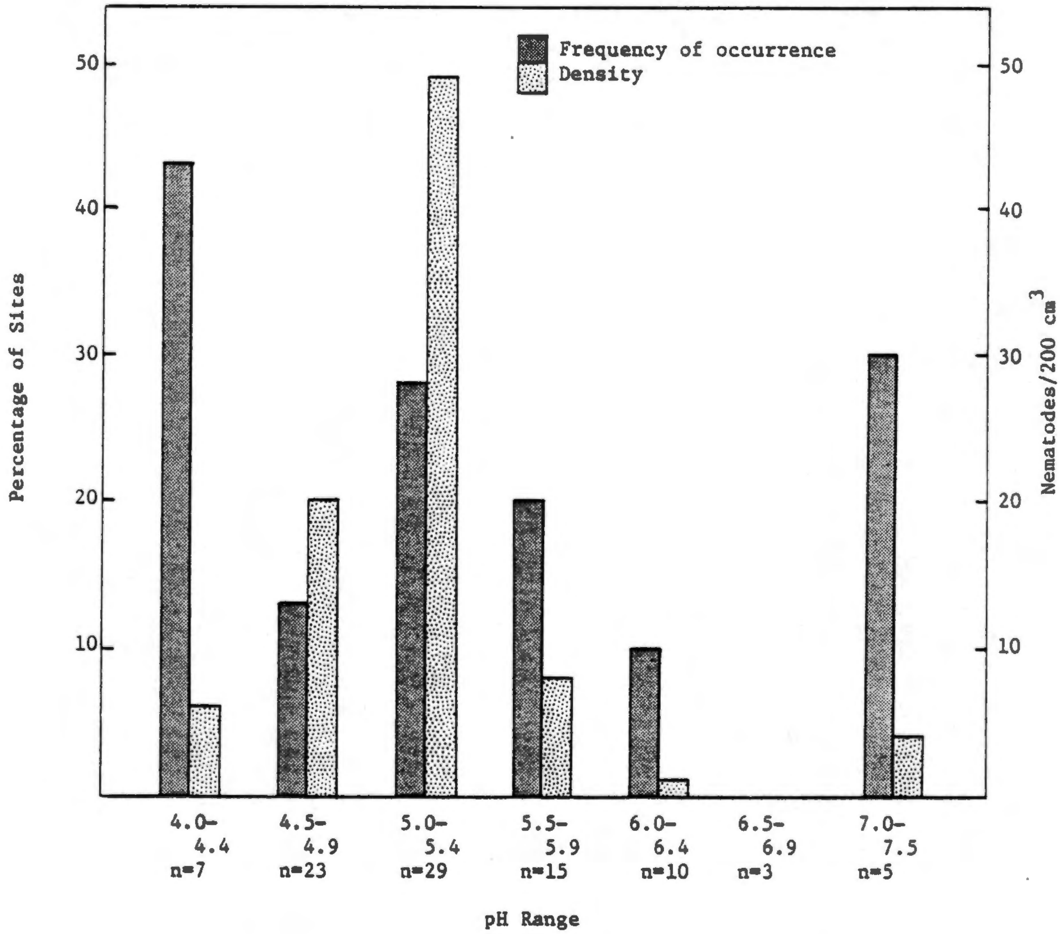

Fig. 15. Relationship of pH to frequency of occurrence and density of Meloidogyne hapla in Tennessee nursery soils.

had peach sites. Densities were uniformly low, with means of less than 50/200 cm^3 (Table 5), and were not correlated significantly with other variables.

Paratylenchus. P. projectus was the most frequently found species among the sites sampled. It occurred in 81 of the 92 at a mean density of 162/200 cm^3 soil, with densities at individual sites of two to 5043. Adult females were rare in March samples and only slightly more frequent in the July and October samples; the ratio of adults to juveniles in July was about 1:100.

Densities of P. projectus were correlated with percent weed cover and number of weed species for all sites, r=+0.292 and +0.335, respectively. Densities were also positively correlated with tree age in dogwood and maple sites (n=75), r=+0.275 (Fig. 16).

Pratylenchus. Seven species of Pratylenchus were found, of which only P. scribneri was found in more than 10% of the sites sampled. P. hexincisus was a new nematode record for the state, and was found in one maple site. P. crenatus and P. neglectus were extracted from two sites each, the former from dogwood and peach and the latter from dogwood and maple. P. penetrans, a known peach parasite, was found twice in peach sites, twice in maple sites, and once in a dogwood site; however, its highest density was in a peach site. P. vulnus, another known peach parasite, was extracted from eight samples, but not from peach. P. zeae was found in six sites: one peach, two maple, and three dogwood. Mean densities given in Table 5 were for nematodes extracted from soil samples which may have contained root segments, and the numbers of these endo-

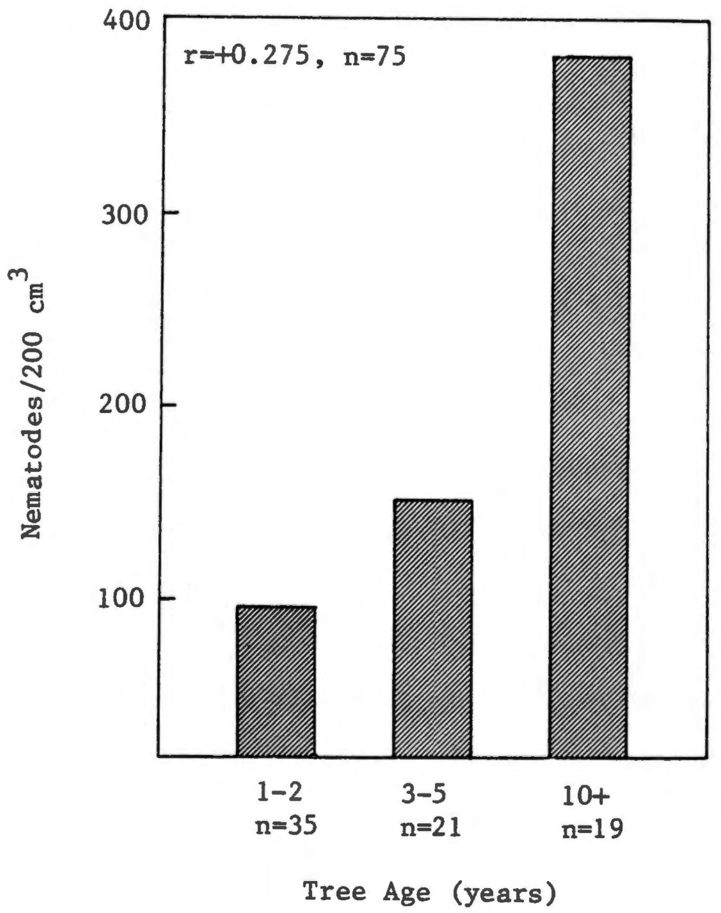

Fig. 16. Densities of Paratylenchus projectus in soil samples from dogwood and maple sites of three age classes.

parasites may or may not reflect numbers within roots.

Tylenchorhynchus. T. claytoni occurred in 14 sites: one peach, seven maple, and six dogwood sites. It is a known parasite of both maple and peach, and its highest density of 1072/200 cm^3 soil occurred in the peach site in the October sample. This species occurred most frequently and in highest densities in soils with a pH between 4.5 and 4.9 (Fig. 17). T. maximus was collected from five sites: one peach, one maple, and three dogwood.

Xiphinema. X. americanum was the only species found, but was the second most commonly extracted plant parasitic species in the nurseries. It occurred in 72 sites, proportionally equally in dogwood, maple, and peach sites. Densities of this species were positively correlated with tree age in dogwood sites (n=48), r=+0.200, and negatively correlated with pH in all sites, r=-0.191 (Figs. 18 and 19).

Genera represented by one or more species occurring in less than 10% of the sites.

Aglenchus. A. agricola was found in four sites, twice each in dogwood and maple. Mean densities were 50 or less per 200 cm^3 for each sampling date. It occurred in nursery blocks with trees five or more years old. Its occurrence constituted a new record for the state.

Aorolaimus. A. helicus was found in three sites in one nursery and one in another, all dogwood sites less than five years old. Mean densities were low for each sample date (Table 5). The species was previously

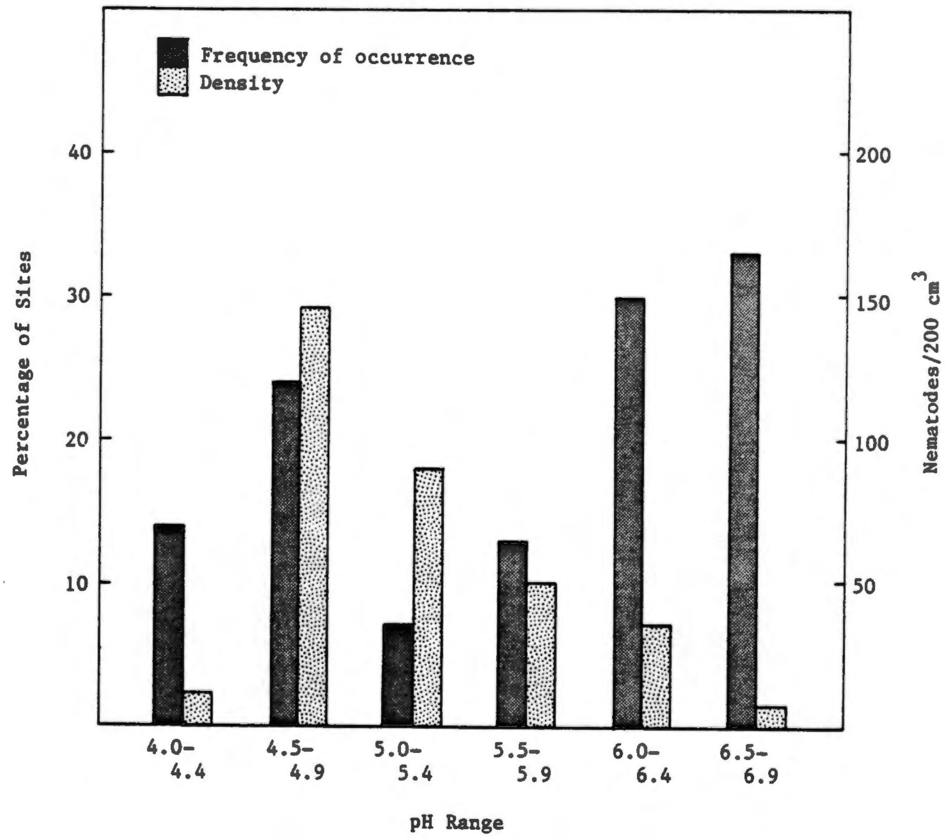

Fig. 17. Relationship of pH to frequency of occurrence and density of <u>Tylenchorhynchus claytoni</u> in Tennessee nursery soils.

