1989

Plant-parasitic Nematodes in Iowa

Don C. Norton
Iowa State University

Recommended Citation
Available at: http://scholarworks.uni.edu/jias/vol96/iss1/8

This Research is brought to you for free and open access by UNI ScholarWorks. It has been accepted for inclusion in The Journal of the Iowa Academy of Science: JIAS by an authorized editor of UNI ScholarWorks. For more information, please contact scholarworks@uni.edu.
Plant-parasitic Nematodes in Iowa

DON C. NORTON

Department of Plant Pathology, Iowa State University, Ames, IA 50011

Ninety-nine species of plant-parasitic nematodes are recorded from Iowa. Twenty-seven are new state records. Most samples were collected from around maize or from prairies or woodlands. Similarity (Sorensen's index) of species was highest for the maize-prairie habitats (0.49), compared with maize-woodlands (0.23), or prairie-woodland (0.37) habitats. Nematode communities were most diverse in prairies with a Shannon-Weiner index (H') of 2.74, compared with 1.65 and 1.07 for woodlands and maize habitats, respectively. Evenness of species (J') was 0.41, 0.78, and 0.48 for maize, prairies, and woodlands, respectively.

INDEX DESCRIPTORS: Nematodes, maize, prairies, woodlands, ecology

Although nematodes are the most numerous multicellular animals and include more species than any other Metazoa, except for the arthropods, they are known mainly to parasitologists and plant nematologists. The best known groups of nematodes probably are the animal parasites that usually are studied in parasitology and medicine. Study of the occurrence and distribution of nematodes parasitizing plants is more than academic. Many are important pathogens that reduce yields or aesthetic appeal and, in some instances, prohibit crop production. Plant-parasitic nematodes range from 300 µm to more than 8 mm long, but most are a millimeter or less. Of the species attacking plants, those in the genera Heterodera, Meloidogyne, and related forms are the best known because they are widespread and many are important pathogens. Much of the nonfamiliarity with the plant-parasitic forms is because they are generally microscopic, and most live underground. Nematodes have been collected in Iowa for nearly 30 years, with emphasis on agricultural crops. Most collections from nonagricultural soils have been made since 1983 as a result of a grant from the Iowa Science Foundation, but a few studies were made previously in prairies and woodlands (19, 32, 34, 43, 45). Results reported here include corrections of earlier Iowa records and nomenclatural changes owing to taxonomic revisions. Annotations are made on morphologies and distributions in many instances.

MATERIALS AND METHODS

Samples were taken in the rhizosphere of the target plants. Maize (Zea mays L.) was the cultivated plant most frequently sampled. Samples from the rhizosphere of plant species were made in prairies and woodlands; attempts were made to keep roots of undesired species to a minimum. In woodlands, soil around rootlets emanating from the primary roots was selected. Care was taken to avoid collection where herbaceous plants were near the tree sampled.

A sample consisted of 200-500 cm³ of soil and fibrous roots collected with a 2.5-cm-diameter core sampler, a shovel, or trowel as the situation dictated. Samples were usually taken to a depth of 15-30 cm and were returned to the laboratory. Soil (100 cm³) from each sample was processed by centrifugal flotation (21), and nematodes were extracted from fibrous roots by the 4-day shaker method (4). Samples were refrigerated at 3°C until processing which was usually within 2-3 days after sampling. Counts given are for 100 cm³ of soil or per gram of dry root. Count figures are for nematodes in the soil unless specified for roots. Where root-knot nematodes were suspected, females, if present, were dissected from the roots. Cultivated plants, especially maize were collected statewide. The major natural areas from which samples were collected are listed in Table 1. Quantitative data for diversity and similarities indices are based on 404, 119, 358 samples collected since 1984 from maize, prairies, and woodlands, respectively. Diversity (H') and evenness (J') were measured by the equations $H' = - \sum p_i \log_2 p_i$ and $J = H'/H_{max}$, respectively (38). Similarity indices were those of Sorensen (51). Representative specimens were mounted on Gabl slides and deposited in the Iowa State University plant-nematode collection in the Department of Plant Pathology. Many individuals were not identified for various reasons, which include poor preservation, immature specimens, insufficient material, and seemingly undescribed species.

Two contrasting treatments of the Tylenchida have been published recently; one by Siddiqi (48) and the other, in a series of articles in the Revue de Nematologie (11, 12, 13, 25, 26, 27, 28, 29, 39, 40). I have followed the latter treatments here.

Table 1. Numbers of soil samples collected for plant-parasitic nematodes in natural areas. Iowa, 1984-1987.

