Plant-Parasitic Nematodes of Michigan: With Special Reference to the Genera of the Tylenchorhynchinae (Nematoda)

Michigan State University Agricultural Experiment Station and Cooperative Extension Service

Research Report

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Plant-Parasitic Nematodes of Michigan:

With Special Reference to the Genera of the Tylenchorhynchinae (Nematoda)[1]

TECHNICAL Information

Introduction

Plant-parasitic nematodes are known to be associated with most agricultural crops produced in Michigan. In many cases they have been shown to cause significant economic losses through relationships as pathogens, predisposition agents or vectors of plant viruses. The objective of this publication is to record the history of phytonematology in Michigan and summarize information about the nature, occurrence and distribution of plant-parasitic nematodes in the state.

The history is presented in two parts, an overall review of the topic and a first printing of a 1953 report by B. G. Chitwood to the Director of the Michigan Agricultural Experiment Station. The occurrence and distribution of plant-parasitic nematodes in Michigan is presented through a listing of all of the known species (1962-1974), taxonomic keys, geographical distribution maps and references to these species, and redescriptions of the Michigan species of the Tylenchorhynchinae.

[1]Including a 1953 nematology report by B. G. Chitwood to the Michigan Agricultural Experiment Station.
[2]Former Nematode Taxonomist, Dept. of Entomology, Michigan State University.
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Plant-Parasitic Nematodes of Michigan:
With Special Reference to the Genera of the Tylenchorhynchinae (Nematoda)[1]

By Natalie Knobloch[2] and G. W. Bird[3]

History Of Michigan Phytonematology

Michigan is unique in the North Central Region of the United States because of its diversity of nematode-susceptible agricultural crops, widespread distribution of soil types that favor nematode reproduction and phytopathogensis, and agricultural climate moderated by the Great Lakes. At least 25 crops grown in Michigan are known to be influenced in a detrimental manner by phytopathogenic nematodes, and economic losses are *circa* $75 million annually. While the science of nematology in Michigan did not grow and develop as rapidly as in some areas of the United States, Michigan has a diverse and interesting nematology history, and one that has been influenced by several of the major personalities in U.S. nematology.

In 1911, Dr. E. A. Bessey (1877-1957), Professor of Botany, Michigan Agricultural College and Collaborator, U.S.D.A., Bureau of Plant Industry, published a major nematological contribution entitled, "Root-knot and Its Control". It was popularized and published as a Farmer's Bulletin in 1915. E. A. Bessey[1] was the son of C. E. Bessey (1845-1915),[2] a Michigan Agricultural College graduate '69 and well known U.S. botanist.

E. A. Bessey's interest in phytonematology developed during his Ph.D. program at Halle University in Germany '04, and his tenure as a U.S.D.A. scientist in southeastern U.S. and Professor of Botany at Louisiana State University. He was also influenced by Professor G. F. Atkinson of Alabama Polytechnical Institute and Dr. J. C. Neal, special agent for the U.S.D.A.

During his travels as a U.S.D.A. agricultural explorer (1902-05), E. A. Bessey differentiated between summer crimp and spring crimp bud diseases of strawberries. In 1942, *Aphelenchoides besseyi* was named in his honor by J. R. Christie. E. A. Bessey, like his father, became a world renowned botanist and influential administrator He specialized in mycology, served as chairman of the Department of Botany and Plant Pathology and dean of the School of Graduate Studies at Michigan State. Bessey Hall was constructed on the M.S.U. campus in

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[1]Ernst Athearn Bessey (1877-1957)

University of Nebraska, B.Sc., 1896
University of Nebraska, M.Sc., 1898
Halle University, Germany, Ph.D., 1904
U.S.D.A. Div. of Vegetable Physiology and Pathology, Asst. Pathologist, 1899-1901
U.S.D.A. Office of Seed and Plant Introduction, Officer-in-Charge, 1901-1902
U.S.D.A. Agricultural Explorer, 1902-1904
U.S.D.A. Bureau of Plant Industry, Pathologist, 1904-1908
U.S.D.A. Subtropical Laboratory and Garden, Miami, Director 1905-1908
Louisiana State University, Professor of Botany, 1908-1910
Michigan Agricultural College, Professor of Botany, and Chairman, Department of Botany and Plant Pathology, 1910-1945
Michigan State College, Dean of the Graduate School, 1930-1944
Michigan State College, Distinguished Professor of Botany, 1945

Selected Contributions

Bessey, E. A. (1911). Root-knot and its control. U.S.D.A. Bureau of Plant Industry Bulletin 217. 89 pp.

Bessey, E. A. and L. P. Byars (1915). The control of root-knot. U.S.D.A. Farmer's Bulletin 648. 19 pp.

Bessey, E. A. (1939). *Text-Book of Mycology.* P. Blakiston's Son & Co., Inc. Phila. 495 pp.

Bessey, E. A. (1950). *Morphology and Taxonomy of the Fungi.* The Blakiston Co. Phila. 791 pp.

[2]Charles Edwin Bessey (1845-1915)

Michigan Agricultural College—Class of 1869 (Horticultural major under Professor A. N. Prentiss '62; however, influenced greatly by Professor A. J. Cook '67).
Professor of Botany, Iowa State University
Professor of Botany and Academic Dean, University of Nebraska

Selected Contributions

Bessey, C. E. (1880). *Botany for High Schools and Colleges.* Henry Holt and Co., N.Y. 611 pp.

Bessey, C. E. and E. A. Bessey (1914). *Essentials of College Botany.* Henry Holt and Co., N.Y. 400 pp.

1961, and serves as a constant reminder of E. A. Bessey's impact on the stature of biology at Michigan State University.

Margaret V. Cobb surveyed fresh-water nematodes of the Douglas Lake region of Michigan in the summer of 1913. Her work was sponsored by a research fellowship from the University of Michigan Biôlogical Station, and performed under the supervision of Professor Frank Smith of the University of Illinois. The collection consisted of 12 known species, eleven new species described in her publication (Cobb, 1915), seven unidentified *Dorylaimus*, *Plectus*, *Rhabditis*, and *Monhystera* spp. and six new species described by N. A. Cobb (Cobb, 1914). *Dolichodorus hetercephalus* was one of the new fresh-water species described from the Douglas Lake region by N. A. Cobb.

Professor Gerald Thorne (1890-1975) made his first of several professional visits to Michigan in 1920, to conduct a *Heterodera schachtii* survey in Michigan's sugar beet growing region. It was not until 1948, however, that Bockstahler (1950) found *H. schachtii* in Michigan.

In 1953 the Michigan Agricultural College Experiment Station commissioned B. G. Chitwood (1907-1972) to evaluate the significance of plant-parasitic nematodes in Michigan. He was housed in the Department of Entomology and provided with graduate assistants. At the conclusion of his six month study, he recommended that the Experiment Station hire a nematologist for each of the following three areas: 1) Nematodes associated with crops grown in muck soil, 2) Nematodes associated with fruit crops, nurseries and forests, and 3) Nematodes associated with field crops.

As a result of these recommendations, Dr. J. A. Knierim was hired by the Department of Entomology in 1954, to develop research, extension and teaching programs in nematology. The first published survey of nematodes associated with a Michigan agricultural crop was made by the Beet Sugar Development Foundation, and released in 1957 as "A Study of Incidence of Nematodes in Sugar Beet Production".

During the developmental years for soil fumigants (1,3-D and DBCP), Michigan phytonematology was influenced by Dr. C. E. Dieter and other scientists from the Dow Chemical Company, Midland, Michigan. Work was frequently coordinated with MSU scientists such as Dr. Robert Lucas. For the past 20 years, M. K. Hanna has actively served as regulatory nematologist for Plant Industry Division of the Michigan Department of Agriculture.

Mrs. Natalie Knobloch was hired in 1962 to direct the Nematode Diagnostic Service Laboratory operated by the Michigan Cooperative Extension Service. In 1963 J. A. Knierim reported that northern root-knot, root-lesion, sugar beet-cyst, stubby-root and onion bloat nematodes were the most economically important phytopathogenic nematodes in Michigan (Knierim, 1963). He found, however, that the root-lesion and dagger nematodes were the most widely distributed plant parasitic genera.

In 1963, Dr. Paul Wooley (1924-1968), an extension entomologist, was given the responsibility of directing the nematology program. Between 1963 and 1969 several nematology consultants visited the state. Professor W. F. Mai made a nematology presentation to the 1964 Annual Meeting of the Michigan Agricultural Pesticide Association. Early in 1967, Dr. J. M. Ferris and Dr. V. R. Ferris served as visiting professors and taught a phytonematology course. Two years later the course was taught by Dr. H. W. Stein (Liebig Univ., W. Germany).

Early in 1969 Mrs. Knobloch studied in Professor Thorne's laboratory at the University of Wisconsin, and during the fall of 1969 Professor Thorne returned to M.S.U. as a temporary consultant. Mrs. Knobloch's taxonomic contributions and annual collecting trips to Mexico were greatly influenced by her correspondence and association with Professor Thorne.