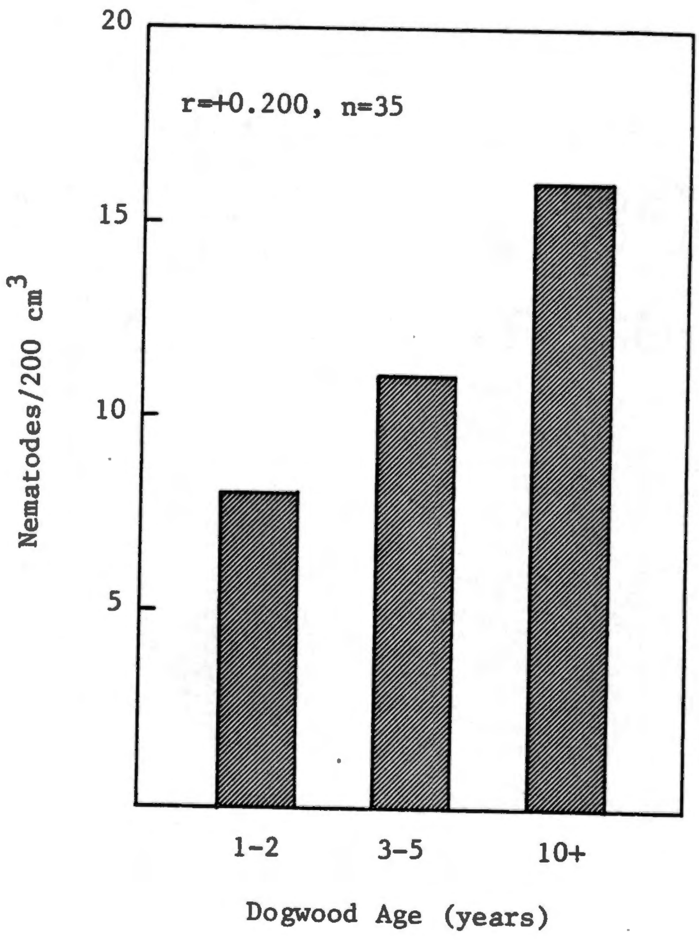

Fig. 18. Densities of *Xiphinema americanum* in soil samples from dogwood sites of three age classes.

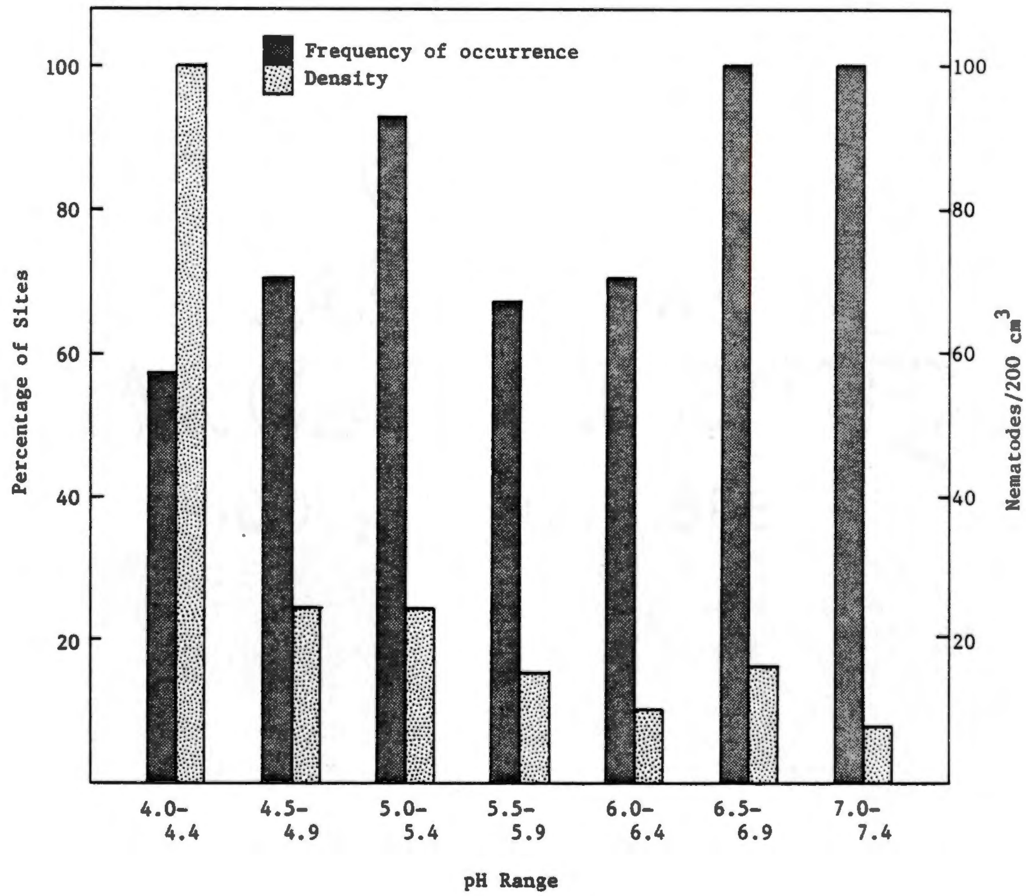

Fig. 19. Relationship of pH to frequency of occurrence and density of *Xiphinema americanum* in Tennessee nursery soils.

reported from field crops in Tennessee (Bernard, 1980).

Basiria. This genus was represented by one unidentified species found in one peach, one maple, and two dogwood sites.

Cephalenchus. One unidentified species was found in large numbers in one five-year old maple block.

Hemicycliophora. Two undescribed species of this genus were found in one ten-year-old maple site. Hemicycliophora sp. 1 occurred in much higher numbers than H. sp. 2, which was not found at all in March or October. A survey of a natural wooded area adjacent to the sample site revealed much higher densities of both species, but with the first still occurring more often than the second at a ratio of about 10:1.

Heterodera. One H. glycines cyst was extracted from a five-year-old dogwood site which had previously been a soybean field (pers. comm. from the nursery general manager). One H. schachtii cyst was extracted from a two-year-old dogwood site containing 5% weed cover. H. lespedezae and H. trifolii were found in two and four sites, respectively.

Nothocriconema. N. demani and N. mutabile were found in low densities, the former once in a ten-year-old maple site, and the latter in one peach and three maple sites.

Paratrichodorus. P. minor is a known maple parasite, and occurred in four maple sites as well as three dogwood sites. Mean densities were low in all samples (Table 5).

Quinisulcius. Q. curvus was found in one maple and three dogwood sites, at low densities (Table 5).

Xenocriconemella. X. macrodora was reported from forest trees, woody ornamentals, and turf associations in Tennessee (Bernard, 1980). In this survey, it was found in two young dogwood sites (one to two years old), but only in March and at a density of 2/200 cm^3 in each site.

Diversity of plant parasitic nematodes in nursery sites

Plant parasitic species occurred in all sites sampled. Measurements of diversity ranged from 0.00 (one plant parasitic species present) to 0.876 (several species present, each represented by similar numbers of individuals). Mean sample diversities were higher for maple sites than for dogwood or peach for all three sampling dates (Fig. 20). Nematodes collected in March comprised the most diverse populations in maple and peach sites, while populations in dogwood sites were more diverse in October. Diversity was least in all sites in July.

Diversity of plant parasites was positively correlated with tree age in dogwood sites (Fig. 21), and with percent weed cover and number of weed species present for all sites (Figs. 22 and 23, respectively).

Species dominance, a measurement of how much one or more species contributes to the total number of individuals present, had an almost perfect negative correlation with diversity; thus, dominance was negatively correlated with percent weeds and number of weed species, r=-0.206 and -0.201, respectively. The only nematode species that was correlated significantly with dominance was Paratylenchus projectus, r=+0.136 (n=81).

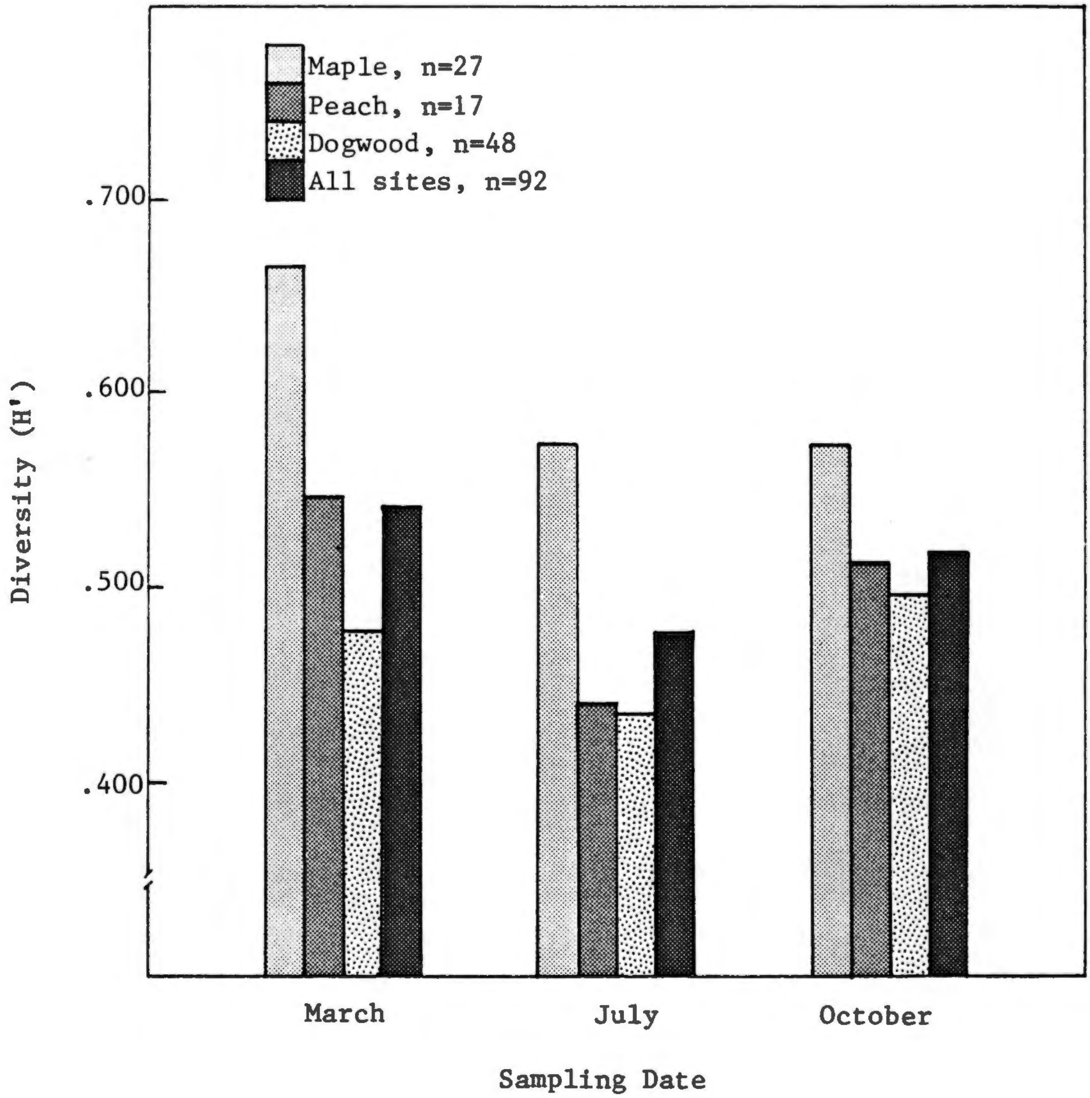

Fig. 20. Diversity of plant parasitic nematode communities in dogwood, maple, and peach nurseries in Tennessee.