<table>
<thead>
<tr>
<th>County</th>
<th>Location</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allamakee</td>
<td>Yellow River Forest</td>
<td>20</td>
</tr>
<tr>
<td>Black Hawk</td>
<td>Cedar Hills Sand Prairie</td>
<td>16</td>
</tr>
<tr>
<td>Boone</td>
<td>Iowa Arboretum</td>
<td>11</td>
</tr>
<tr>
<td>Boone</td>
<td>Ledges State Park</td>
<td>5</td>
</tr>
<tr>
<td>Butler</td>
<td>Heery Woods State Park</td>
<td>5</td>
</tr>
<tr>
<td>Clayton</td>
<td>Pikes Peak State Park</td>
<td>10</td>
</tr>
<tr>
<td>Delaware</td>
<td>Backbone State Park</td>
<td>10</td>
</tr>
<tr>
<td>Dubuque</td>
<td>White Pine Hollow Preserve</td>
<td>30</td>
</tr>
<tr>
<td>Fayette</td>
<td>Brush Creek Canyon Preserve</td>
<td>30</td>
</tr>
<tr>
<td>Fayette</td>
<td>Volga River State Forest</td>
<td>15</td>
</tr>
<tr>
<td>Floyd</td>
<td>Idlewild County Park</td>
<td>2</td>
</tr>
<tr>
<td>Fremont</td>
<td>Waubonsie State Park</td>
<td>5</td>
</tr>
<tr>
<td>Hancock</td>
<td>Pilot Knob State Park</td>
<td>8</td>
</tr>
<tr>
<td>Hardin</td>
<td>Pine Lake State Park</td>
<td>4</td>
</tr>
<tr>
<td>Hardin</td>
<td>Tower Rock County Park</td>
<td>10</td>
</tr>
<tr>
<td>Lee</td>
<td>Donnellson Unit, Shimek State Forest</td>
<td>11</td>
</tr>
<tr>
<td>Lucas</td>
<td>Lucas Unit, Stephens State Forest</td>
<td>10</td>
</tr>
<tr>
<td>Lyon</td>
<td>Gitchie Manitou</td>
<td>10</td>
</tr>
<tr>
<td>Monona</td>
<td>Lewis and Clark State Park</td>
<td>10</td>
</tr>
<tr>
<td>Monona</td>
<td>Loess Hills north of Turin</td>
<td>24</td>
</tr>
<tr>
<td>Monona</td>
<td>Preparation Canyon State Park</td>
<td>16</td>
</tr>
<tr>
<td>Muscatine</td>
<td>Wild Cat Den State Park</td>
<td>19</td>
</tr>
<tr>
<td>Van Buren</td>
<td>Lacy-Kosauqua State Park</td>
<td>10</td>
</tr>
<tr>
<td>Webster</td>
<td>Brushy Creek Recreational Area</td>
<td>1</td>
</tr>
<tr>
<td>Webster</td>
<td>Dolliver Memorial State Park</td>
<td>20</td>
</tr>
<tr>
<td>Webster</td>
<td>Woodman Hollow Preserve</td>
<td>20</td>
</tr>
<tr>
<td>Woodbury</td>
<td>Liberty Wildlife Area</td>
<td>8</td>
</tr>
<tr>
<td>Woodbury</td>
<td>Stone State Park</td>
<td>15</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Ninety-nine species of plant-parasitic nematodes are recorded from Iowa, of which 27 are new state records. Although many species are economically important, most species included have not been sufficiently investigated to measure their economic importance. The most plant-parasitic species found in one sample was nine around Ulmus americana L. at Brush Creek Canyon. The number of species per plant averaged 2.9, 3.6, and 4.9 for maize, woodlands, and prairies, respectively.

ANGUINIDAE Nicoll, 1935

Ditylenchus Filipjev, 1936. Three collections from roots of maize contained species of this genus; in one over 2,000 individuals were recovered. This genus is not well investigated in Iowa.

Subanguina Paramonov, 1967. The only species found in Iowa causes galls on leaves of Calamagrostis spp.

S. calamagrostis (Wu, 1967) Brzeski, 1981. This species is a common parasite of Calamagrostis canadensis (Michx.) Beauv. and C. inefascans A. Gray in wet native prairies. The nematode has been found in the Bergman, Crossman, Hayden, Mark Sand, Steele, Stinson, and Williams prairies, as well as in C. canadensis in Ohio and Wisconsin (36) and in Canada (61). The nematode probably occurs in Minnesota, but this needs to be confirmed (36).

DOLICHODORIDAE Chamberlin, 1930.

Dolichodorus Cobb, 1914. This was associated with grass by the Skunk River, Inis Grove Park, Ames.

BELONOLAIMIDAE Whitehead, 1960

Belonolaimus Steiner, 1949.

B. nortoni Rau, 1963. Kerr and Wysong (22) stated that a Belonolaimus sp. associated with maize in Nebraska was close to B. nortoni except that the "... female tail and spear lengths are slightly larger and the vulval lips less protruding than originally described for B. nortoni. Males differ by having a slightly longer tail." Specimens that I collected around grass near Sergeant Bluff in Woodbury County and from maize in Holt and Rock counties, Nebraska and in natural range in Rock County generally agree with the conclusions stated by Kerr and Wysong. Most styler and tail lengths that I examined were in the upper range given by Allen (1). Rau reported that B. nortoni has protruding vulval lips. The vulval lips in my material ranged from not protruding to slightly protruding in the same population. In Iowa, the nematode was collected around grass in a sandpit near the Liberty Skunk River, Inis Grove Park, Ames.

**TELOTYLENCHINAE** Siddiqi, 1960

*Melionema* Siddiqi, 1970

*Melionema jacutum* (Thorne, 1949) Sher, 1974 was found at the Cayler and Kalow prairies (43) and around perennials in a home garden. *Nagelius Thorne & Malek, 1968*

*N. leptus* (Allen, 1955) Siddiqi, 1979 was found mainly in woods, but it was also found in lawn turf. The highest count in woods was 250 around Kentucky coffee tree (*Gymnocladus dioica* (L.) K. Koch) at the Iowa Arboretum.