Late in 1969, Dr. C. W. Laughlin, formerly Extension Nematologist, University of Florida, was appointed to develop and direct the Michigan State University teaching, research and extension programs in phytonematology. During the fall of 1970, Dr. M. Brzeski served as a visiting research professor.

In the mid 1960's, B. G. Chitwood returned to Michigan and settled in Marquette in the Upper Peninsula. He served as a biological consultant at Northern Michigan University, initiated a florist and nursery business, and was one of the Society of Nematologist's most active contributors to the Nematology News Letter. In the spring of 1972, the junior author of this contribution accidently forwarded B. G. Chitwood a blank Society of Nematologists election ballot. It was promptly returned with a few humorous notations and a most delightful letter about his recent activities and future plans. B. G. Chitwood died from a heart attack on November 19, 1972, in Marquette, Michigan.

In 1973, Dr. Laughlin was appointed Assistant Director of Academic and Student affairs of the M.S.U. College of Agriculture and Natural Resources, and Dr. G. W. Bird, former Nematologist, Canada Department of Agriculture and Associate Professor of Nematology, University of Georgia, was appointed to coordinate the Michigan State University phytonematology programs. The present research program is designed around a project entitled, "Nematode Population Management in Michigan Crop Production," and it is hoped that this will be incorporated into the overall interdisciplinary pest management program that has been developed at M.S.U. during the past decade.

The basis of the extension program is the M.S.U. Nematode Diagnostic Service Laboratory, which is operated in conjunction with local extension agents (Bird and Elliott, 1980). The formal academic program is comprised of an undergraduate nematology course, Nematode Diseases of Economic Plants, and a graduate-level course, The Biology of Nematodes.

In 1972, John Davenport was hired to coordinate field research activities. Natalie Knobloch retired (1978) and her position was filled by Lindy Rose. With Dr. Bird's 1979 appointment as Acting Chairman of the Department of Entomology, Dr. Alma Elliott was promoted to the rank of Instructor of Nematology. On January 1, 1980, Dr. Bird assumed the role of part-time Director of Integrated Pest Management Programs for the College Agriculture and Natural Resources, and plans were initiated to acquire an additional nematologist. Dr. John A. Knierim retired on September 30, 1980.

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Plant-Parasitic Nematode Problems In Michigan[1]

By B. G. Chitwood[2]

A nematode survey of Michigan indicated three basic agricultural needs. Each may require a full-time scientist.

1. Vegetable and speciality crops (predominantly muck farms).
2. Orchards, vineyards, berries, cover crops, nurseries, and forests.
3. Field crops.

1. Vegetable and Speciality Crops

Plant-parasitic nematodes are extremely important in all the muck areas of the state. Most of the plant parasites causing damage were probably introduced into these lands; however, root-lesion, and perhaps spiral and pin nematodes are native.

Onions are infected with many plant-parasitic nematodes. One, the potato rot nematode *(Ditylenchus destructor)*, is a subject of quarantines in some areas. It has been found on one farm and a separate report submitted. Other nematodes causing trouble on onions include root-knot nematodes *(Meloidogyne* spp.), root-lesion nematodes, spiral nematodes, and stubby root nematodes *(Trichodorus*, according to Dieter). There is probably some specificity or resistance among varieties.

Lettuce, radishes, carrots, tomatoes, celery, rutabaga, and most of the other vegetable crops are affected by a variety of plant nematodes. In the case of mixed infections, with our present knowledge, no crop rotational plans can be presented.

Soil fumigation is usually economical where the infestations are heavy. One of the problems of vegetable farmers is keeping their land free of introduced pests, especially on clean or newly opened land. *Plants and potatoes used in rotation are the chief means of introducing diseases.*

A means of obtaining root-knot free potatoes has been proposed. Plant beds should be fumigated in most instances. Thorough and proper study of the nematode genera and species in muck lands might make rotational programs sound. Mints and wormwood are affected by pin nematodes, probably with considerable damage.

Soil fumigation has been used in the case of wormwood. Host range and host specificity studies for pin nematodes are in order. Related forms are involved in the truck crop lands in the Beulah area. The matter of developing clean mint plants should be investigated.

2. Orchards, Vineyards, Berries, Cover Crops, Nurseries, Florists and Forests

Peach, cherry, apple, and pear orchards have nematodes associated with poor yields, poor growth, and deficiencies. These problems are complex with many ramifications. The nematodes associated with the problems most generally are various local and introduced species of root-lesion nematodes. Ectoparasites such as dagger, ring and stubby-root nematodes are probably native—the ectoparasites may be the causes of the most extensive losses.

All of these organisms can, at times, be found on the grasses used as cover crops in orchards. Some are native to the indigenous trees in the forests. Site fumigation is being tried in some orchards and has been found particularly beneficial in cherry orchards. More will be accomplished by obtaining clean or resistant understocks and studying the parasites' host range. Orchards constitute a large nematode problem, but it is questionable as to which organisms are the most serious. Site fumigation is all that can be suggested; drenches are possible, but not recommended.

Stunting and poor yields in vineyards may be caused by ring or dagger type nematodes. Both organisms are probably native, transferred from forests.

The blackberry, raspberry, and blueberry nematode problems are closely related to forest and wild berry organisms, with some imported species. Blackberries are infected with ring nematodes, dagger nematodes, and members of the *Tylenchus costatus* group. All of these are apparently parts of the native fauna. Immune understock is the long range answer.

Raspberries are infected with root-lesion nematodes, dagger nematodes and root-knot nematodes. The dagger nematodes and perhaps some of the meadow nematodes are native. Finding resistant types, use of soil fumigation and obtaining clean stock are the proper procedures for the present.

Blueberries are infected with root-lesion nematodes, *Tylenchus*, and *Tylencholaimus*. Perhaps other nema-

[1]B. G. Chitwood, 1953, Michigan Agricultural Experiment Station, Report to the Director.
[2]Edited by G. W. Bird.

todes would be involved with wider study.

Nurseries and the distribution of nursery stock constitutes one of the most serious methods of distribution of all plant nematode diseases. Little time was spent on this subject during the present survey. Root-lesion nematodes and root-knot nematodes are the most general ones. According to Steiner and Tarjan, boxwood is infected with root-lesion nematodes which cause considerable difficulty. There is no recommended remedy at present, but plant treatment, sterile cuttings, and soil fumigation at sites, and perhaps drenches, are in order.

Pachysandra terminalis was found infected with spiral nematodes. Forest seedlings (pine) was infected with ring nematodes, dagger nematodes, and other parasites. Fumigation of nursery soil might get the plants off to a good start, but, since all forests have natural nematode stations, search for tolerant, resistant, or immune types will be of lasting benefit. (This consists of helping natural selection go on continuously in nature.)

Hardwoods of lawns and forests have nematode problems, including ring nematodes, root-lesion, root-knot, *Tylenchorhynchus*, *Hemicycliophora*, and various undescribed species. *Nursery inspection could limit the distribution of these pests.* Study of the pathogenecity and host range of many of the organisms should be made, for with such knowledge, and an understanding of the natural fauna of an area, naturally resistant species could be encouraged.

It is questionable in which category strawberries should be placed, but due to shipping of the plants, they are placed here. They also fit well with truck and speciality crops. Root-lesion, root-knot nematodes, and bud eelworms are the chief pests. Production of root disease-free plants by runners and planting in fumigated soil is in order. Hot water treatment can be done in the dormant stage. Movement of strawberry plants should be regulated and subject to inspection—*with the nursery inspector provided with a miscroscope.*

Very little emphasis was placed on floricultural crops. On the whole, however, florists (commercial) are aware of nematode diseases caused by root-knot and foliar nematodes. Carnation soil contained pin nematodes, root-lesion, ring nematodes, and *Tylenchorhynchus*. For these problems, florists should consider soil sterilization. Roses were found to have root-lesion nematodes.

Field grown peonies were infected with root-knot nematodes and treated under the supervision of nursery inspectors. Pin nematodes were found on weeds in a field used for this crop, and may be detrimental in tulip production. Both florists visited had nematode problems they did not know about; unfortunately, the florist and nursery industries are usually suspicious of inspections; they fear regulation and restriction, particularly of things like potted plants.

3. Field Crops

Field crops included potatoes, cabbage, oats, wheat, barley, corn, sugar beets, alfalfa, and clover. The sugar beet cyst nematode in Michigan and its control were reported by Bockstahler (1950). With the exception of sugar beets, field crops do not warrant soil fumigation. This suggests a need for careful analyzing of the species of nematode pathogens, host ranges, crop rotation schemes, and development of resistant or immune varieties for the other field crops.