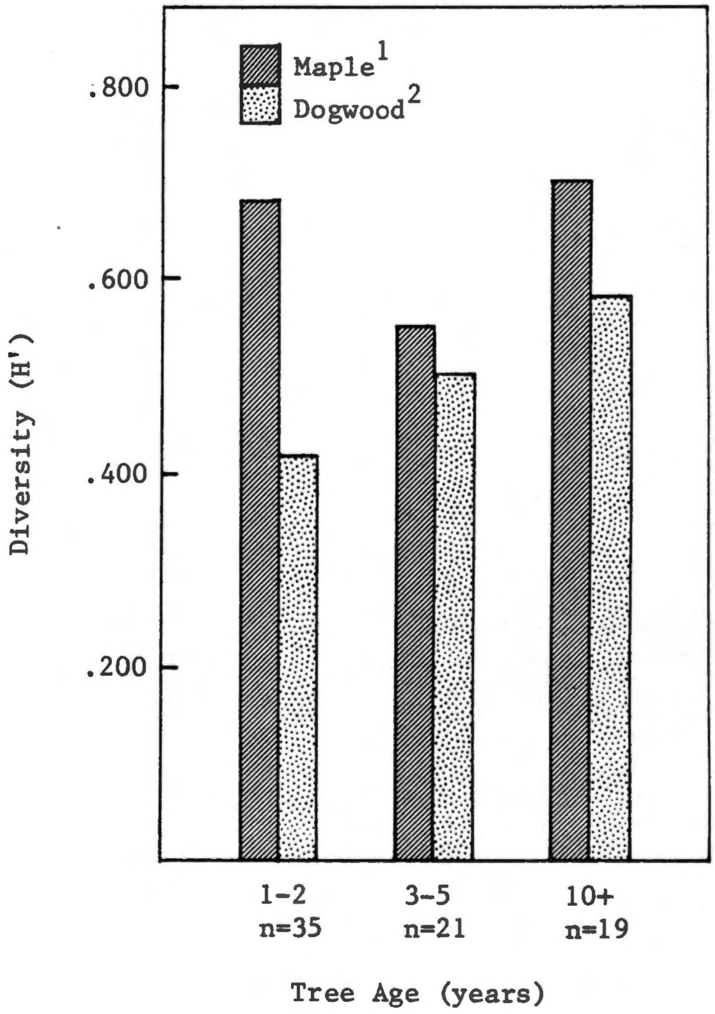

Fig. 21. Relationship of diversity of plant parasitic nematode communities to dogwood and maple tree age classes.

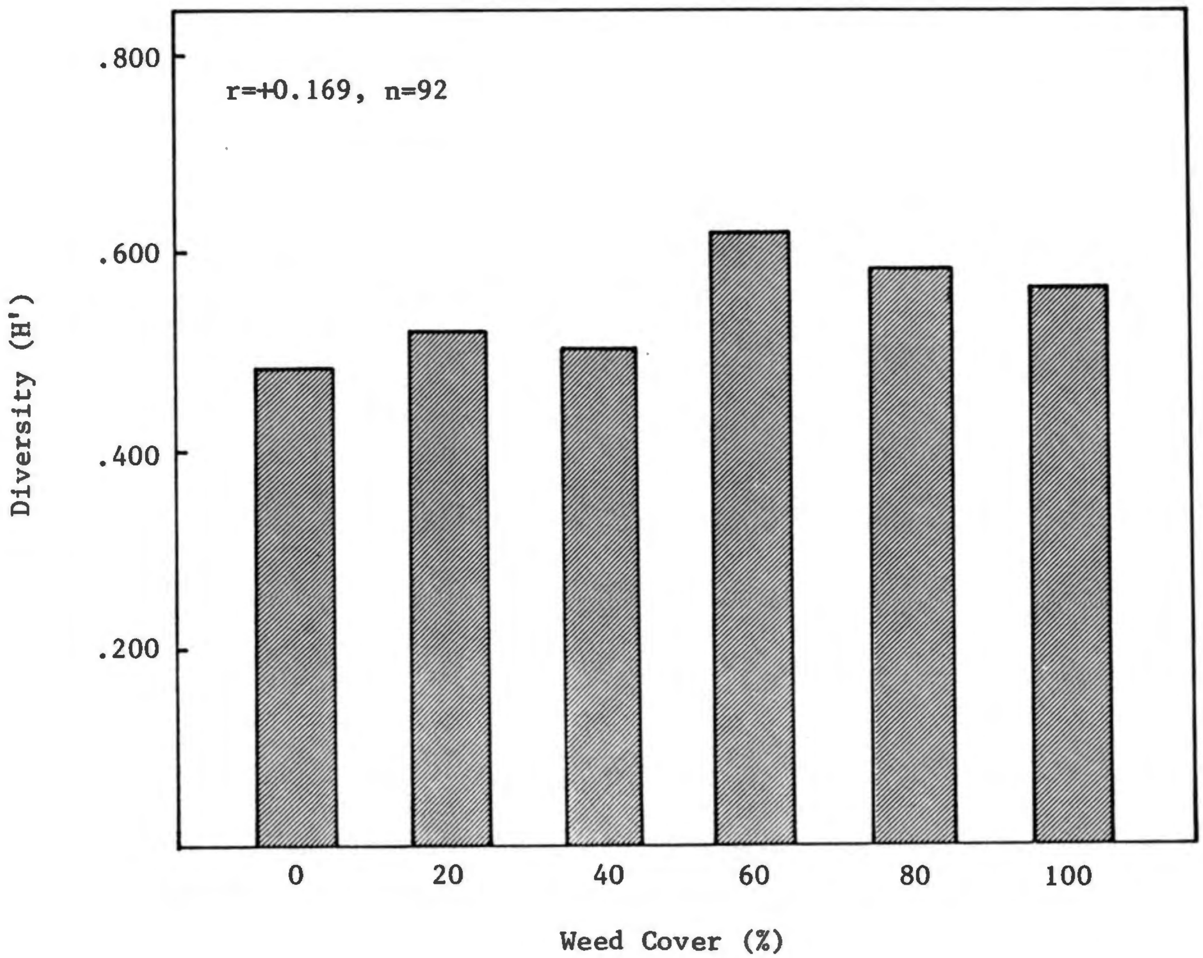

Fig. 22. Relationship of percent weed ground cover to diversity of plant parasitic nematode communities in dogwood, maple, and peach nurseries in Tennessee.

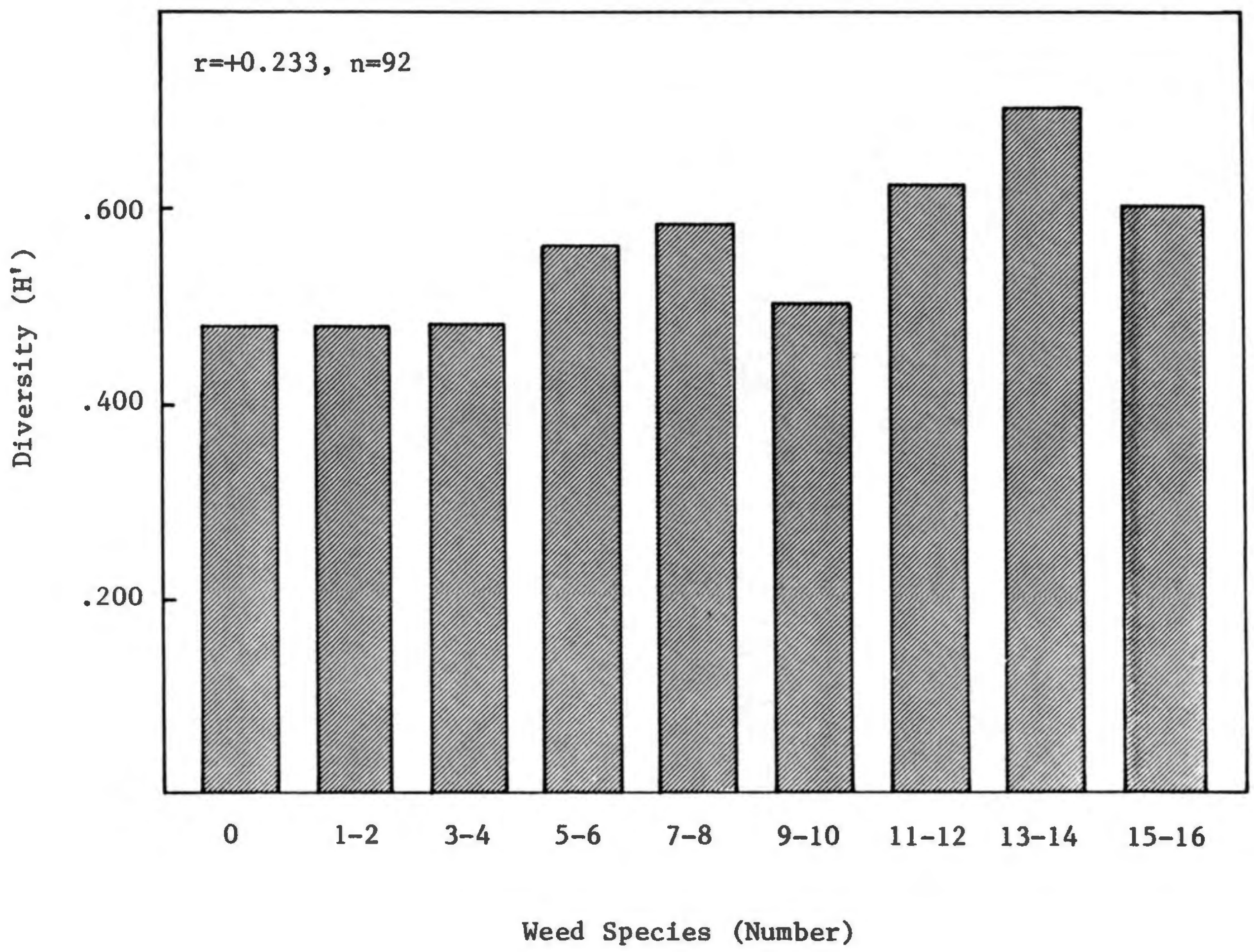

Fig. 23. Relationship of number of weed species present to diversity of plant parasitic nematode communities in dogwood, maple, and peach nurseries in Tennessee.

Ordination of sites based on plant parasitic nematode communities

Site ordination with Beals' (1960) community ordination technique was performed for all sites together, and then separately for dogwood, maple, and peach sites. The ordination of all sites is illustrated in Fig. 24. The low reference site for the X-axis, the site with the least similarity to all other sites, was one which contained only one species: Malenchus sp. The high reference site for the X-axis, the one most dissimilar to the low site, had five species, all of which were frequently found; these included: Filenchus cylindricus, Paratylenchus projectus and Xiphinema americanum. The clustering of sites toward the high end of the X-axis reflects the greater similarity of most sites to the more diverse community of plant parasites of the high reference site. The only factor related to clusters of sites along the X-axis and in the plane of the ordination was that of location, and then only for some sites.

Illustrated in Figs. 25a and b are clusters of sites according to the individual nursery of which the sites were a part. Actual sites within a nursery were in some cases separated by several miles, but were relatively closely spaced in the ordination. Illustrated in Fig. 26 are clusters of sites of several nurseries located in Franklin County, geographically the most distant from the others but not different in the edaphic characteristics or other variables measured.

In Fig. 27, sites containing trees in the 10+ year age class are emphasized. This apparent clustering according to tree age was not borne out when dogwood and maple sites were separated and ordinated. The results of those ordinations are illustrated in Figs. 28 and 29, respectively.

As in the overall ordination (Fig. 24), the sites within the matrix were similar to each other, though spread out somewhat more. However, some of the reference sites for the X- and Y-axes for both the dogwood and the maple ordinations had different soil types from the majority of the sites (73% loams or silt loams). The soil type of the low reference site on the X-axis for dogwood sites (Fig. 28) was a sandy loam and the high reference site was a clay loam. The high reference site for the Y-axis was a silty clay loam. The high reference site for the X-axis for maple sites (Fig. 29) was a clay loam, which the low Y-axis site was a sandy loam. The remaining sites did not cluster according to soil type, but it is significant that the reference sites differed. Sites in neither of these ordinations clustered according to tree age, or any other factor, of those measured.