*Tylenchorhynchus* Cobb, 1913. The species reported here are commonly associated with naturally occurring and cultivated grasses.

*T. acutatus* Thorne and Malek, 1968. This was collected around *Petalostemon purpureum* (Vent.) Rhydb. at the Freda Haffner Kettlehole in Dickinson County. It is also found from native sod in Montana, North Dakota, and South Dakota (56).

*T. acutus* Allen, 1955. This is a common nematode around maize and other grasses, especially in well-drained loess soils. The maximum numbers obtained, 650-700, were around maize in Woodbury County. It is also common in the Fred Haffner Kettlehole and prairies of the loess hills.

*T. agri* Ferris, 1963 is occasionally associated with maize. The greatest population was 210 in Black Hawk County. It also was found at the Freda Haffner Kettlehole, with a high count of 270, and in the isolated prairie patches at Woodman Hollow.

*T. annulatus* (Cassidy, 1930) Golden, 1971 was uncomon, but was found occasionally in prairies and maize. However, a count of 2,470 occurred in the hanging peat bog in Plymouth County, the only high count obtained.

*T. capitatus* Allen, 1955. A count of 80 was found in the soil around *Yucca glauca* in the loess hills at Waubonsie State Park. The length was 85 µm, which is in the upper range of measurements given by Allen (1). The excretory pore was at the middle instead of at the beginning of the esophageal bulb as given by Allen.

*T. claytoni* Steiner, 1937 was associated with stunted maize in highly sandy soils in Black Hawk, Butler, and Muscatine counties. The nematode was also collected at the Cedar Hills Sand Prairie where it is probably native. The highest count was 280, with a mean of 100 in the six samples in which the species was identified.

*T. emriolus* Allen, 1955 was found in one sample each in the Kalsow and Cedar Hills Sand prairies. The highest count was 90.

*T. maximus* Allen, 1955 is common in lowland prairies and in turf. It was not found in the dry prairies of the loess hills or the hill-prairies around Dubuque. The highest count observed was 2,360 in a pasture in Worth County. The highest count in any native prairie was 552 at the Kalsow Prairie. A nematode that fits *T. maximus* in most respects was found around grasses in the loess hills north of Turin. The main difference in this nematode from *T. maximus* is that this nematode has males. Otherwise the females have similar measurements and appearance to *T. maximus*.

*T. naudus* Allen, 1955. One of the most common parasitic nematodes associated with maize in all but the loess soils of western Iowa. The most number associated with maize was 38, with a maximum of 260 in Allamakee County. It is also common in the Cayler, Kalsow, and Sheeder prairies.

*T. silicaticus* Ferris, 1963. Although the species was found in Shimek State Forest, this nematode is basically a prairie species being found in the grasslands of the Cayler, Kalsow, and Sheeder prairies and in grasslands at Gitchee Manitou and the Mines of Spain. The maximum count was 520 with a mean of 70 for the 17 samples in which it was found.

**PRATYLENCHIDAE** Thorne, 1949

Hirschmannella Luc & Goodey, 1964

H. gracili (de Man, 1880) Luc & Goodey, 1964 is a nematode of
Ambrosia trifida (59), Lewis and Clark State occur in a sample, making counts per species subject to considerable error with basswood dry root sometimes could be greater than Hills Sand Prairie. Nematodes attacking maize and soybeans material, these nematodes have been identified as P. baith. Pratylenchus Filip'ev, 1936. Lesion nematodes. Because of their widespread distribution and proven pathogenicity, species of this genus are among the most common and economically important nematodes attacking maize and soybeans (Glycine max (L.) Merr.) in Iowa. They are found occasionally in woodlands and native prairies, but cultivated agriculture has favored their existence. They are basically endoparasitic. It is common for more than one species to occur in a sample, making counts per species subject to considerable error. Some species are difficult to identify. Frequently species identifications were not made in routine surveys and much extension work, total counts in the genus serving as the record. Numbers per gram of dry root sometimes could be greater than 50,000. From 385 maize samples, the mean number per gram of dry root was 3,400, with a maximum of more than 84,000. From 40 soybean samples, the mean was 2,846 with a maximum of 31,000. From 299 woodland samples, species of Pratylenchus were found only four times. The nematodes were found in only nine of 118 prairie samples. Quantitative data for the combined Pratylenchus species associated with maize were given by Norton (31).

P. alleni Ferris, 1961. This is the third most common species of the genus associated with maize. Although it is statewide and is found in many different soil types, it has been recovered most frequently from roots of maize growing in loess soils in the western third of Iowa and in sandy soils elsewhere. The most found was 27,000 per gram of dry root from maize in Woodbury County. The nematode was found in small numbers at the Williams Prairie.

P. contillatoris Seinhorst, 1959. The only material available is from maize in Monona County. The morphometrics agree with the original description except that the tail annules are more coarse than described by Seinhorst (46), being more like that illustrated by Loof (24). The tail is somewhat more truncate, as illustrated by Loof.