Potatoes are a major crop for certified seed and tuber production in both mineral and muck soils. While there are numerous nematode parasites of potatoes, root-knot nematode *(Meloidogyne hapla)* and root-lesion nematodes *(P. scribneri* group) are the most prevalent. Even more serious, however, is the fact that potatoes from root-knot infested fields serve to disseminate root-knot nematodes to non-infested potato fields. This pest is not native. Truck farmers are bothered by *M. hapla* in other crops and have no source of clean seed. A root-knot certification over and above standard certification for the benefit of such farmers is recommended.

Crop rotation and cultural practices are helpful in field crop production; however, since root-lesion nematodes are common in grains (a number of species) and several species are probably native, this is a two edged sword. Grains can be used as a means for control of *M. hapla*. Legumes commonly increase population densities of root-lesion nematodes. Investigation of grain and legume varieties for resistance to both root-lesion and root-knot nematodes is essential. This could be done at the Upper Peninsula Experiment Station at Charham and also at Houghton.

Woods in grain fields (i.e., *Viola arvensis*, Allen Nordeen responsible for determination) may explain the carryover of root-knot in grain fields. A third testing center might be the Escanaba area. The nematode fauna of these areas is not markedly different; however, the land and climate differ. Soil fumigation is a good means of checking nematode damage to these crops even though it is not financially sound.

Grains and grasses are important nematode hosts. Damage is expressed in symptoms such as stunting, poor growth, and malnutrition. Nematode populations are increased for other crops. In the case of grasses, this may be particularly important in orchards. Both ectoparasites and endoparasites of several genera are involved.

Root-lesion nematodes are the most prevalent but may not be the most important. For the study of grass parasites in relation to orchards, the Shelby, Cheboygan-Traverse City, Skandia, or Chatham areas are suggested. Identification of cover grasses for orchards that do not serve to propagate pathogens of the orchard trees would be extremely beneficial.

Grains, including oats, wheat, corn, and barley, have a list of nematode pathogens.

The most prevalent nematode on oat, wheat, corn, and barley grains is the root-lesion nematode. *Tylenchorhynchus*, *Ditylenchus*, dagger, ring, and root-knot nematodes have also been found associated with poorly growing plants. Nearly all areas of poor growth in fields abound with these organisms free in the soil or in roots. Soil fumigation tests should be set up to test growth differences in various locations. Isolations of the various pathogens should be made and varietal tests of the isolates analyzed from the standpoint of rate of reproduction and growth differences of the hosts.

In addition to root-knot nematodes, poor spots in clover fields or lawns were found to be associated with *Heterodera trifolii*. *Tylenchus*, a possible new genus near *Hemicycliophora*, *Ditylenchus*, *Pratylenchus*, *Tylenchorhynchus* and *Helicotylenchus*, and ring nematodes were all associated with clover. Identification of the clovers on which these reproduce least is needed.

Too few samples of alfalfa were taken for proper interpretation. The need for additional information about alfalfa is needed. Soybeans in a poor spot were infected with root-lesion nematodes.

APPENDIX

PLANT-PARASITIC NEMATODE PROBLEMS IN MICHIGAN

1. *Heterodera*. Cyst forming parasites of roots.
   - A. *Heterodera schachtii* (sugar beet cyst nematode). This species has been reported from Macomb, Saginaw and Bay Counties. It is a very old and well known pathogen reducing the sugar content as well as the total crop of beets. Known hosts include beets, cabbage, lambsquarters, nightshade, and dock. Control measures include crop rotation, soil fumigation, and inspection of seed for the parasite. Amelioration of damage by added potash in fertilizer.
   - B. *Heterodera weissi* (polygonum smartweed nematode). This species is common in lower Michigan. Only importance as a hazard in identification of parasites of economic crops.
   - C. *Heterodera trifolii* (clover cyst nematode). A parasite of various clovers (some varietal differences) and to some extent other legumes. Causes poor growth, stunting, malnutrition. It is found on white and red clover in Ingham County.
   - D. *Heterodera* spp. At least one more species of *Heterodera*, probably a parasite of an economic crop, has been observed on several occasions. Specimens have never been in identifiable condition. Other species of economic crops that might be expected to occur in this state include: *H. avenae* of oats, *H. goettingiana* of peas and sweet peas, *H. punctata* of wheat and grass, *H. carotae* of carrots, and *H. cruciferae* of crucifers.
2. *Meloidogyne* (Root-knot nematodes). Until recently these nematodes were known as *Heterodera marioni*. A dozen species of this genus are now known, with varied, though overlapping, host ranges. Further divisions of some of the species on both morphological and host range evidence may be necessary. Under various older names, members of the genus have been reported from the majority of counties in the state. The following three species have been identified:
   - A. *Meloidogyne hapla* (Northern root-knot nemotode). Characteristically forms small galls. Hosts from which it has been identified in Michigan include: strawberry (key host), celery (South Haven), carrots (Imlay City), onions (Imlay City), potatoes (Ingham County near Dansville [variable type] and Petoskey), and probably many other centers under the name *H. marioni*.

     Control measures include restriction of infected planting materials, soil fumigation, and crop rotation. Hot water treatment is of use in some florist and nursery operations. Resistant hosts include; grains, yellow globe onions, and *Prunus* spp. Clover and alfalfa, as well as beans, are hosts and besides being injured, serve to increase the soil population by building up a very deep infestation. Peanuts are also a key host. *M. hapla* moves on nursery stock, seed potatoes, and strawberries.
   - B. *Meloidogyne incognita* (Southern or big-gall root-knot nematode) is apparently a native of the southern part of the U.S., Mexico, and various off-shore islands; and is commonly introduced from the south on plants (i.e., tomatoes). Hosts from which it has been identified in this state include: onions (variety and locality not specified), and *Acer saccharum* (Muskegon). Known non-hosts include: strawberry, peanuts, Yunnan and Shalil peach, *Crotalaria mucronata*, and ragweed. *Lycopersicon peruvianum*, alfalfa, and some cottons are resistant. *M. incognita* reproduces well on okra, most grains, watermelon, peppers (California Wonder) and Lovell peach.

     Control measures include crop rotation,

planting of clean stock, restriction of movement of infected planting stock, and soil fumigation.

C. *Meloidogyne arenaria thamesi* (Thame's root-knot nematode) produces a relatively small gall. Its distribution and host range are not well known. Peanut is a key nonhost. It has been identified from *Acer saccharum* (Muskegon), and celery (Beulah). Control measures as above, but host range and key hosts for the most part are not determined. Species that have not as yet been identified but may be expected, at least in greenhouses, include *M. javanica*, *M. incognita acrita*, and *M. arenaria*.

3. *Pratylenchus* (Root-lesion nematodes) are endoparasites of roots commonly causing brown lesions, sloughing, root branching, and sometimes stunting and evidences of malnutrition. Thus far, the host range, specificity (though it exists), and crop rotation procedures have not been worked out. As in the case of the root-knot nematodes, the majority of the records refer to the genus rather than the species. Inoculation studies have seldom been made. Some species are apparently native, while others are introduced in plants, nursery stock, potatoes and strawberry plants. Species which have been identified thus far from the state include:

   A. *P. pratensis*-like cherry (Shelby).

   B. *P. scribneri*, potatoes (Rockford, Mt. Clemens, Reed City, Imlay City); peach roots (Shelby); elm (Muskegon); corn (northeast of Lansing, Swartz Creek). *Ligustrum* prob. *amurense* (Muskegon). Probably native.

   C. *P. vulnus*, cherry (Hart); *Ligustrum* prob. *amurense* (Muskegon); cherry (East Lansing).

   D. *P. minyus*, *Malus pumila niedetskyama* (East Lansing); *Ligustrum* prob. *amurense* (Muskegon).

   E. *P. penetrans*, corn (muck farm north of Lansing).

   Control measures include crop rotation, determinations of host specificity, limitation of movement of infected nursery stock, hot water treatment of perennials, breeding of resistant varieties, and soil fumigation.

4. *Helicotylenchus* (Sprial nematodes). These are semi-ectoparasitic root and tuber parasites. They cause root injury, root branching, and root blindness, perhaps also malnutrition and decline of perennials. *H. nannus*, Yellow Globe onions (Parma, Jackson County); corn (Northeast of Lansing); *Quercus alba* (East Lansing); red clover (east of Lansing); potatoes (Petoskey). Probably native. Control measures include crop rotation, limitation of movement of perennials, hot water treatment of perennials, and soil fumigation.

5. *Hoplolaimus* (Lance nematode). Endo- to semi-ectoparasitic root feeding nematodes. Known elsewhere to attack vegetable crops and fruit plants. *H. coronatus*, *Acer saccharum* (Muskegon); elm (Muskegon).

6. *Tylenchorhynchus* (Stunt nematode). Usually endoparasitic root feeding nematodes. Cause stunting of plants, malnutrition, poor root growth.