The cluster in the peach site ordination (Fig. 30) was according to the fumigation history of the site. Four sites had been fumigated with methyl bromide in the previous five years, two of which were reference sites. The other reference sites in this case did not reflect differences in soil type, nor did the remaining sites cluster according to any of the other variables measured.

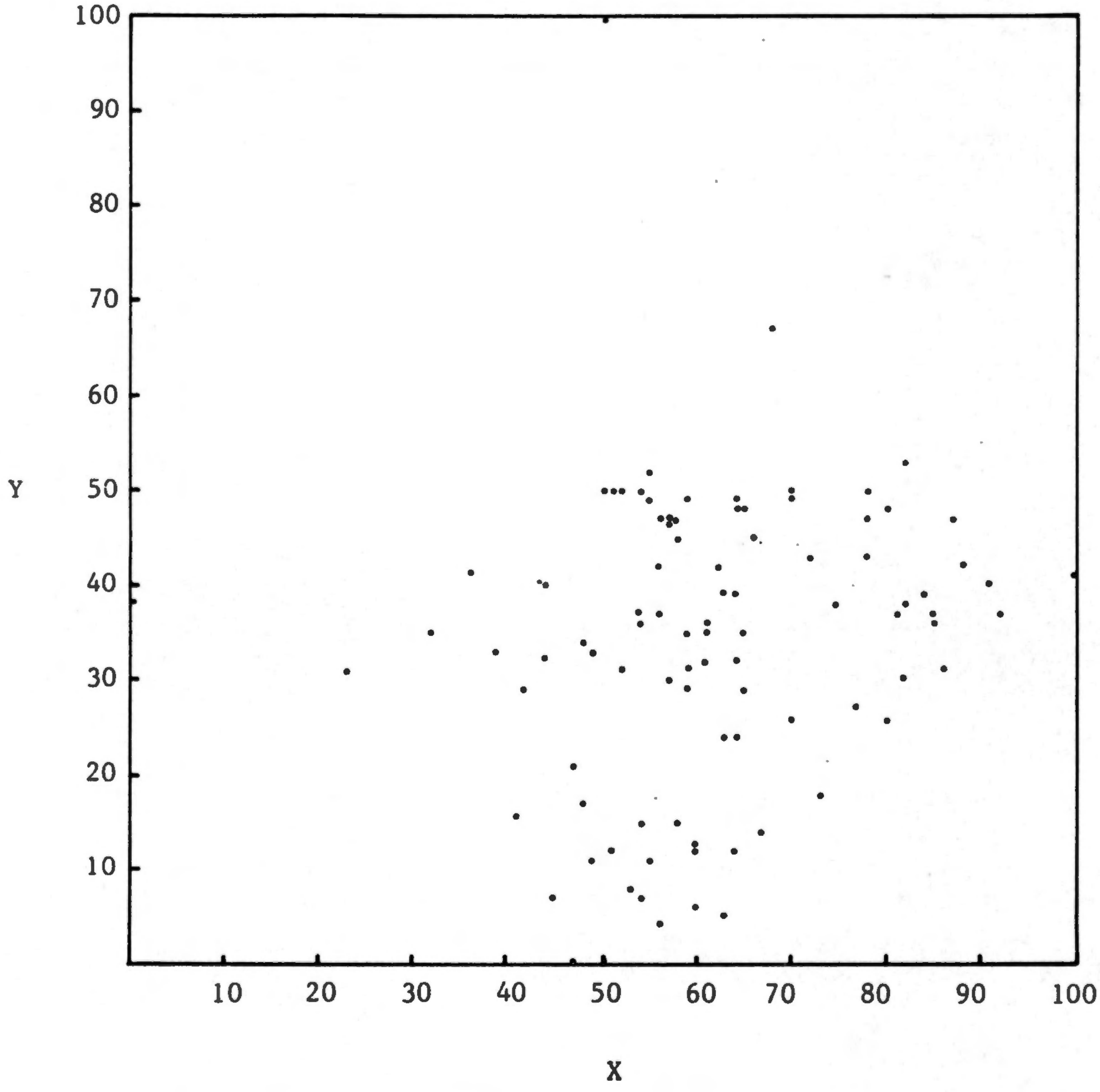

Fig. 24. Ordination of plant parasitic nematode communities in dogwood, maple, and peach nurseries in Tennessee.

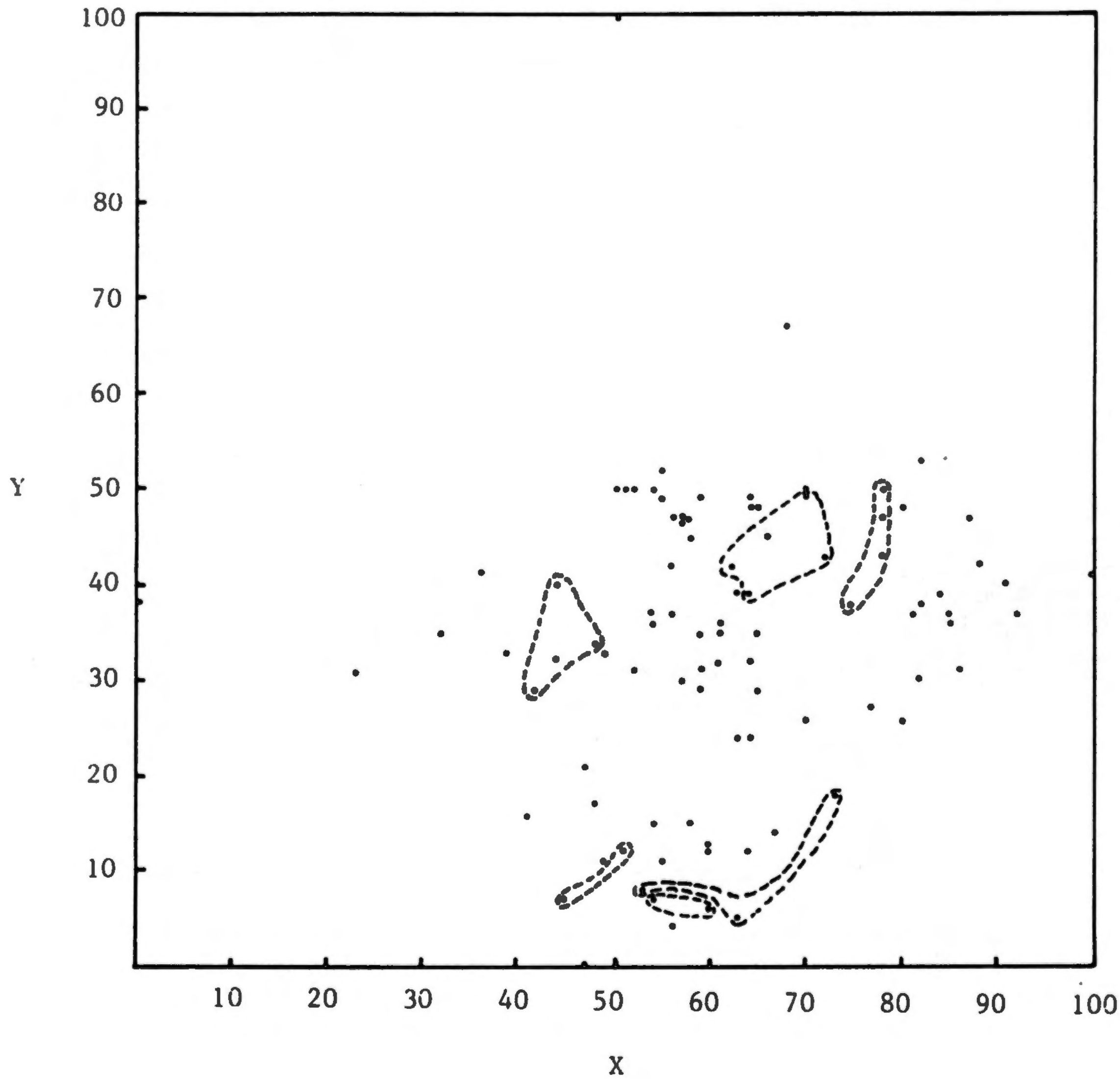

Fig. 25a. Ordination of plant parasitic nematode communities in dogwood, maple, and peach nursery sites. Each outline includes all sites within an individual nursery.

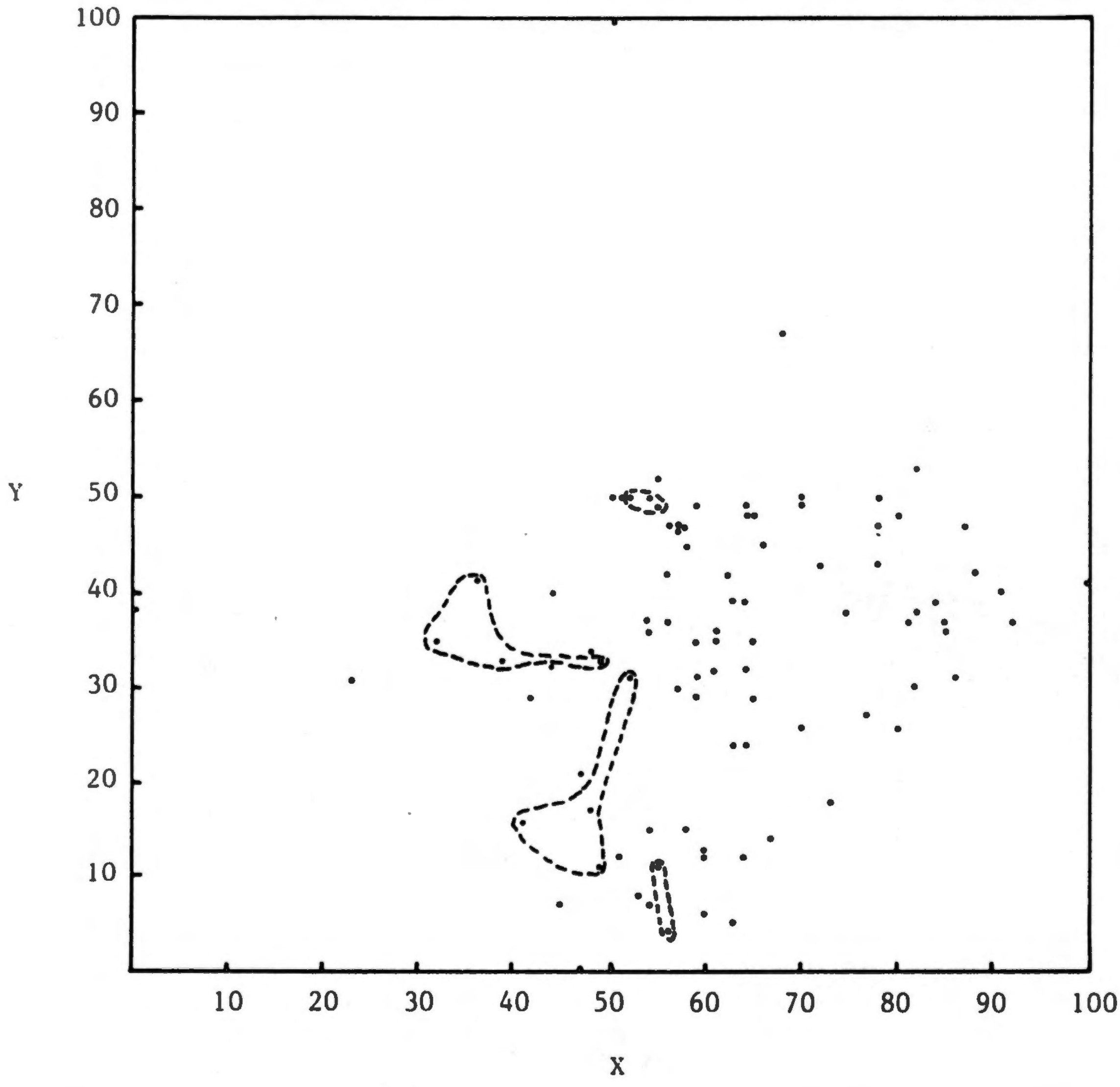

Fig. 25b. Ordination of plant parasitic nematode communities in dogwood, maple, and peach nursery sites. Each outline includes all sites in an individual nursery.