P. flakkensis Seinhorst, 1968. An uncommon species found occasionally around maize and other grasses. The tails are more coarsely annulated than described by Seinhorst (47). Besides the reports of Thomas and Norton (54) and Williams (59), the nematode was found around maize in Monona, Ringgold, and Winnebago counties, alfalfa (Medicago sativa L.), and grass in Wapello County; and from grasses at the Rez Memorial and Hitchie Manitou preserves. The highest count in maize roots was 1,100 (59).

P. hemicus Taylor & Jenkins, 1957. Possibly this is the most common species of the genus in the state, at least in maize. It has also been found around Yucca glauca in the loess hills near Turin and around little bluestem [Schizachyrium scoparium (Michx.) Nash] in the hill-prairies near Dubuque.

P. nigrae (Rensch, 1924) Filip'ev & Schuurmans Stekhoven, 1941. Williams (59) found this species associated with maize in Benton and Lee counties, with counts in the roots being 4,000 or less. Had we made more species identification, the nematode probably would be more extensively known in Iowa than our records indicate.

P. scripturi Steiner, 1945. Along with P. hemicus, P. scripturi is one of the most common nematodes of the genus in maize. It is statewide and found in a variety of soils, although I have the impression that P. hemicus is more common in the heavier soils. In native areas few P. scripturi were found.

P. thorneti Sher & Allen, 1953. Although several records from maize were listed as P. thorneti, I have no voucher specimens. A voucher is available from strawberries in a nursery in southwestern Iowa, where the nematode was possibly shipped in.

P. vulnus Allen & Jensen, 1951. Schmitt (44) reported this nematode in lilac from a nursery in southwestern Iowa, where it was possibly introduced.

HOPLOLAIMIDAE Filip'ev, 1934. This family contains some of the most common plant parasites in Iowa. Agricultural practices certainly favor some species, but many species doubtless have been eliminated under cultivation.

Aorolaimus Sher, 1963 A. baldus Thorne & Malek, 1968 is a common nematode in the loess hill prairies along the western edge of Iowa. It was recovered from Waukon and Preparation Canyon state parks, the loess hills north of Turin to the loess hills in Story County. It was never found in wooded areas. The nematode was obtained in 21 samples, with an average of 134 and a maximum of 790. The only previous reports are from South Dakota (49, 50, 56). I also collected it around lead plant (Amorpha canescens Pursh) and grass in the Willa Cather Prairie near Red Cloud, Nebraska.

A. torridus Thorne & Malek, 1968. This species was found in the Hayden Prairie and around boxelder (Acer negundo L.) with grass cover at the Ames High Prairie. Thorne and Malek (56) recorded the styler as 23 µm long. Examination of material marked “Aorolaimus torridus” from South Dakota, and kindly supplied by James D. Smolik, revealed the styler to be about 32 µm. I suspect that the original was a reverse typographical error.

Helicotylenchus Steiner, 1945. Many samples contained individuals of Helicotylenchus that were not identified.

H. amblycus Sher, 1966. This species was associated with Acer negundo in Lee County and with canary grass (Phalaris canariensis) in Story County, both along the Skunk River. The maximum number was 344. I also collected this species around sandbar willow (Salix interior Roslew) in sandy soil near the Platte River just south of Grand Island, Nebraska.

H. californicus Sher, 1966. It was associated with Calamagrostis canadensis in the Williams Prairie, Carex sp. in the Cedar Hills Sand Prairie, and Sagittaria latifolia Willd. in the Freda Haffner Kettlehole, where the largest population of 1,930 occurred.

H. digonius Perry in Perry, Darling & Thorne, 1959. This species was common in all prairies examined with the largest population being 2,120 in the hill-prairies near Dubuque. I also collected it at the Willa Cather Prairie near Red Cloud, Nebraska.

H. daphnoides (Cobb, 1893) Sher, 1961 is a common nematode in prairies, often in the drier sites. It was found at the Ames High School, Gitche Manitou, Kalsow, Freda Haffner Kettlehole, Cedar Hills Sand and Williams prairies, the loess hills north of Turin, Preparation Canyon, and Stone Park, and the small prairie bluffs at Woodman Hollow. Common associates were big bluestem (Andropogon gerardi Michx.) and little blue grasses, side oats grama [Bouteloua curtipendula (Michx.) Torr.] and Indian grass (Sorghastrum nutans (L.) Nash). The maximum number, 740, was around lespedeza (Lespedeza capitata Michx.) and grass at Gitche Manitou. Pathotypes also exist because the nematode is common around maize in the southern United States, but I have never found it associated with maize in Iowa. I have found it commonly associated with maize in Colombia, South America (35). The species is variable morphologically (15). A few were associated with shagbark hickory (Carya ovata (Mill.) K. Koch) at the Dooliver Memorial.

H. exallii Sher, 1966. This uncommon species was associated with Verbena stricta Vent. at the Freda Haffner Kettlehole, Carya ovata at the Childs Access in Black Hawk County, various prairie plants in the Kalsow Prairie (43), and turf in Shelby County, which contained the
Heteroderidae damaging forms. Cysts are common in soil and have been found in these nematodes except in two instances. These are among our most diverse habitats; doubtless many more species than those treated elsewhere in North America, it was associated with quaking aspen. The largest number, 1,000/g at Ames High School, Gitchie Manitou, Hayden, Dubuque, Cedar Hills Sand and Shobler prairies, and at the loess hills near Turin. The largest population of 1,470 was found around big bluestem north of Turin.