   A. *T. dubius*, pine seedlings (Chittenden Nursery, Wellston); peach (South Haven).

   B. *T. claytoni*, potatoes (Rockford).

   C. *T.* sp. near *magnicauda*, Bent grass turf and *Quercus alba* (East Lansing).

   D. *T.* n. sp., corn (Lake Odessa Road, Ionia).

7. *Dolichodorus* (awl nematode). *D. heterocephalus*, parasites of plant roots. First described from Douglas Lake, Michigan. Since found as a pathogen of both aquatic plants, field and vegetable crops. Not recorded on such so far in Michigan.

8. *Hemicycliophora* (Sheath nematode). Members of this genus are relatively sedentary semi-ectoparasitic on plant roots. Cause root lesions, malnutrition and growth limitation.

   A. N. sp. *Quercus alba* (Marquette).

   B. N. sp. red clover (east of Lansing).

9. *Criconema* (Scaly nematode). Sedentary ectoparasites of plant roots, causing root lesions, growth limitation and malnutrition. *C. octangulare*, *Acer saccharum* (Muskegon).

10. *Criconemoides* (Ring nematodes). Sedentary ectoparasites of plant roots, causing lesions, malnutrition, leaf dropping and replanting problems in orchards; also stunting and chlorosis in some field crops.

    A. *C. simile*, peach (South Haven); wormwood (Vandalia).

    B. *C.* sp., *Quercus borealis* (Marquette).

    To genus only: elm (Muskegon); *Acer saccharum* (Muskegon); potatoes (Rockford); spirea (South Haven).

11. *Paratylenchus* (Pin nematode). Sedentary ectoparasites of plant roots, reducing growth and causing malnutrition. *P.* sp. potatoes (Rockford); white pine (Wellston); celery (Kalamazoo); tulip (Kalamazoo); new species, mint (north of Lansing); sugar beets (north of Lansing); another sp., cherry (East Lansing).

12. *Xiphinema* (Dagger nematode). Ectoparasitic on plant roots, migrant, apparently the cause of decline, stunting, chlorosis and replanting problems.

A. *X. americanum*, wormwood (Vandalia), strawberry (South Haven); peach (Paw Paw); corn (east of Davidson, 2 miles west of Lapeer).

B. *X.* sp., cherry (East Lansing); *Ulmus americana* (East Lansing); peach (Paw Paw).

Taxonomy, Taxonomic Keys And Distribution Of The Plant-Parasitic Nematodes Of Michigan

Between 1962 and 1974, Natalie Knobloch processed *circa* 6,000 soil samples and identified the plant-parasitic nematode species present. Seventy-eight species were identified from sites in Michigan. This section describes the nature and distribution of the species.

The following seventy-eight plant-parasitic nematode species are known to be present in Michigan (Figs. 1-31):

Aschelmintha
- Nematoda
  - Secernentea
    - Tylenchida
      - Tylenchina
        - Atylenchoidea
          - Atylenchidae
            - Atylenchus
              1. *A. decalineatus*
        - Criconematoidea
          - Criconematidae
            - Criconematinae
              - Criconema
                2. *C. cobbi*
                3. *C. fimbriatum*
                4. *C. menzeli*
              - Lobocriconema
                5. *L. serratum*
                6. *L. thornei*
              - Nothocriconema
                7. *N. mutabile*
                8. *N. permistum*
                9. *N. petasum*
                10. *N. princeps*
                11. *N. sphagni*
            - Macroposthoniinae
              - Macroposthonia
                12. *M. axesta*
                13. *M. curvata*
                14. *M. ornata*
                15. *M. reedi*
                16. *M. xenoplax*
              - Xenocriconemella
                17. *X. macrodora*
            - Hemicycliophorinae
              - Hemicycliophora
                18. *H. similis*
                19. *H. uniformis*
                20. *H. vaccinium*
                21. *H. vidua*
        - Tylenchulidoidea
          - Paratylenchidae
            - Paratylenchinae
              - Paratylenchus
                22. *P. hamatus*
                23. *P. projectus*
              - Gracilacus
                24. *G. acicula*
                25. *G. straeleni*
          - Tylenchulidae
            - Sphaeronematinae
              - Trophonema
                26. *T. arenarium*
        - Tylenchoidea
          - Tylenchidae
            - Ditylenchinae
              - Ditylenchus
                27. *D. dipsaci*
            - Tylenchinae
              - Tylenchus
          - Hoplolaimidae
            - Hoplolaiminae
              - Hoplolaimus
                28. *H. galeatus*
            - Rotylenchinae
              - Rotylenchus
                29. *R. buxophilus*
                30. *R. robustus*
              - Helicotylenchus
                31. *H. californicus*
                32. *H. crenacauda*
                33. *H. digonicus*
                34. *H. platyurus*
                35. *H. pseudorobustus*
          - Dolichodoridae
            - Dolichodorinae
              - Dolichodorus
                36. *D. heterocephalus*
          - Pratylenchidae
            - Pratylenchinae
              - Pratylenchus
                37. *P. crenatus*
                38. *P. neglectus*
                39. *P. penetrans*
                40. *P. scribneri*
                41. *P. vulnus*
            - Radopholinae
              - Hirschmanniella
                42. *H. gracilis*
              - Pratylenchoides
                43. *P. laticauda*
          - Tylenchorhynchidae
            - Tylenchorhynchinae

Tylenchorhynchus
44. *T. agri*
45. *T. clarus*
46. *T. claytoni*
47. *T. dubius*
48. *T. martini*
49. *T. maximus*
50. *T. nudus*
51. *T. parvus*
Quinisulcius
52. *Q. acti*
53. *Q. acutus*
54. *Q. capitatus*
Merlinius
55. *M. brevidens*
56. *M. joctus*
57. *M. microdorus*
58. *M. tessellatus*
Geocenamus
59. *G. longus*
Heteroderoidea
Heteroderidae
Heterodera
60. *H. iri*
61. *H. schachtii*
62. *H. trifolii*
63. *H. weissi*
Meloidogynidae
Punctodera
64. *P. punctata*
Meloidogyne
65. *M. hapla*
66. *M. microtyla*
67. *M. naasi*
68. *M. sp. n.*
Nacobbidae
Nacobbinae
Nacobbus
69. *N. batatiformis*
Adenophorea
Dorylaimida
Dorylaimina
Longidoroidea
Longidoridae
Longidorinae
Longidorus
70. *L. elongatus*
Xiphinemidae
Xiphinema
71. *X. americanum*
Diphtherophorina
Trichodoroidea
Trichodoridae
Trichodorinae
Trichodorus
72. *T. proximus*
73. *T. primitivus*
74. *T. similis*
Paratrichodorus (Atlantadorus)
75. *P. (A.) atlanticus*
76. *P. (A.) pachydermus*
77. *P. (A.) porosus*
(Nanidorus)
78. *P. (N.) christiei*

The following outlines the taxonomy (including references) and distribution of the seventy-eight species recovered between 1962 and 1974. The distribution maps are arranged alphabetically.

PLANT-PARASITIC NEMATODES
(Represented by Only One Species)

Atylenchus decalineatus, Cobb, 1913.
Ditylenchus dipsaci, Filipjev, 1936; phlox, garlic
Dolichodorus heterocephalus Cobb, 1914; beach grass, trees in woods
Hirschmanniella gracilis (deMan, 1880) Luc & Goodey, 1963; woods, Douglas Lake
Hoplolaimus galeatus (Cobb, 1913) Thorne, 1935; Fig. 6
Longidorus elongatus (deMan, 1876) Thorne and Swanger, 1939; mint
Pratylenchoides laticauda Braun & Loof, 1967; mint, Fig. 14
Trophonema arenarium Raski, 1956; woods, Douglas Lake
Xiphinema americanum Cobb, 1913; Fig. 31

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Man, J. G. de. (1876). Onderzoekingen over vrij in de aarde levende Nematoden. Tijdschr. Nederl. Dierk. Vereen. 2:78-196, pls. 3-13, figs. 1-51.

Man, J. G. de. (1880). Die einheimischen, frei-in der reinen Erde und im sussen Wasser lebende Nematoden. Tijdschr. Ned. Dierk. Vereen 5, 1-104.