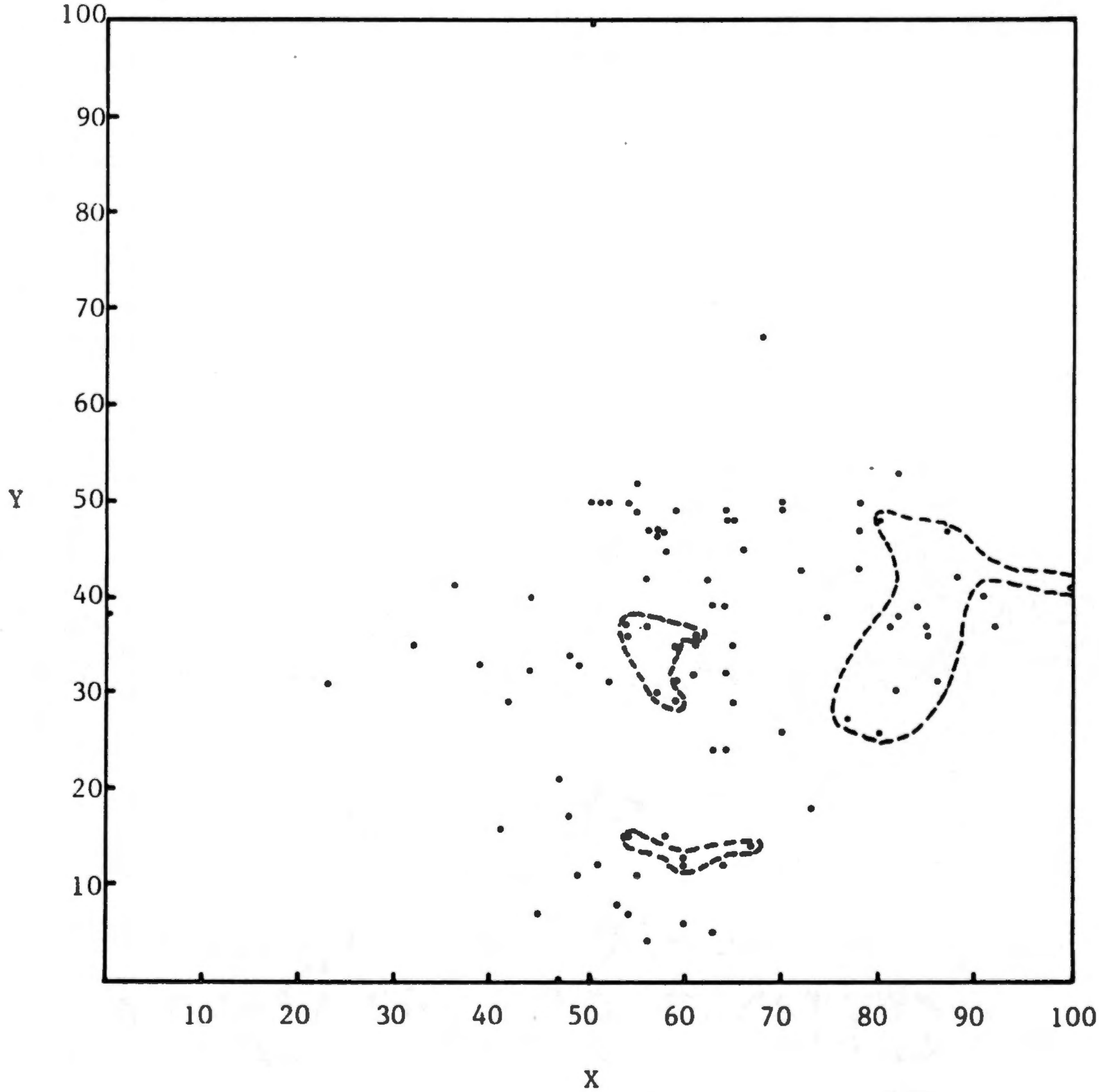

Fig. 26. Ordination of plant parasitic nematode communities in dogwood, maple, and peach nurseries in Franklin County.

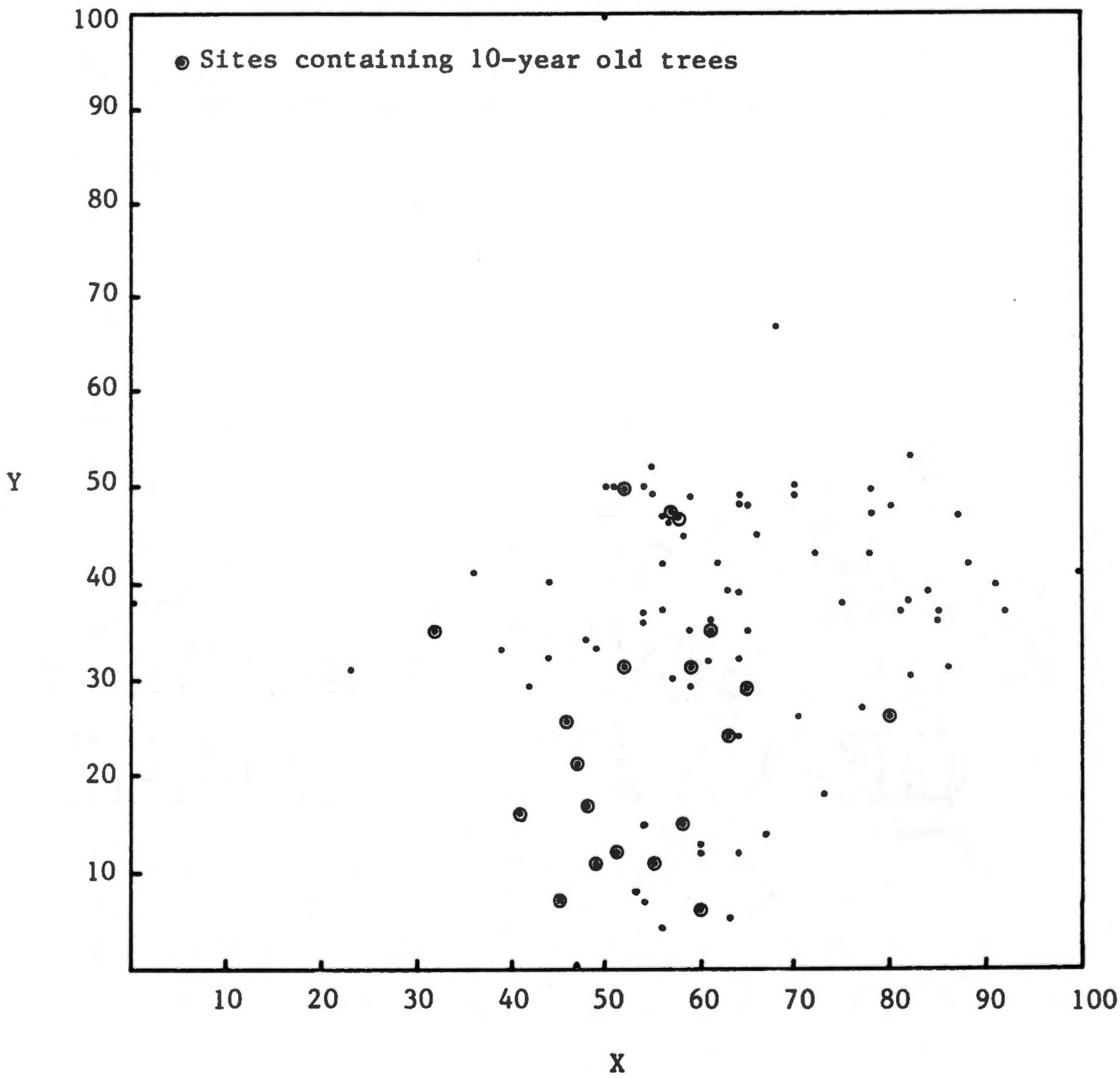

Fig. 27. Ordination of plant parasitic nematode communities in dogwood, maple, and peach nursery sites, with clustering of sites containing 10-year-old trees.

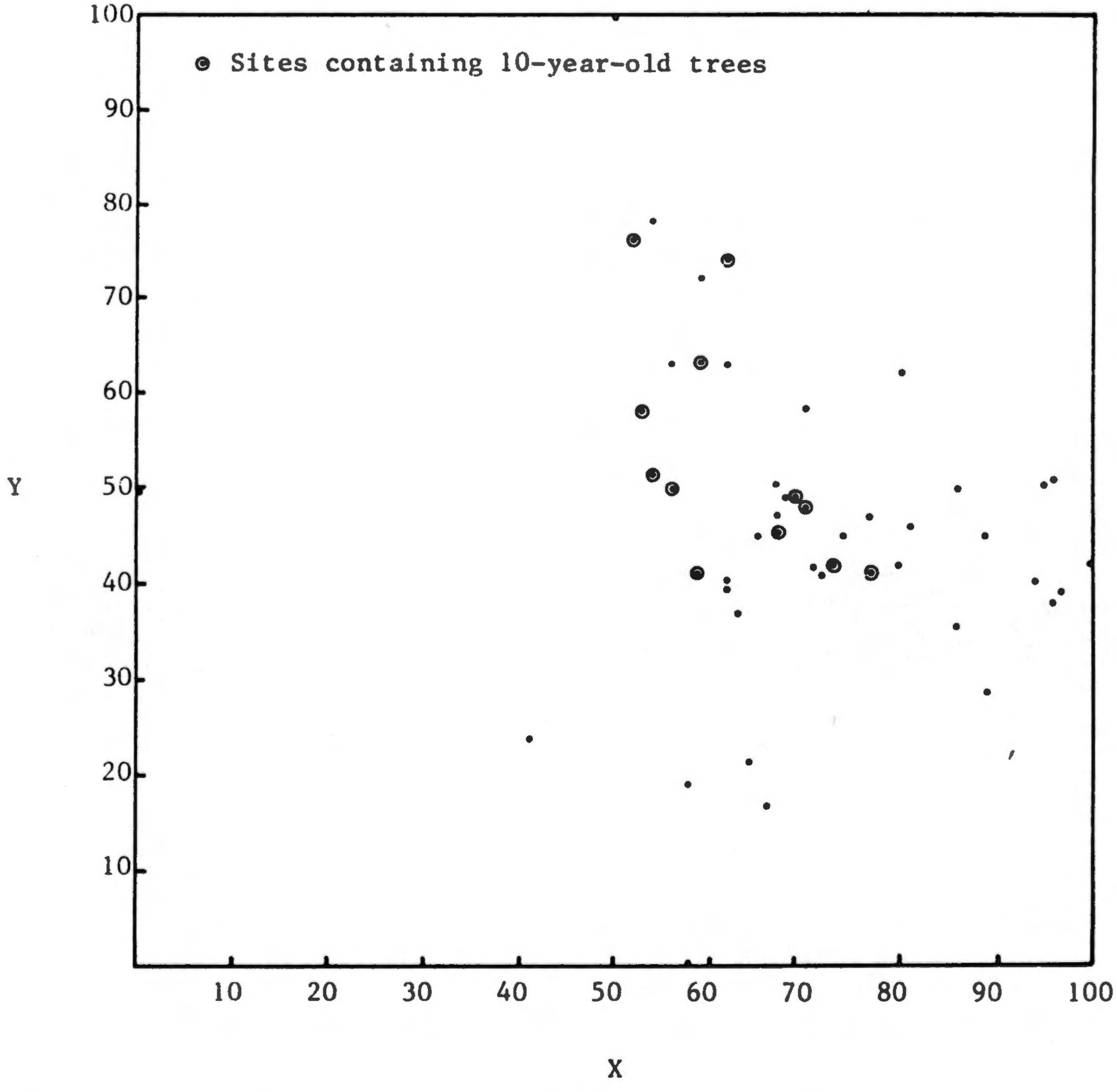

Fig. 28. Ordination of plant parasitic communities in dogwood nursery sites.