H. leonchozal Sher, 1966 was found at the Cayler, Kalkow, and Williams prairies.

H. playyatus Perry in Perry, Darling & Thorne, 1959 is common in woodlands in all parts of the state, but has been found in small patches of prairies adjoining woodlands. It was found in 55% of all woodland samples and occurred in 68% of 19 Caryota ovata samples, and 62% of 37 ironwood [Ostrya virginiana (Mill.) K. Koch] samples. The largest population of 850 occurred around black cherry (Prunus serotina Ehrh.) at Pilot Knob State Park. Few were found around conifers.

H. pseudorobustus (Steiner, 1914) Golden, 1956. This is one of the most common plant-parasitic nematodes in Iowa. Although the nematode occurs in woodlands and native prairies, agricultural practices has favored this species. It probably can be found in every established maize or soybean field because both plants are good hosts. The largest number, 2,570, was found in March in overwintered maize in Des Moines County. Generally, few were found in highly sandy soils (31). The record also include specimens of H. bradyi Thorne & Malek, 1968, which Boag and Jatrapuri (5) maintained as a separate species, but which was made a synonym of H. pseudorobustus by Fortuner et al. (14).

Hoplolaimus von Daday, 1905.

H. galalati (Cobb, 1913) Thorne, 1935. This was the only species of the genus found in Iowa. It was obtained from 12, 14, and 1% of the roots processed for endoparasites of maize, prairies, and woodlands, respectively. The maximum found was 2,597, 419, and 113/g dry root from maize, prairie plants, or woodland plants, respectively. Numbers were usually few, but when numbers were greater than 1,000/g dry root, plants were severely stunted. Most large numbers were from maize plants in sandy soils in the southeastern part of the state.

Paranamylmenus Baldwin & Bell, 1981.

P. blustumyzae Baldwin & Bell, 1981. This species was found only around Abies balsamea and yew (Taxus canadensis Marsh.) at the Postville site stand and around sugar maple (Acer saccharum Marsh.) in Brush Creek Canyon. The maximum count was 430 around A. balsamea. The only other North American report is around wild rose (Rosa sp.) in Soldier Canyon, Sevier County, Utah (3).

P. hopperi Baldwin & Bell, 1984. This species was found only around herbs and white pine (Pinus strobus L.) at the Bluffton site stand and White Pine Hollow where the maximum number found was 208. Elsewhere in North America, it was associated with quaking aspen (Populus tremuloides Michx.) at 7,500 feet in the Wasatch National Forest, Utah (20).

Rotylenchus Filip'ev, 1936.


Heteroderidae Filip'ev & Schuurmans Stekhoven, 1941

Heteroderinae Filip'ev & Schuurmans Stekhoven, 1941

No major threat has been made to make an extensive survey for these nematodes except in two instances. These are among our most damaging forms. Cysts are common in soil and have been found in diverse habitats; doubtless many more species than those treated below occur in Iowa.

Castoridae Krall' & Krall', 1978

Ledges, Maquoketa, Pine Lake, Pikes Peak, White Pine Hollow, Wild Cat Den, Yellow River, and Volga River state parks or preserves. The most was 270 around Pinus strobus at Pine Lake State Park.

C. sphagni Micoltezyk, 1925 was found only around yellow birch (Betula lutea Michx.) at Tower Rock. This species is common around trees growing in acid soils of the northeastern states of the U.S.A. (19). The Iowa collections and some from northern Minnesota (18) are the farthest west known occurrences of this species.

Cenonomella De Grisse & Loof, 1965

Cenonomella sp. #1. This evidently is a new species. It was found only in the dry loess bluffs in the Loess Hills from Preparation Canyon to Stone Park in western Iowa. The highest count was 120, with a mean of 48 in the eight samples in which the nematode was identified. Specimens are deposited in the U.S.D.A. nematode collection at Beltsville, Maryland.

C. axatii (Fassulliotis & Williamson, 1959) Luc & Raski, 1981. Hoffmann (18) reported it to be associated with Careya ovata in the Donnelson Unit of Shimek State Forest and around Tilia americana in the Yellow River Forest Preserve.

C. bakeri (Wu, 1965) Luc & Raski, 1981 was found only around Abies balsamea and Pinus strobus at the Bluffton fir stand. The juveniles have beaded or very short fringed annules, and thus would not fit in with the limits set by Raski and Luc (40), who state that the juvenile annules are smooth to crenate with three exceptions. Whether C. bakeri is another exception remains to be seen. Wu (60) did not mention juveniles in her description of the nematode. Certain related species have been confusing to taxonomists, but for now, the nematode is given the epithet of C. bakeri. Specimens have been deposited in the U.S.D.A. nematode collection, Beltsville, Maryland.

C. curvata (Raski, 1952) Luc & Raski, 1981 was found in only five samples with the highest count being 360 in turf in Muscature County. It was also found around maize in Black Hawk County, and at the Cedar Hills Sand Prairie, and at Melanphy Springs in Winneshiek County.

C. discus (Thornc & Malek, 1968) Luc & Raski, 1981. Hoffmann (18) reported this as occurring in the Kalsow Prairie. I found it associated with sedge and grass in Louisa County.