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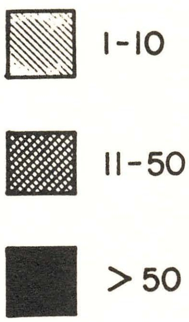
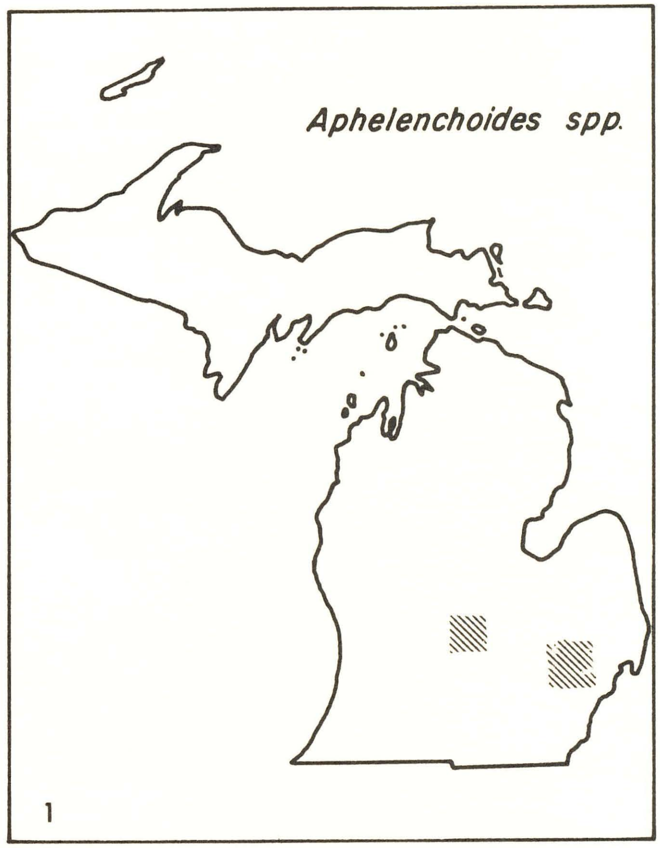
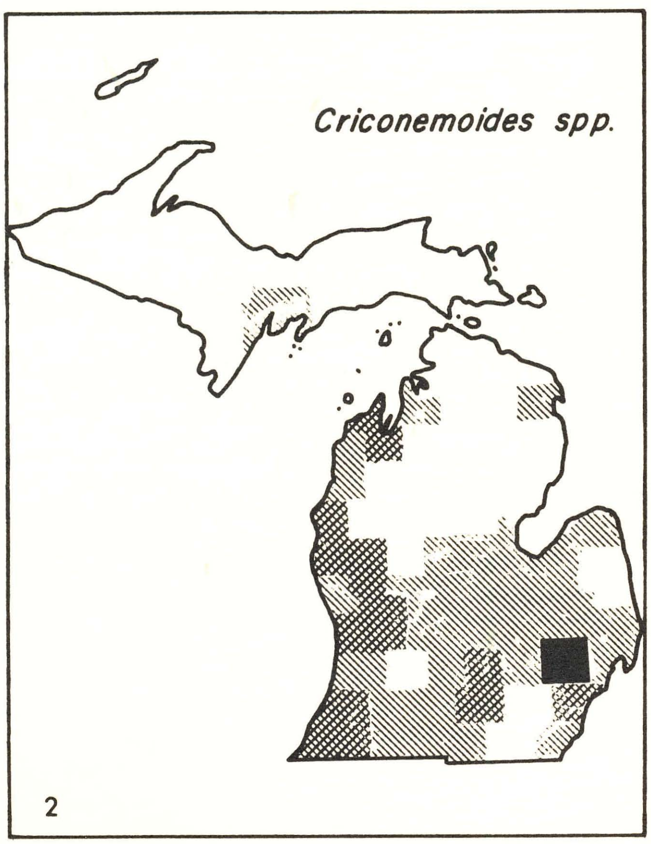
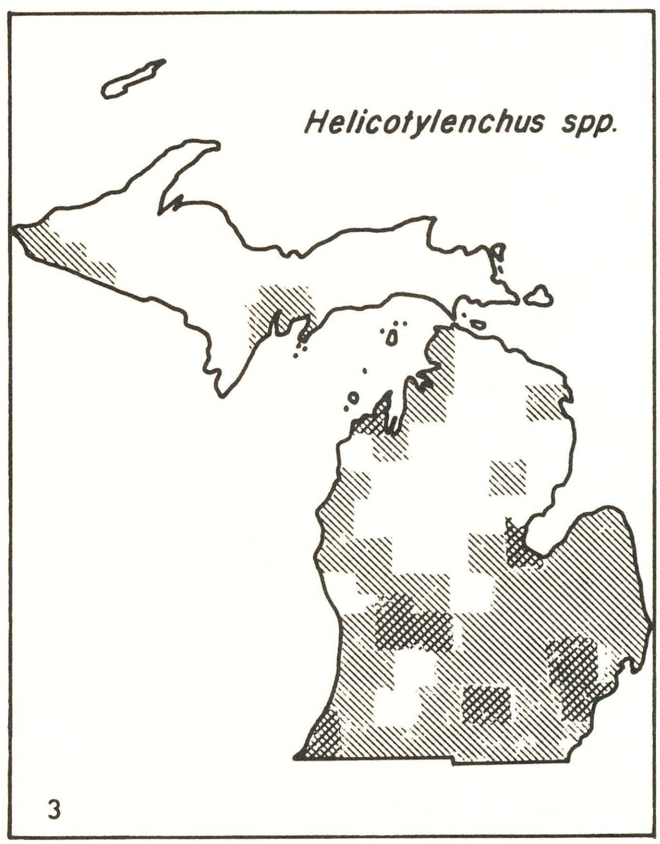
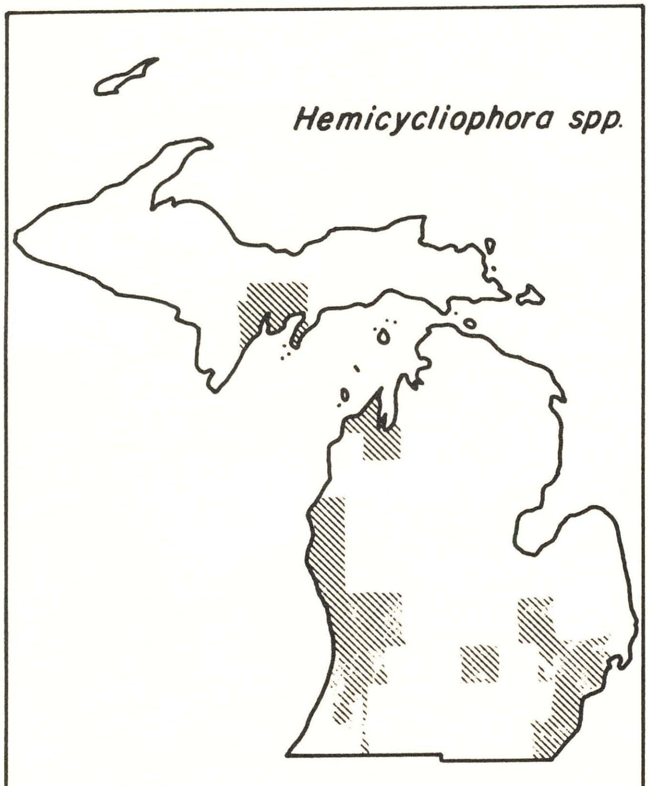
Figs. 1-31 Number of samples containing respective nematode species per 100cc of soil.



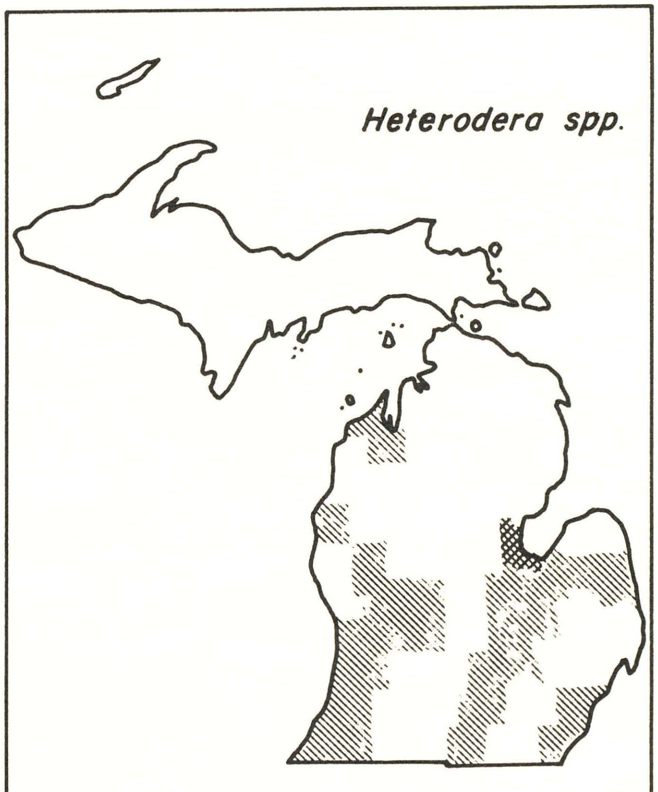




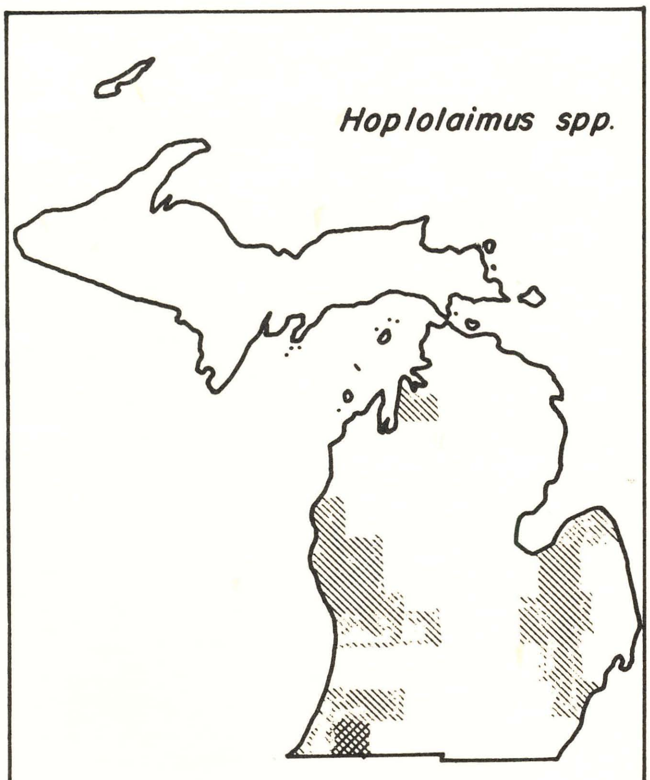



Hemicycliophora spp.