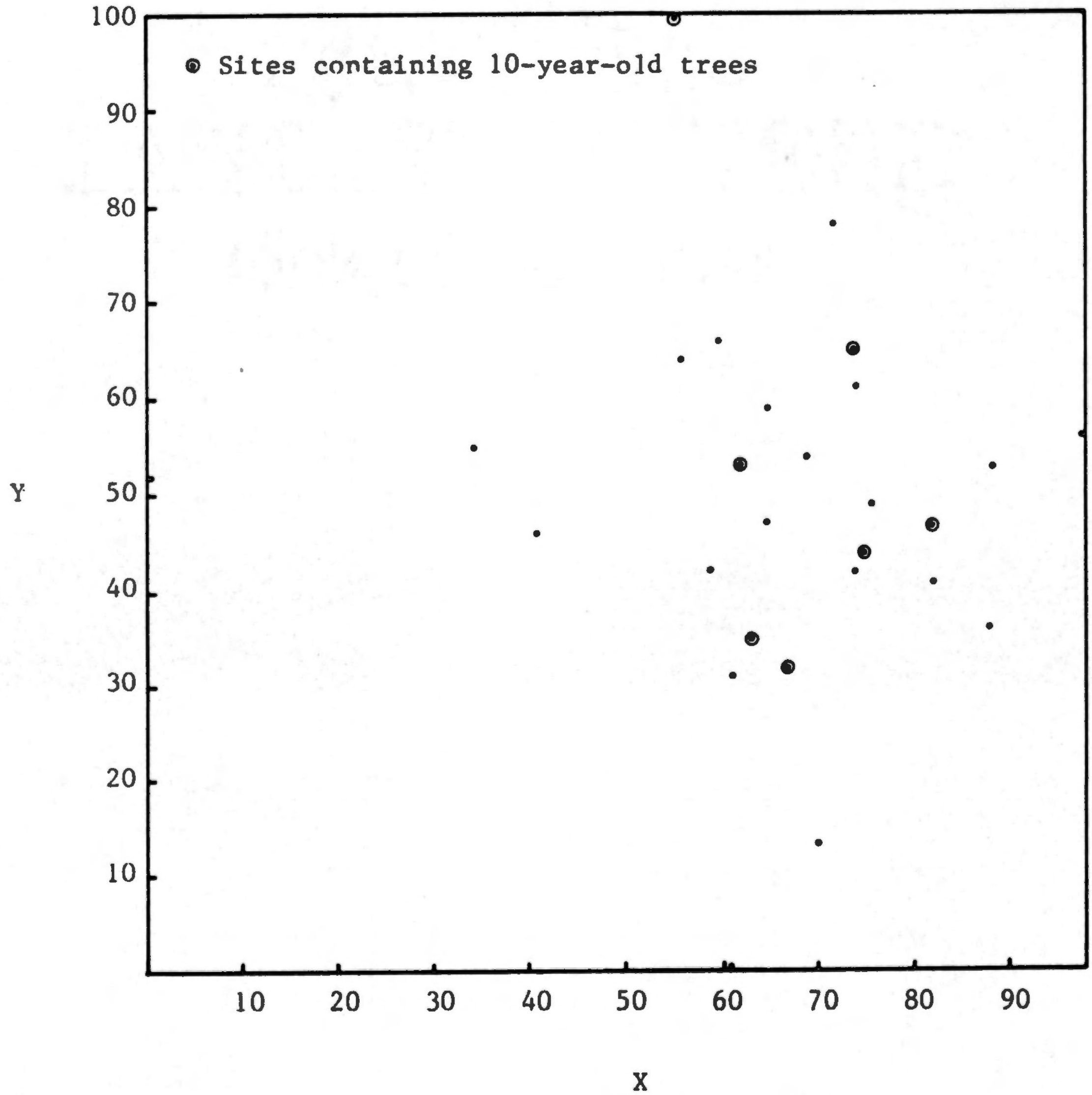

Fig. 29. Ordination of plant parasitic communities in maple nusery sites.

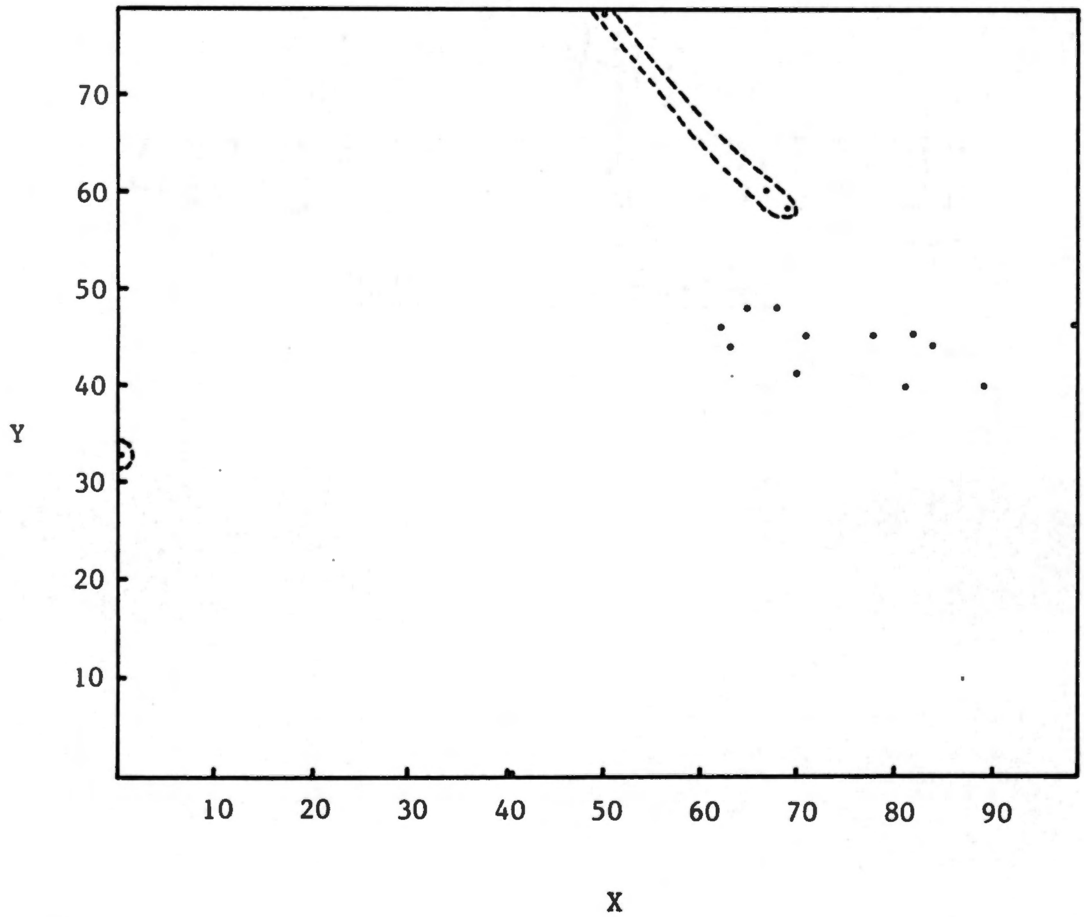

Fig. 30. Ordination of plant parasitic communities in peach nursery sites. Outlined sites were fumigated within the last five years.

CHAPTER V

DISCUSSION

I. TROPHIC GROUP STRUCTURE OF NEMATODE COMMUNITIES IN NURSERY SITES

As with the patterns found in natural wooded areas (Ferris and Ferris, 1974; Yeates, 1979), total nematode densities were higher in spring (March) and fall (October). The microbivorous group predominated on all three sampling dates. The monocultural aspect of the nurseries, their major characteristic in common with agricultural ecosystems, was evidenced by the high position of the plant parasitic group and the low position of the omnivorous group relative to the others (Fig. 2). Johnson *et al.* (1974) surveyed 18 Indiana hardwood stands and found that one site, which had been cut over and allowed to grow back an even-aged stand of black locust, differed from the others in having a higher percentage of tylechid nematodes (=plant parasites) and a lower percentage of Dorylaimida (=omnivores, excluding the plant parasites *Xiphinema* and *Paratrichodorus*). They considered the dorylaimids valuable as indicators of ecological change, as the less disturbed sites had greater numbers and more diverse dorylaimid fauna. In the sampled Tennessee nursery sites, the numbers and percentages of omnivores found were low (Table 3), but correlations between tree age and both absolute and relative density of omnivores ($r=+0.450$ in dogwood and $+0.317$ in maple sites) support the hypothesis that omnivores increase with increasing time from the time of major disturbance (in this case, planting). The means for omnivore densities in peach sites further support this; the low means for dogwood and maple sites can be partly explained by the large percentage (46%) of 1-2 year-old tree sites included in those means.

The third-ranked group, the fungivores (Fig. 2), attained their highest relative position in the spring in all sites, but large increases in the numbers of Aphelenchoidea in peach sites by October resulted in a reversal of this group's position with that of plant parasites (Table 3). Another reversal occurred in March in peach sites, when densities of the fungivores were lower than densities of plant parasites although their mean percentage was higher. The absolute and relative densities of the fungivores in peach sites represented the only significant deviation from the trophic group structure illustrated in Fig. 2. Peach trees grown in these nurseries remain in the field only one or two years, and are cultivated more often than are dogwood and maple sites. The difference in fungivore populations may be a reflection of the more frequent site disturbance.

The group containing the smallest absolute and relative densities were the predators (Table 3). Predators occurred in higher numbers and percentages in March than on other dates and were consistently the least numerous group in all sites.

Factors affecting trophic group structure

Johnson *et al*. (1973) found that when all nematode orders found in 18 hardwood sites were combined for analysis of site similarity by community ordination, the resulting positions of sites on the ordination could not be correlated with any of the physical or floristic variables they measured. Because the orders represented diverse trophic groups, they concluded that trophic groups do not respond similarly to the same environmental influences. After studying the nematode community structure of alfalfa stands, Wasilewska (1967) suggested that reciprocal interactions occurred among trophic groups, because the percentages of these groups were similar in several habitats but the absolute densities were highly variable (Ferris and Ferris, 1974). This is another way of approaching the contention of Johnson _et al_. (1973) that trophic groups do not respond similarly to the same environmental conditions. In this study, positive correlations were found for total nematodes with percent weed cover ($r=+0.371$) and number of weed species ($r=+0.458$); contributing to the increase were not only numbers of plant parasites, as expected, but also numbers of both microbivores ($r=+0.310$ and $+0.376$) and omnivores ($r=+0.360$ and $+0.420$). The negative correlation with percent weed cover and number of weed species with percentages of microbivores ($r=-0.250$ and -0.258) despite the positive one with densities, could reflect a reciprocal interaction connected indirectly to the diversity of ground cover. Kimpinski and Welch (1971) studied nematode communities in Manitoba soils, and attributed differences in nematode numbers to differences in the amount of plant material, regardless of trophic group.