C. incrassata (Raski & Golden, 1966) Luc & Raski, 1981 was found 39 times, all in woodlands. The mean count was 41, with a high of 300 around Prunus serotina in Wild Cat Den State Park.

C. informis (Micoltezyk, 1922) Luc & Raski, 1981. Hoffmann (18) collected this nematode around sweet corn in a home garden in Ames.

C. incrustata (Hoffmann, 1974) Luc & Raski, 1981. This species was collected in Parmel Woods at Iowa State University (17) and around wild rye (Elymus virginicus L.) along the Kate Shelly Trail in Boone County.

C. macrodora (Taylor, 1936) Luc & Raski, 1981. One of the most common nematodes in woodlands, it was found in 31% of the samples. The only time that it was found outside woodlands was in a maize field adjacent to woods. In woodlands, the nematode was found 116 times, with a mean count of 216 per sample and a maximum of 3,000 around Sisyrinx virginiana at Woodman Hollow. It was found in 71% of 17 bur oak (Quercus macrocarpa Michx.) samples and 61% of 18 white oak (Q. alba L.) samples, tree species of mainly upland habitats in Iowa.

C. psuedoolinaga (De Grisse, 1964) Luc & Raski, 1981 was found at the Williams and Cayler prairies and those at the Kettlehole and Mines of Spain. The mean of five samples was 165, with a high of 570 associated with Sisyrinx sp. at the Mines of Spain.

C. raskienis (De Grisse, 1964) Luc & Raski, 1981 was found in only five samples in nonwoodland habitats at the Cedar Hills Mark Sand Prairie, the Freda Haflner Kettlehole, Stone Park, and in Boone County. The maximum was 560 around Sisyrinx sp. in the Kettlehole. In the U.S.A., the species was found beneath grass in North Dakota (9) and on a slough bank in South Dakota (56).

C. rudi (Diab & Jenkins, 1966) Luc & Raski, 1981 was collected by Hoffmann (18) around Typha angustifolia L. at the Donnelson Unit of Shimek State Forest. I also collected it around river birch (Betula nigra L.) and weeds in the same area.

C. rustica (Micoltezyk, 1915) Luc & Raski, 1981. Counts were made from 15 samples, mostly around grasses at the Williams Prairie and the Mines of Spain, but also from a few varied habitats and plants. The highest count of 280 was in the Williams Prairie.

C. sphaerocephala (Taylor, 1936) Luc & Raski, 1981 is known from only six samples at five locations, all around grasses. The most found were 190 around Sisyrinchium sp. around the loess bluffs at Stone Park.

C. xenoplax (Raski, 1952) Luc & Raski, 1981. Two forms of the nematode are used here. Typical C. xenoplax is common in woodlands, but was generally found in less than 50% of the samples from any tree species. A short stylet form as described by Hoffmann (18) occurs infrequently in prairies and around maize growing in sandy soils.

Hemimeronemoides Chitwood & Birchfield, 1957

H. nitida Pinoche & Raski, 1975 is an uncommon species found only in woodlands, including those at Heery Woods, the loess hills, Preparation Canyon, Waubonsie, White Pine Hollow, and Yellow River. Numbers were generally fewer than 25 per sample.

Dissorcionema De Grisse & Loof, 1965

D. incarnata Hoffmann, 1974 is an uncommon nematode found mainly around grasses, including those at the Kalsow and Sheeder prairies (17). I also found it associated with dogwood (Cornus stolonifera Michx.) and grass along the Kate Shelley Trail in Boone County.

Ogma Southern, 1914

O. cobbi (Micoltezyk, 1925) Siddiqi, 1986 was collected only around Careya ovata at the Childs Access in Black Hawk County.

O. decilnimatum (Chitwood, 1957) Andrassy, 1979 was found only five times, mainly in prairies. Except for a count of 4,300 around Yucca glauca in Stone Park, numbers were less than 200.

O. fimbrisetum (Cobb in Taylor, 1939) Lucsi & Raski, 1987 was found only in woodlands in 13 samples, the most being 90 around Pinus strobus in White Pine Hollow. It was also found around the Retz Memorial, Shimek State Forest, and Ledges, Maquoketa, and Wild Cat Den state parks.

O. hungarianum (Andrassy, 1962) Siddiqi, 1986 is a rare nematode in Iowa. Hoffmann (18) recorded it from Shimek and Stephens state forests and at Pilot Knob and Wapello state parks. We also found it at Brush Creek Recreational Area in Webster County and around Populus tremuloides in Black Hawk County. Few were found at any location.

O. nemzeli (Sreflanski, 1924) Sch. Stekhoven & Trunissen, 1938 is common in woodlands throughout the state, with an average of 58 nematodes in the 82 samples in which it was found. The most recovered was more than 850 around hackberry Celtis occidentalis L.) at Brush Creek Canyon.

O. octangulare (Cobb, 1914) Sch. Stekhoven & Trunissen, 1938 is cosmopolitan in woodlands, the only habitat in which the nematode was found. The average number was 140 in the 104 samples in which it was found, with a maximum of 860 around Acer saccharum at Yellow River Forest Preserve.

HEMICYCLIOPHORINAE Skarbilovich, 1959

Hemicyclophora de Man, 1921.