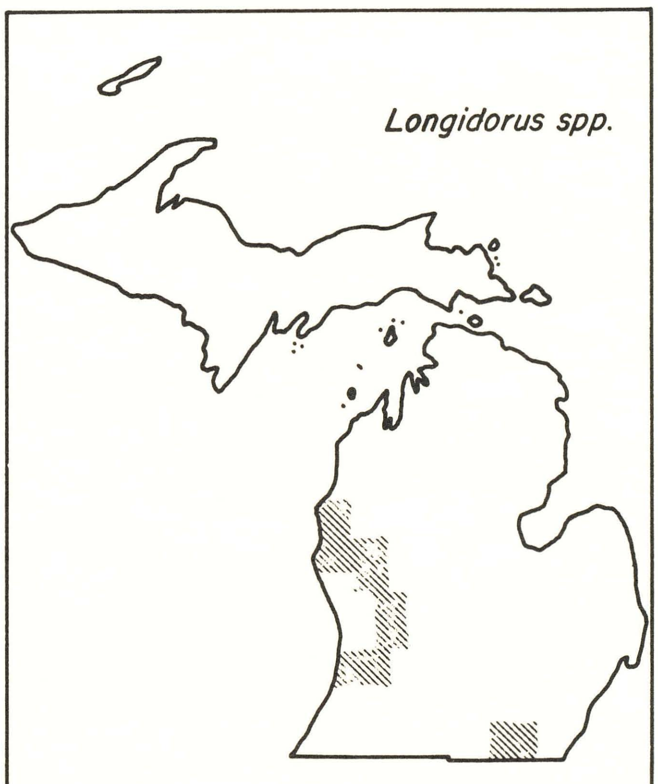
4


Heterodera spp.

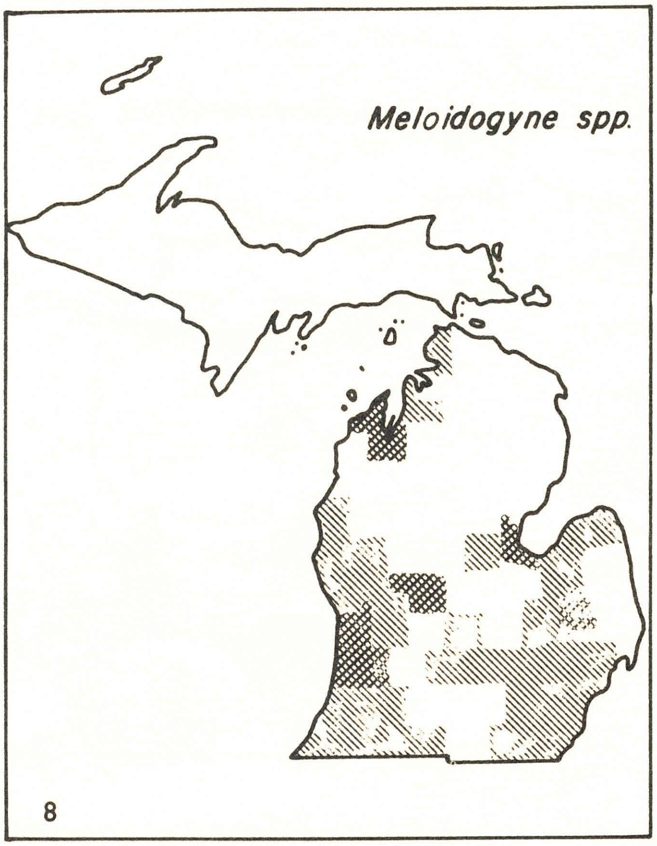
5

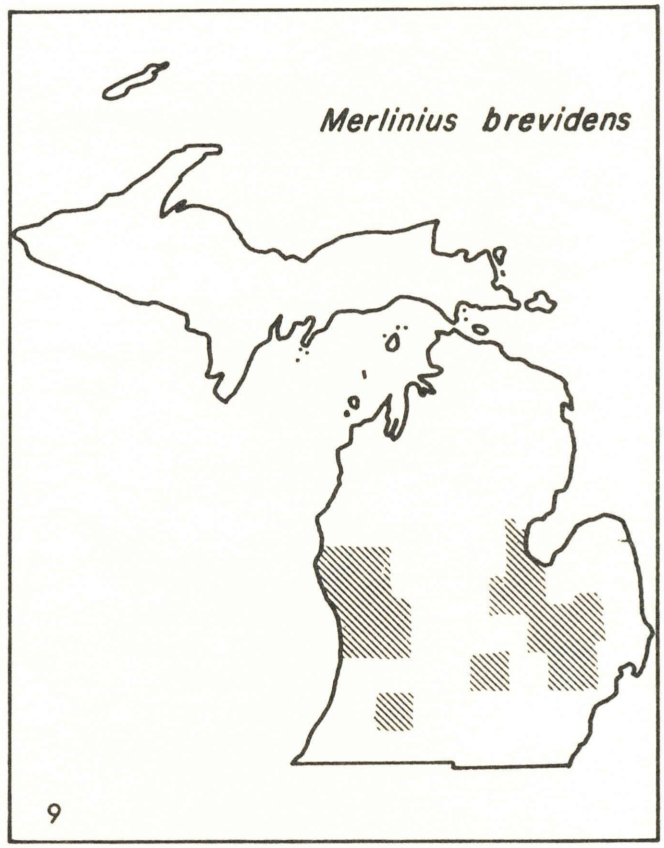

Hoplolaimus spp.