As previously discussed, tree age in dogwood and maple sites was positively correlated with number and percentages of plant parasites, while in dogwood sites, microbivores and fungivores were negatively correlated with tree age (Fig. 4), along with total nematode density (Fig. 3). Wasilewska (1967) found a similar association with nematode abundance and age of alfalfa, and with plant succession in forested sand dunes

(1971). In the latter sudy, however, she found a decrease in the densities of omnivores over time. Her results in this case were different from those of Johnson et al. (1974), and those reported herein.

The positive correlations between numbers of omnivores and percent sand (r=+0.137) and bulk density (r=+0.140), respectively, are outwardly contradictory if either is used as a reflection of pore space. Though the percentage of sand had a wide range, bulk density did not, and therefore the latter correlation may be a result of sample error. The same may be true for the correlation between predator numbers and organic matter, measurements for which fell in the narrow range between 0.70 and 2.79%.

Conclusions

Ferris and Ferris (1974) suggested that perennial crops have some characteristics of both natural and agricultural ecosystems. The data gathered in Tennessee nursery sites and reported herein led to the conclusion that woody perennial crops share certain characteristics in common with natural wooded areas and with monocultured areas in complete nematode community structure. Furthermore, in accordance with the conclusion of Kimpinski and Welch (1971), the diversity of plant material is the main factor affecting numbers of all nematode groups regardless of trophism.

II. PLANT PARASITIC NEMATODE COMMUNITY STRUCTURE IN NURSERY SITES

Parasites of dogwood, maple, and peach

The only known nematode pathogen of dogwood, *Meloidogyne* incognita, was found only once, in a dogwood site. M. hapla was the only root-knot nematode found in peach sites. Pratylenchus vulnus, also a peach parasite, occurred in maple and dogwood sites but not in peach; P. penetrans, however, was found in peach sites as well as dogwood and maple. Other known peach parasites found in peach sites were: Hoplolaimus galeatus, Tylenchorhynchus claytoni, Macroposthonia xenoplax, and Xiphinema americanum. T. claytoni, M. xenoplax, and Paratrichodorus minor, known maple parasites, were found in various maple sites.

All of the above except Meloidogyne incognita were found in three or more sites, and were not limited to associations with trees for which a host-parasite relationship has been established experimentally.

Factors associated with distribution and density of plant parasitic nematodes

pH. Relationships were found between soil pH and the densities of several species (Figs. 6,11,12,14,17, and 19). In general, densities were highest in the range 4.5 to 5.9, even though distributions were not limited to this range except in the case of Coslenchus costatus (Fig. 6). Norton et al. (1971) and Norton and Hoffman (1974) found positive correlations between Helicotylenchus pseudorobustus densities and pH in Iowa soybean fields (pH 6.0-8.0) and woodlands (pH 4.5-7.9), respectively. In both cases, the highest densities were found at the highest pH measured. In the present study, although the species was found in 53% of the sites, including some in every pH class from 4.0 to 7.5, its highest density was in the 4.5-4.9 range (Fig. 11). H. dihystera densities were similar, but its distribution among pH classes was more restricted (Fig. 12).

A negative correlation of pH with densities of *Xiphinema americanum* was found in soybean fields (Norton *et al*., 1971, Fig. 2) and a positive correlation between the two in woodlands (Norton and Hoffman, 1974, Fig. 1-A). Furthermore, in the latter study, the species was not found at all in soils below pH 4.3. In the present study, the highest densities of *X. americanum* were found in soils of 4.0-4.4 pH, and a negative correlation of density with pH over the range 4.0-7.5 (Fig. 19).

Norton *et al*. (1971) also found a negative correlation between *Hoplolaimus galeatus* densities and pH in soybean fields. The data illustrated in Fig. 14 for this species in nursery sites are similar to their results.

Data from other sources for other species found in this study are not available for correlations of pH with density. All the species found exhibited peak populations between 4.5 and 5.9 in nursery sites. This is the optimum range for host nutrition as well as the most common range for Tennessee soils. It appears that the effect is indirect through the host plant, as suggested by Burns (1971) and Brzeski and Dowe (1969).

Other factors. Correlations were found between percent sand and densities of *Filenchus cylindricus*, *F. parvissimus*, and *Tylenchus davainei* (Fig. 7). Norton *et al*. (1971) found higher densities of *Tylenchus* spp. in certain soil types, but no correlation with percentages of sand, silt, or clay. Other species found in this study exhibited no preference for soil type. Wallace (1973) and Norton (1978) both suggested that other soil factors unrelated to soil type were more important in species distribution, although many studies have related species distribution to soil type. In the nurseries studied, soil type does not appear to be an important factor in specific occurrences.

Percent organic matter and densities of Hoplolaimus galeatus were positively correlated (Fig. 13), but conclusions about this relationship are questionable because of the narrow range of organic matter. Bulk density measurements were also narrow in range, and the two correlations found between species densities and this factor do not lend themselves to valid speculation.

Tree age was positively correlated with densities of several species: Filenchus parvissimus and Tylenchus davainei (Fig. 8); Paratylenchus projectus and Gracilacus aculenta (Fig. 9) in both dogwood and maple sites; Helicotylenchus pseudorobustus (Fig. 10) and Xiphinema americanum (Fig. 18) in dogwood sites; and Meloidogyne hapla in maple site. In the cases of G. aculent, H. pseudorobustus, and X. americanum, correlations were not found between nematode densities and percent weed cover, which led to the hypothesis that these species are parasites of the trees with which the relationships were found. The other species were also correlated with percent weed cover, and, except for Filenchus parvissimus and Tylenchus arcuatus, with number of weed species. The wide distribution of H. pseudorobustus (53% of sites) and X. americanum (77% of sites) is probably a reflection of their wide host ranges, as suggested by Norton and Hoffman (1974).

Diversity of plant parasitic nematode communities

The diversity (H') of plant parasites was correlated with percent weed cover and number of weed species (Fig. 22 and 23), but the diversity in sites with no weeds was still relatively high (0.450). Dominance was correlated negatively with the same variables, and was correlated positively with only one of the plant parasites identified. This species, Paratylenchus projectus, was the most common nematode in the nurseries, and its occurrence in high densities (Table 5) accounts for this relationship.

None of the plant parasites occurring in more than 10% of the sites were limited in distribution to any tree species. This, coupled with the overall high diversity of plant parasites even in the absence of weeds, led to the conclusions that those species were: a) native to Tennessee, and b) polyphagous. Dogwood and maple are both native to Tennessee forests, and the occurrence of the same species in peach sites with no weeds can be explained by the polyphagy of those species.

The edaphic factors measured did not significantly affect diversity. More important to the diversity of the communities of plant parasites were weed cover and number of weed species, tree species, and tree age class. Diversity was higher in maple than in peach or dogwood sites, and higher in 10-year-old dogwood sites than in the younger age classes, but not correlated with tree age in maple (Fig. 20). Diversity was higher in weedy sites and/or sites with higher numbers of weed species (Figs. 22 and 23), but not much more so than in sites with no weeds regardless of tree species or age class. Diversity was also not related to total plant parasitic nematodes in a site.

Ordination of plant parasitic nematode communities

The ordination of sites based on species of nematodes is a useful tool to determine non-linear relationships among variables. In these ordinations, it was found that nursery sites had very similar plant parasitic nematode communities. This was expected, because the most common species, Paratylenchus projectus, occurred in high densities (Table 5) and thus had a strong influence on quantification of similarity among sites. Furthermore, 22 of the species found occurred in 10% or more of the sites, which increased the likelihood that two sites had common species. Clustering of the sites in one quadrant of the matrix reflected this. Plant parasitic communities were shown to be similar regardless of tree species or edaphic factors, but sites did cluster according to the individual nursery in which they were located even if the sites were separated by large geographical distances. This clustering can be explained by the hypothesis that the distribution of species within nurseries is due in some degree to the movement of soil by humans on tools and machinery, a method of dispersal often suggested to explain nematode distribution (Wallace, 1973). That the reference sites in the dogwood and maple ordinations were of different soil types than the majority of sites is significant in that these sites were the most dissimilar to the others, but this may not be directly due to soil type.

III. SUMMARY AND CONCLUSIONS

With regard to the objectives of this investigation, the conclusions were threefold. First, the trophic group structure of nematode communities in dogwood, maple, and peach nurseries had characteristics of both natural and agricultural ecosystems. Communities in older (10+ years) sites were more similar to those in natural wooded areas, and communities in peach sites were more similar to those in agricultural areas. The position of the plant parasitic group in both absolute and relative densities was a reflection of the monocultured aspect of nurseries. Second, plant parasitic nematode communities were diverse, and reflected natural communities to some degree, as diversity was more dependent on weeds than on crop or soil factors. Known nematode parasites of all three tree species occurred in nursery sites, as did pathogens of other crops. Third, the most important factor in determining the distribution of plant parasitic species appeared to be artificial soil transfer by machinery or tools.

LITERATURE CITED

LITERATURE CITED

Andrássy, I. 1976. Evolution as a basis for the systematization of nematodes. Pitman Publ., San Francisco. 288 p.

Anonymous. 1960. Distribution of plant parasitic nematodes in the South. USDA Southern Coop. Ser. Bull. 74. 72 p.

Anonymous. 1982. Tennessee agriculture - projections to 1990. Univ. Tenn. Agric. Expt. Sta. Res. Rpt. No. 82-07. 36 p.

Badenhop, M.B., and A.E. Einert. 1980. Factors affecting production costs and returns for flowering dogwood. USDA Southern Coop. Ser. Bull. 246. 58 p.

Barker, K.R., and C.N. Clayton. 1973. Nematodes attacking cultivars of peach in North Carolina. J. Nematol. 5:265-271.

Barker, K.R., et al. 1978. Determining responses to control agents. Pp. 114-134 in Methods for evaluating plant fungicides, nematicides, and bactericides. Am. Phyopathol. Soc., St. Paul, MN. 141 p.

Baver, L.D., W.H. Gardner, and W.R. Gardner. 1972. Soil physics, 4th edition. John Wiley & Sons, NY. 498 p.

Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72:156-181.

Bernard, E.C. 1980. Identification, distribution, and plant associations of plant-parasitic nematodes in Tennessee. Univ. Tenn. Agric. Expt. Sta. Bull. 594. 18 p.

Bouyoucos, G.J. 1936. Directions for making mechanical analyses of soil by the hydrometer method. Soil Sci. 42:225-229.

Brzeski, M.W. 1965. Nematodes associated with citrus trees infected by four viruses and comments about nematode distribution in Florida citrus groves. Pl. Dis. Rep. 49:610-614.

Brzeski, M.W., and A. Dowe. 1969. Effect of pH on Tylenchorhynchus dubius (Nematoda: Tylenchidea). Nematologica 15:403-407.

Burns, N.C. 1971. Soil pH effects on nematode populations associated with soybeans. J. Nematol. 3:238-245.

Chitood, B.G. 1949. Ring nematodes (Criconematinae). A possible factor in decline and replanting problems of peach orchards. Proc. Helm. Soc. Wash. 16:6-7.

Cohn, E. 1969. The occurrence and distribution of species of Xiphinema and Longidorus in Israel. Nematologica 15:179-192.

Dhanavartari, B.N., P.W. Johnson, and V.A. Dirks. 1975. The role of nematodes in crown gall infection of peach in southwestern Ontario. Pl. Dis. Rep. 59:109-112.

Di Sanzo, C.P., and R.A. Rohde. 1969. Xiphinema americanum associated with maple decline in Massachusetts. Phytopathology 59:279-284.

Dropkin, V.H. 1980. Introduction to plant nematology. John Wiley & Sons, NY. 283 p.