These nematodes with wide distinct annules, a long stylet, and the presence of an extra cuticle are mainly woodland species. Numbers found generally are less than 100, although there are exceptions.

H. ferrisae Beetzky, 1974 was associated with woody plants in woodlands mainly in the northeastern part of the state at the Retz Memorial and with Acer saccharum at the Bluffton fir stand. It was also found around bloodroot (Sanguinaria canadensis L.) at Oaklands Mills State Park and white ash (Fraxinus americana L.) along the Kate
Shelley Trail in Boone County. This last sample contained high count of 200 for this species.

*H. gracilis* Thorne, 1955 was found only once, which was around *Ostrya virginiana* in the Donnelson unit of Shimek State Forest. Only 10 were recovered.

*H. niitara* Wu, 1966. This species is widespread and was found 23 times with a mean count of 55 in the samples in which it occurred. It was found around woody plants at the Bluffton and Postville fir stands and around maples, oaks, or ironwood at Oakland Mills and Watoukenise state parks, the Retz Memorial in Clayton County, and in Story County, among other places. It was found mainly on upland sites. Brzeski (6) examined specimens associated with *Acer saccharum* at Oakland Mills State Park in Henry County.

*H. nortoni* Brzeski, 1974 was associated with grasses, goldenrod (*Solidago* sp.) and sunflower (*Helianthus* sp.) in the Williams Prairie, and by *Salix interior* along the Skunk River at Inis Grove Park in Ames, Story County (6).

*H. similis* Thorne, 1955 was found around *Phalaris canariensis* at Inis Grove Park in Ames, Story County.

*H. uniformis* Thorne, 1955 averaged 105 nematodes per 16 samples. It was associated with white birch (*Betula papyrifera* Marsh.) at the Bluffton fir stand, with plants in the Cedar Hills Sand Prairie, and around several trees in Backbone, White Pine Hollow, Woodman Hollow, Brush Creek Canyon, Wildcat Den, and Maquoketa state parks or preserves.

*H. vestini* Reed & Jenkins, 1963 was found around *Acer saccharum* at Dolliver Memorial, and *Calamagrostis canadensis* at the Cedar Hills Sand Prairie.

*H. vidar* Raski, 1958 was found 18 times, with a mean of 64 nematodes per sample. This species was associated with many different plants, mostly trees in different habitats, including *Carya ovata* at the Childs Access in Black Hawk County, and with *Phalaris arundinacea* L. at the Retz Memorial.

**TYLENCHULIDAE** Skarbilovich, 1947

*Graclacaus* Raski, 1972 and *Paratylenchus* Micoletzky, 1922. These genera contain some of the smallest plant-parasitic nematodes known. Many often pass through the finer sieves used in processing; thus, quantitative data are unreliable. Large numbers, however, are recovered in some instances. In addition, the preadult juveniles are frequently more resistant to desiccation than adults and the latter may be scarce under dry conditions.

*G. acicula* (Brown, 1959) Raski, 1962 was found in the Kalsow Prairie by Schmitt (43), and I recovered it around grass on the bluffs in Stone Park.

*G. steudeli* (De Coninck, 1931) Raski, 1976. This species was identified from 88 samples, with all but two of them being associated with woody plants. The two highest counts of 730 and 600 were associated with *Acer saccharum* in Maquoketa State Park and red oak (*Quercus rubra* L.) in Brush Creek Canyon, respectively. Many samples in woodlands contained a few nematodes of this genus but were not identified.

*P. elachitus* Steiner, 1949 was found around *Morus* sp. in Pimmel Woods, Iowa State University.

*P. microdorus* Andnassy, 1959 was found at the Ames High School and the Kalsow (43) prairies, and is common around maize in the loess soils of western Iowa (33). It was also found in the dry hill-prairies and the Mines of Spain near Dubuque.

*P. namus* Cobb, 1923. This was associated with *Aegrotis* sp. turf in Hamilton County and with *Andropogon* sp. in the Hayden Prairie.

*P. projectus* Jenkins, 1936 was reported by Schmitt (43) from the Kalsow Prairie. It has also been associated with maize and other plants around the state.

*P. teniuscudatus* Wu, 1961 was found around *Phalaris* sp. at Pikes Peak State Park and around *Phalaris arundinacea* at the Retz Memorial.
TRICHODORIDAE (Thorne, 1935) Clark, 1961


T. proculus Allen, 1957 is mainly a prairie inhabitant found at the Freda Haffner Kettlehole and at the Cayler, Kalsow, and Cedar Hills Sand prairies. Numbers were under 60 per sample.

P. minor is known best in maize fields in highly sandy soils where it is sporadic in occurrence.

ECOLOGICAL NOTES ON THE OCCURRENCE OF PLANT-PARASITIC NEMATODES IN IOWA

Frequency Distributions.

A typical frequency distribution for nematodes is illustrated by H. platyurus in woodlands in Fig. 1. Most samples in which a given species is found contain relatively few individuals, with few samples containing many individuals of the nematode in question.