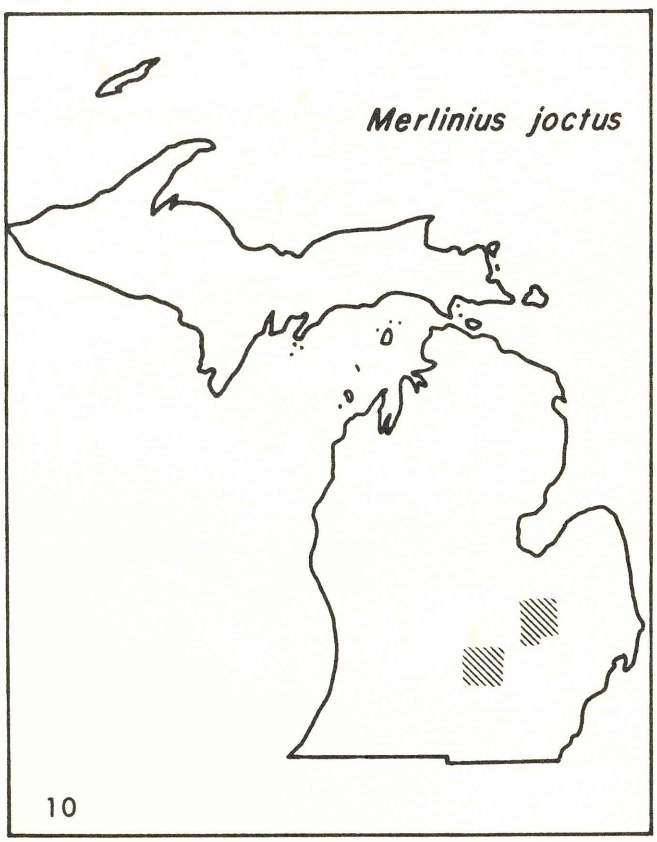
6

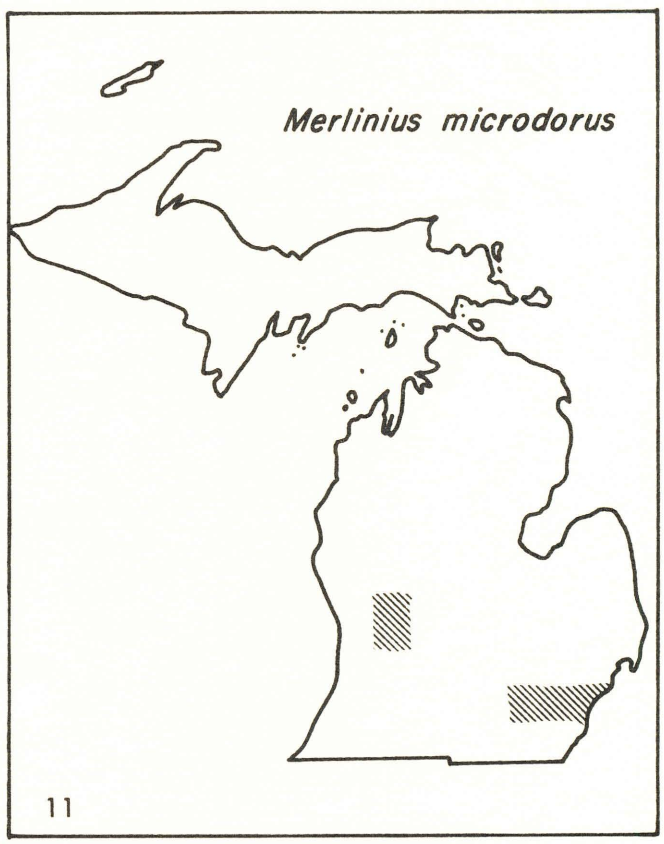

Longidorus spp.

7


Meloidogyne spp.
8

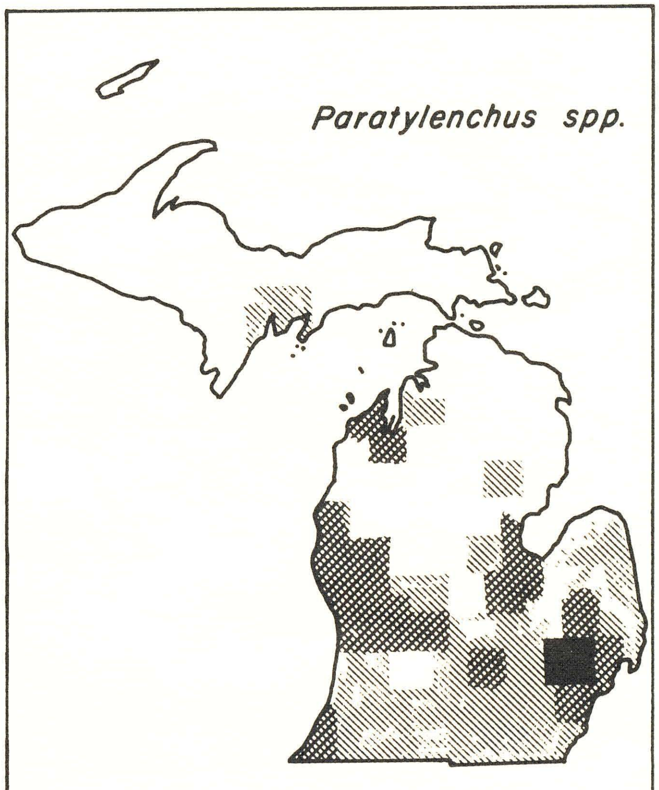

Merlinius brevidens
9


Merlinius joctus
10

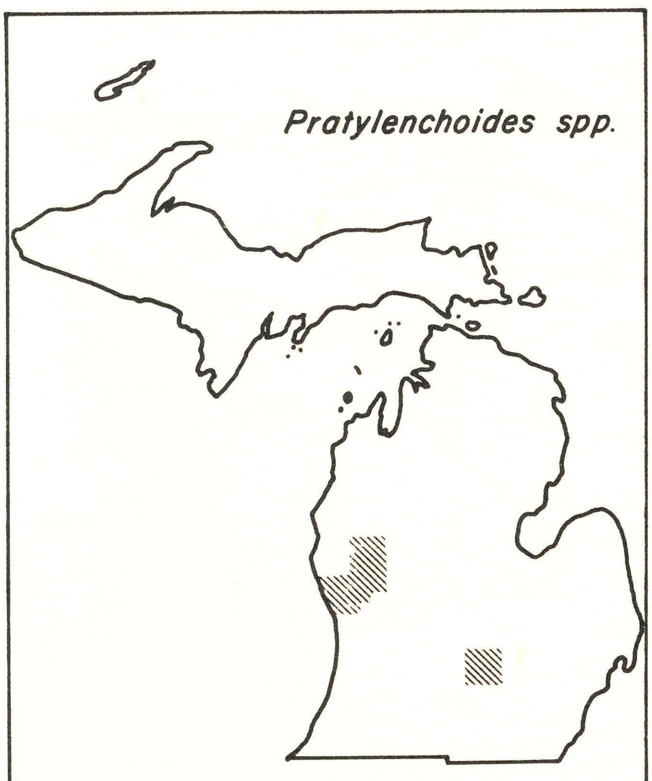

Merlinius microdorus
11


Merlinius tessellatus

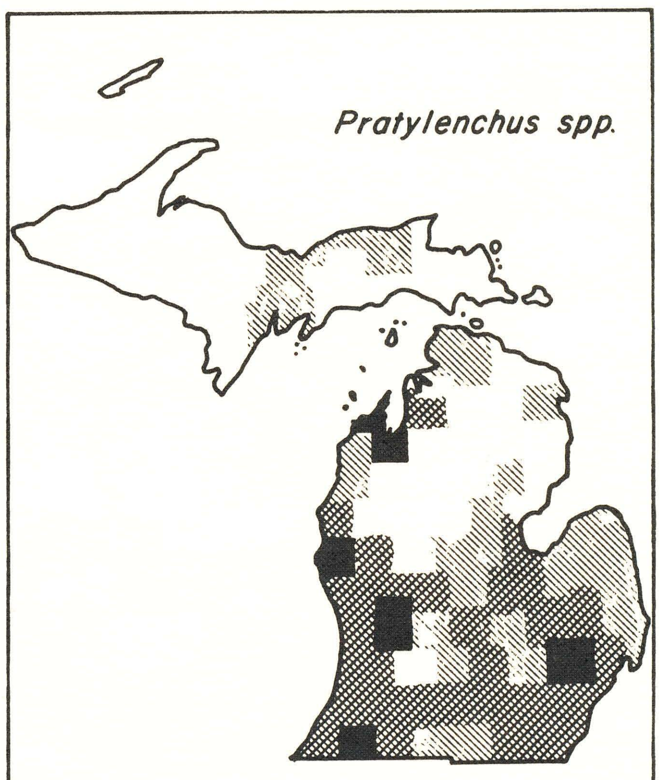
12


Paratylenchus spp.