Ferris, V.R., and J.M. Ferris. 1974. Inter-relationships between nematode and plant communities in agricultural ecosystems. Agro-Ecosystems 1:275-299.

Ferris, V.R., J.M. Ferris, R.L. Bernard, and A.H. Probst. 1971. Community structure of plant parasitic nematodes related to soil types in Illinois and Indiana soybean fields. J. Nematol. 3:399-408.

Goodey, J.B., M.T. Franklin, and D.J. Hooper. 1965. T. Goodey's the nematode parasites of plants catalogued under their hosts. Commonwealth Agric. Bureau, Farnham Royal, Bucks, England. 214 p.

Hague, N.G.M. 1972. Nematode diseases of flower bulbs, glasshouse crops, and ornamentals. Pp. 409-434 in Economic nematology, J.M. Webster, ed. Acad. Press, NY. 563 p.

Hammond, R.B. 1981. Soybean cyst nematode introduced into Ohio. Pl. Dis. 65:846.

Hibben, C.R. 1964. Identity and significance of certain organisms associated with sugar maple decline in New York woodlands. Phytopathology 54:1389-1392.

Hoffman, J.K., and D.C. Norton. 1974. Distribution patterns of some Criconematinae in different forest associations. J. Nematol. 8: 32-35.

Hung, Chia-Ling Pi, and W.R. Jenkins. 1969. Criconemoides curvatum and the peach tree decline problem. J. Nematol. 1:12 (abstr.)

Huntsberger, D.V., and P. Billingsley. 1977. Elements of statistical inference, 4th edition. Allyn and Bacon, Boston. 385 p.

Jenkins, W.R. 1964. A rapid centrifugal-flotation method for separating nematodes from soil. Pl. Dis. Rep. 48:692.

Jenkins, W.R., D.P. Taylor, R.A. Rohde, and B.W. Coursen. 1957. Nematodes associated with crop plants in Maryland. Univ. Md. Agric. Expt. Sta. Bull. A-29. 25 p.

Johnson, A.W., T.J. Ratcliffe, and G.C. Freeman. 1970. Control of Meloidogyne incognita on dogwood seedlings by chemical dips. Pl. Dis. Rep. 54:952-955.

Johnson, S.R., V.R. Ferris, and J.M. Ferris. 1972. Nematode community structure of forest woodlots. I. Relationships based on similarity coefficients of nematode species. J. Nematol. 4:175-183.

Johnson, S.R., J.M. Ferris, and V.R. Ferris. 1973. Nematode community structure in forest woodlots. II. Ordination of nematode communities. J. Nematol. 5:95-107.

Johnson, S.R., J.M. Ferris, and V.R. Ferris. 1974. Nematode community structure of forest woodlots. III. Ordinations of taxonomic groups and biomass. J. Nematol. 6:118-126.

Jones, F.G.W., and A.J. Thomasson. 1976. Bulk density as an indicator of pore space in soils usable by nematodes. Nematologica 22:133-137.

Kimpinski, J., and H.E. Welch. 1971. The ecology of nematodes in Manitoba soils. Nematologica 17:308-318.

Klobe, W.D. 1976. Occurrence of plant parasitic nematodes in seven west Tennessee counties. Tenn. Farm and Home Sci. 99:14-15.

Knobloch, N., and G.W. Bird. 1978. Criconematinae habitats and Lobocriconema thornei n. sp. (Criconematidae: Nematoda). J. Nematol. 10:61-70.

Lehman, P.S., and E.L. Barnard. 1982. A root-knot nematode pathogenic to flowering dogwood, Cornus florida. Nematology Cir. #84, Fla. Dept. Agric. and Consumer Serv. 2 p.

Lembright, H.W. 1976. Solutions to problems associated with the replanting of peaches. Down to Earth 32: 12-21.

Lloyd, M., J.H. Zar, and J.R. Karr. 1968. On the calculation of information-theoretical measures of diversity. Am. Midl. Nat. 79:257-272.

Lownsbery, B.F. Factors affecting populations levels of Criconemoides xenoplax. Phyopathology 51:101-103.

Lownsbery, B.F., H. English, E.H. Moody, and F.J. Schick. 1973. Criconemoides xenoplax experimentally associated with a disease of peach. Phytopathology 63:995-997.

Lownsbery, B.F., H. English, G.R. Noel, and F.J. Schick. 1973. Influence of Nemaguard and Lovell rootstocks and Macroposthonia xenoplax on bacterial canker of peach. J. Nematol. 9:221-224.

McElroy, F.D. 1972. Nematodes of tree fruits and small fruits. Pp. 335-376 in Economic nematology, J.M. Webster, ed. Acad. Press, NY. 563 p.

Metz, L.J., and D.L. Dindal. 1975. Collembola populations and prescribed burning. Environ. Entomol. 4:583-587.

Meyer, A.J. 1976. Plant parasitic nematodes associated with peach orchards in the Western Cape Province. Phytophylactica 8:21-22.

Marchant, E.H.J. 1934. The estimated number of nemas in the soils of Manitoba. Can. J. Res. 1:594-601.

Norton, D.C. 1978. Ecology of plant parasitic nematodes. John Wiley & Sons, NY. 286 p.

Norton, D.C., L.R. Fredrick, P.E. Ponchillia, and J.W. Nyhan. 1971. Correlations of nematodes and soil properties in soybean fields. J. Nematol. 3:154-163.

Norton, D.C., and J.K. Hoffman. 1974. Distribution of selected plant parasitic nematodes relative to vegetation and edaphic factors. J. Nematol. 6:81-86.

Norton, D.C., and M. Oard. 1981. Plant parasitic nematodes is loess toposequences planted with corn. J. Nematol. 13:314-320.

Ponchillia, P.E. 1975. Plant parasitic nematodes associated with burley tobacco in Tennessee. Pl. Dis. Rep. 59:219-220.

Reddick, B.B., O.W. Barnett, and L.W. Baxter, Jr. 1977. Occurrence and identification of viruses affecting dogwoods in South Carolina. Proc. South. Nurserymen's Assoc. Res. Conf., 22nd Ann. Rep. 207 p.

Reddick, B.B., O.W. Barnett, and L.W. Baster, Jr. 1980. Viruses of dogwoods: symptomatology, isolation, and damage. Ornam. South 5:4-7.

Rich, S., and G.S. Walton. 1975. Decline of sugar maples along streets in Connecticut. Proc. Am. Phytopathol. Soc. 2:104-105. (abstr).

Riffle, J.W. 1963. Meloidogyne ovalis (Nematode: Heteroderidae), a new species of root-knot nematode. Proc. Helm. Soc. Wash. 30:287-292.

Riffle, J.W., and J.E. Kuntz. 1966. Nematodes in maple blight and maple dieback areas in Wisconsin. Pl. Dis. Rep. 50:677-681.

Ruehle, J.L. 1967. Distribution of plant parasitic nematodes associated with forest trees of the world. Southeast Forest Expt. Sta., Asheville, NC. USDA unnumbered release. 156 p.

Ruehle, J.L. 1971. Nematodes parasitic on forest trees: III. Reproduction on selected hardwoods.

Ruehle, J.L. 1972. Nematodes on forest trees. Pp. 312-334 in Economic nematology, J.M. Webster, ed. Acad. Press, NY. 563 p.

Schmitt, D.P., and D.C. Norton. Relationships of plant parasitic nematodes to sites in native Iowa prairies. J. Nematol. 4:200-206.

Scribner, F.L. 1889. Diseases of the Irish potato. Bull. Tenn. Agric. Expt. Sta. 2:27-43.

Seinhorst, J.W. 1959. A rapid method for the transfer of nematodes from fixative to anhydrous glycerin. Nematologica 4:67-69.

Sher, S.A. 1966. Revision of the Hoplolaiminae (Nematoda). VI. Helicotylenchus Steiner, 1945. Nematologica 12:1-56.

Siddiqui, I.A., S.A. Sher, and A.M. French. 1973. Distribution of plant parasitic nematodes in California. Calif. Dept. Food Agric., Sacramento, CA. 324 p.

Springer, J.K. 1964. Nematodes associated with plants in cultivated woody plant nurseries and uncultivated woodland areas of New Jersey. N.J. Dept. Agric. Circ. 429, Trenton, NJ. 40 p.

Taylor, A.L., and J.N. Sasser. 1978. Biology, identification, and control of root-knot nematodes (Meloidogyne species). Coop. Publ. N.C. State Univ. and USAID. N.C. State Univ. Graphics, Raleigh, NC. 111 p.

Tarjan, A.C., and B.E. Hopper. 1974. Nomenclatorial compilation of plant and soil nematodes. Soc. Nematol., Inc. 419 p.

Telíz, D., B.F. Lownsbery, R.G. Grogan, and K.A. Kimble. 1967. Transmission of peach yellow bud mosaic virus to peach, apricot, and plum by Xiphinema americanum. Pl. Dis. Rep. 51:841-843.

Van Gundy, S.D., and J.P. Martin. 1962. Soil texture, pH, and moisture effects on the development of citrus nematode (Tylenchulus semipenetrans). Phytopathology 52:31 (abstr).

Van Gundy, S.D., J.P. Martin, and P.H. Tsao. 1964. Some soil factors influencing reproduction of the citrus nematode and growth and reproduction of sweet orange seedlings. Phytopathology 54:294-299.

Walkley, A. 1946. A critical examination of a rapid method for determining organic carbon in soils - effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-263.

Walkley, A., and I.A. Black. 1934. An examination of the Degtjareff method for detemining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

Wallace, H.R. 1973. Nematode ecology and plant disease. Crane, Russak, and Co., NY. 228 p.

Wasilewska, L. 1967. Analysis of the occurrence of nematodes in alfalfa crops. II. Abundance and quantitative relations between species and ecological groups of species. Ekol. Pol., Ser. A. 15:347-371.

Wasilewska, L. 1971. Nematodes of the dunes of the Kampinos Forest. II. Community structure based on numbers of individuals, state of biomass, and respiratory metabolism. Ekol. Pol. 19:651-688.

Wehunt, E.J., and J.M. Good. 1974. Nematodes on peaches. Pp. 223-231 in The peach. Varieties, culture, marketing, and pest control. N.F. Childers, ed. Cook College, Rutgers Univ., New Brunswick, NJ. 377 p.

Wehunt, E.J., and D.J. Weaver. 1972. Effect of nematodes and Fusarium oxysporum on the growth of peaches in the greenhouse. J. Nematol. 4: 236. (abstr.)

Whittle, W.O., and B.D. Drain. 1940. The root-knot nematode in Tennessee. Its prevalence and suggestions for control. Univ. Tenn. Agric. Expt. Sta. Circ. 54. 8 p.

Yeates, G.W. 1979. Soil nematodes in terrestrial ecosystems. J. Nematol. 11:213-229.

VITA

Terry L. Niblack was born at Reese Air Force Base, Lubbock, Texas, on May 8, 1953. In 1976, she received the B. S. degree with a major in Ornamental Horticulture and Landscape Design from The University of Tennessee, Knoxville. From the fall of 1976 until the summer of 1980, she taught Ornamental Horticulture as a Vocational Agriculture instructor for Knox County Schools, at Farragut High School, Farragut, Tennessee. During that time, she participated in the development of vocational horticulture curriculum materials for both the County and State Departments of Education.

In August, 1980, she entered the Department of Entomology and Plant Pathology at The University of Tennessee, Knoxville, as a graduate research assistant. In August, 1982, she received the M. S. degree with a major in Entomology and Plant Pathology.

Ms. Niblack is a member of the Society of Nematologists, the American Phytopathological Society, and Gamma Sigma Delta, the agricultural honor society.