Occurrences of Nematodes by Associated Trees

As in most local biota distributions, a few species often are abundant to common with the remaining being infrequent to rare. As an example, of the species identified in the Iowa woodlands the eight (Xiphinema rivesi > Helicotylenchus platyurus > Criconemella macrodora > Ogma octangulare > Criconemella xenoplax > Ogma menzeli > Gracilacus straeleni > Criconemella incrassata) most common in percentage of times found comprised 79% of all the plant-parasitic nematodes recovered in this habitat. The most numerous, however may not be the most important biologically as based on fresh weight as calculated by Andrassy's method (2). The third most numerous species in woodlands (X. rivesi) had over six times the biomass of the most numerous species (C. macrodora).

Occurrences of four common nematodes associated with the seven trees sampled most commonly in woodlands is depicted in Table 2. X. rivesi was associated most frequently and was most numerous around A. saccharum and least around P. strobus. The mean number of O. menzeli was greatest around Q. alba but was not found around P. strobus. Although C. macrodora was not as frequent as H. platyurus and X. rivesi it was generally the most numerous and is a reflection of its small size compared with the others. Although O. menzeli is about the same size as C. macrodora, the differences in occurrences and numbers indicate differences in possible degrees of parasitism. Because associations do not prove parasitism, controlled studies are needed to provide more definite answers.

Sorensen's Similarity Indices

Even though sampled the most, fields of maize contained the fewest species, 27 for maize compared with 43 species in prairies, and 44 species in woodlands. The greatest degree of similarity was in the maize-prairie ecosystems (0.49) and the least in the maize-woodland ecosystems (0.23). The prairie woodlands index was 0.37. Because maize is a grass and prairies contain many grasses, it seems logical to conclude that nematodes would have affinities for similar types of vegetation even though maize is an annual and most prairie grasses are perennials. Such similarities are only general, however. Species of Pratylenchus are rare in prairies and woodlands but are among the most common nematodes in corn and soybean fields. Agriculture undoubtedly has favored species of this genus.

Diversity and Eveness

Diversity (H') of species in prairies, woodlands, and maize habitats were 2.74, 1.65, and 1.07, respectively. Eveness (J') of species in the three habitats were 0.78, 0.48, and 0.41, respectively. Thus, H's and J's were highest in the prairies and lowest around maize. The monoculture of maize and the diversity of plants in prairies probably account for these differences even though both are basically grass habitats. The higher H' in prairies than in woodlands agrees with studies in Montana (58), Poland (57), Switzerland (8), and New Zealand (10) where either numbers of diversities of nematode species or genera were greatest in grasslands and least in forests or cultivated areas.

This report brings up to date the known distributions of plant-parasitic nematodes in Iowa. Of the 99 species of nematodes reported here, 27 are new state records. There is no illusion that this report is definitive. Most knowledge on plant and soil nematodes in Iowa

Table 2. Occurrences of four common nematodes associated with the most frequently sampled tree species in Iowa woodlands. 1984-1987.

<table>
<thead>
<tr>
<th>Associated plant</th>
<th>Nematode</th>
<th>Helicotylenchus platyurus</th>
<th>Criconemella macrodora</th>
<th>Ogma menzeli</th>
<th>Xiphinema rivesi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostrya virginiana</td>
<td>63-59-220</td>
<td>37-312-3,000</td>
<td>26-24-100</td>
<td>58-69-370</td>
<td></td>
</tr>
<tr>
<td>Quercus rubra</td>
<td>57-103-260</td>
<td>48-215-1,400</td>
<td>38-87-300</td>
<td>52-65-380</td>
<td></td>
</tr>
<tr>
<td>Pinus strobus</td>
<td>42-64-280</td>
<td>21-453-800</td>
<td>0-0-0</td>
<td>32-19-260</td>
<td></td>
</tr>
<tr>
<td>Caraya ovata</td>
<td>72-54-190</td>
<td>39-236-1,300</td>
<td>44-21-40</td>
<td>44-77-300</td>
<td></td>
</tr>
<tr>
<td>Quercus alba</td>
<td>61-112-770</td>
<td>61-150-825</td>
<td>22-116-288</td>
<td>61-31-70</td>
<td></td>
</tr>
<tr>
<td>Tilia americana</td>
<td>44-18-40</td>
<td>22-76-200</td>
<td>33-58-190</td>
<td>39-61-140</td>
<td></td>
</tr>
</tbody>
</table>

1Numbers in ( ) are the times the species was sampled.

2The first number is the frequency of recovery around the tree sampled, the second is the average number of individual numbers recovered, and the third is the maximum number in any sample. Numbers are per 100 cm³ soil.
remains to be discovered. The economic impact on plants for most nematode species, as well as their interrelationships with other biota, is largely unknown.

ACKNOWLEDGEMENTS

Much of this work was supported by Grant ISF-84-6 from the Iowa Science Foundation. The author thanks Larry J. Wilson of the Iowa Conservation Commission, Dean M. Rosas of the Iowa Preserve Board, David Ewert of the Iowa Chapter of the Nature Conservancy, and Peter Van der Linden of the Iowa Arboretum for permission to collect in areas under their jurisdiction. Many graduate students and other colleagues contributed samples for which I am grateful. Special thanks go to Lynda Brown and Janet Edwards for assistance in collecting and with technical help. I also thank V.R. Ferris, A.M. Golden, F. Lamberti, S. Lewis, R. Robbins, M.R. Siedlaci, and A.C. Tarjan for their opinions on identifications of certain specimens.

REFERENCES

34. SCHMITT, D.P. 1973a. Population fluctuations of some plant parasitic