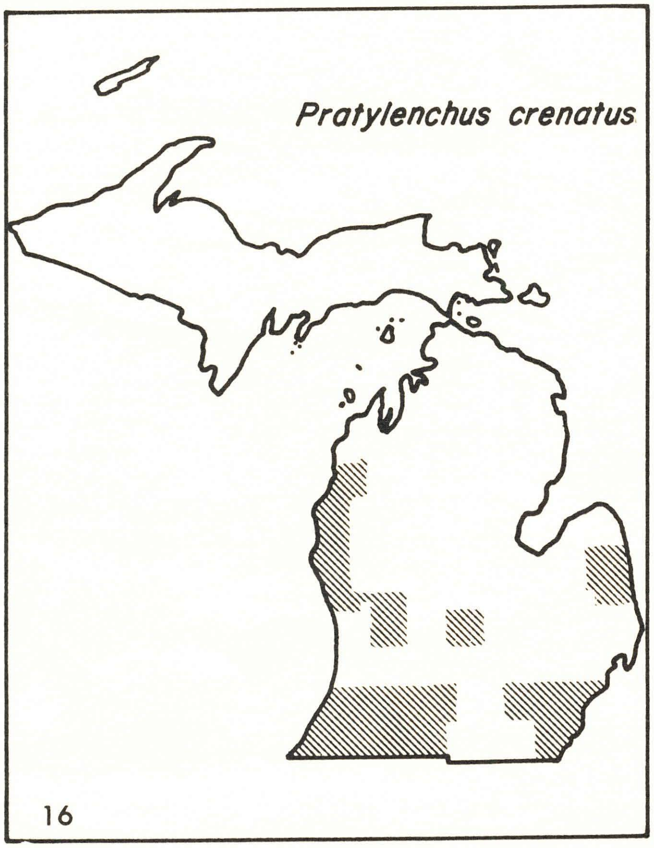
13

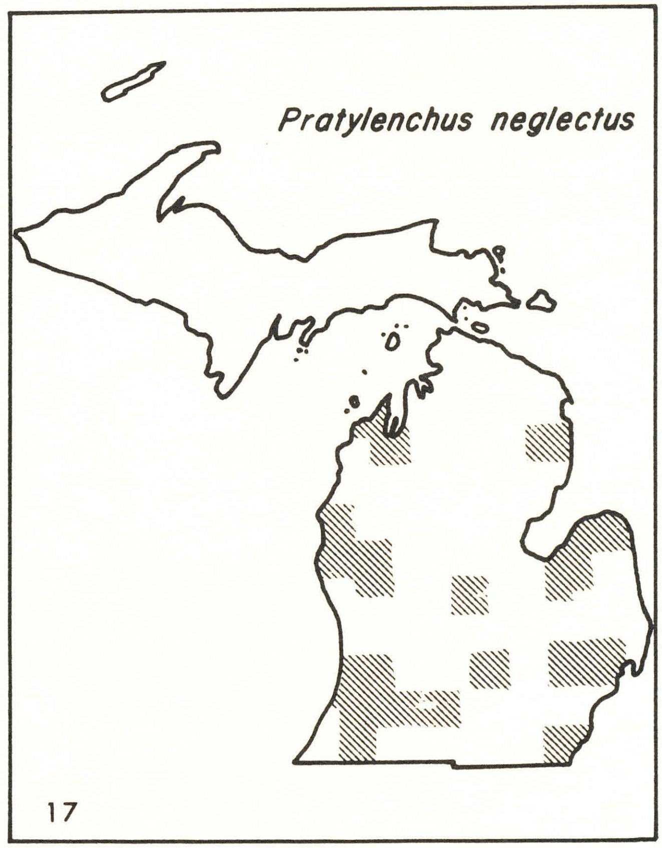

Pratylenchoides spp.

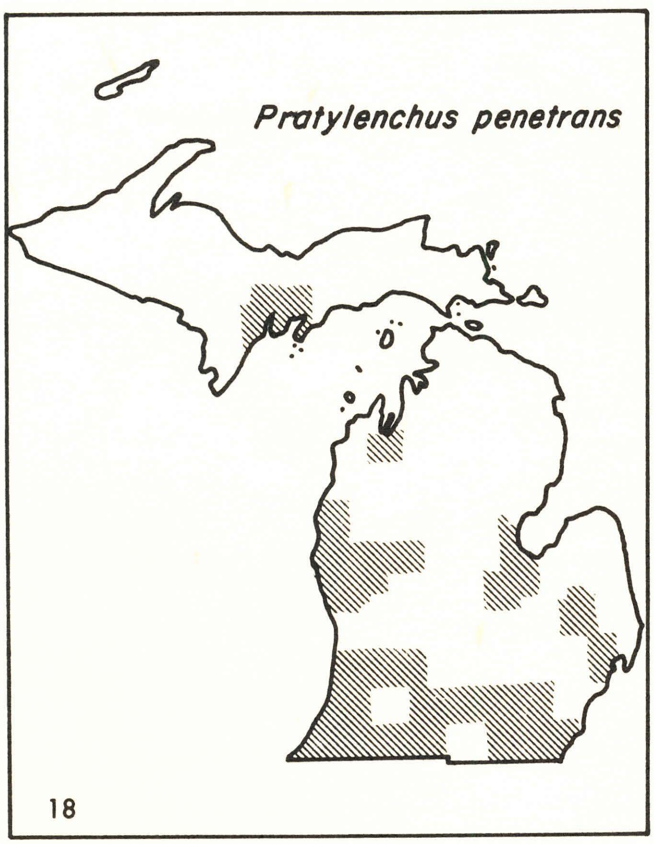
14

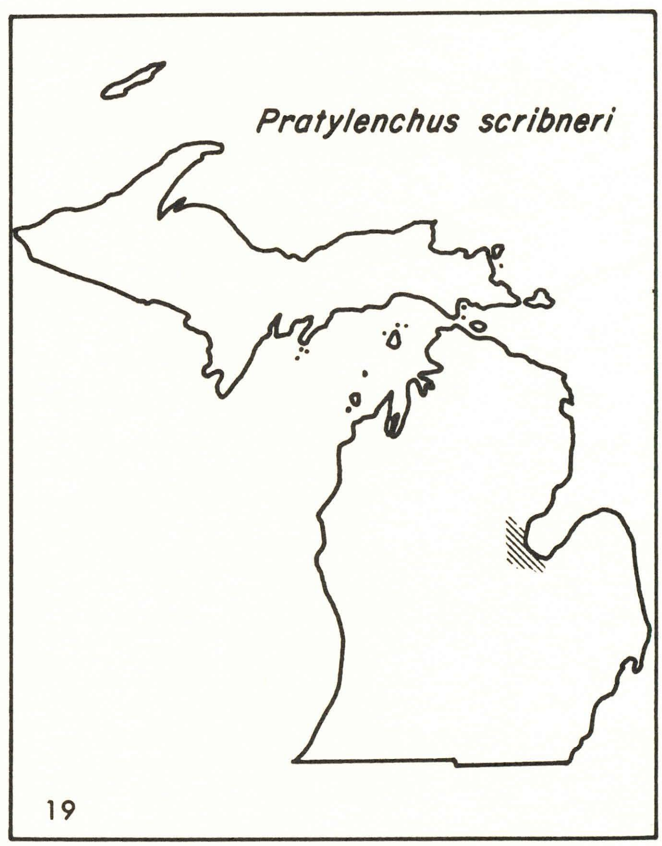

Pratylenchus spp.

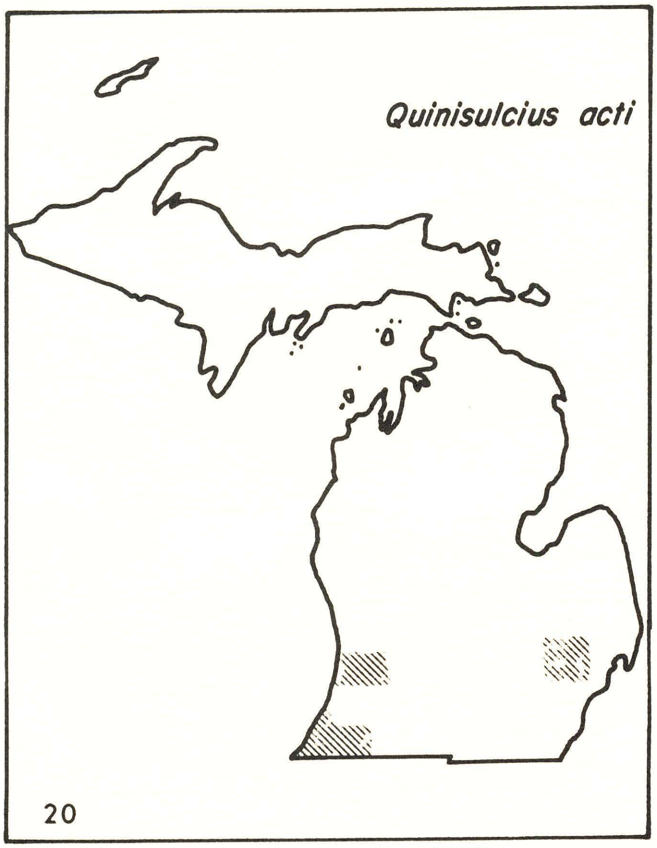
15

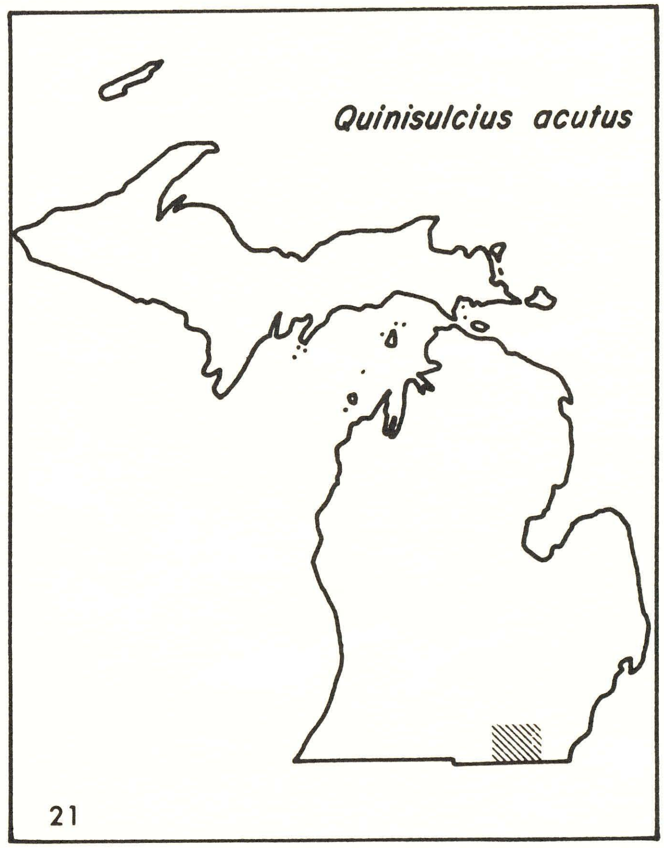

Pratylenchus crenatus
16

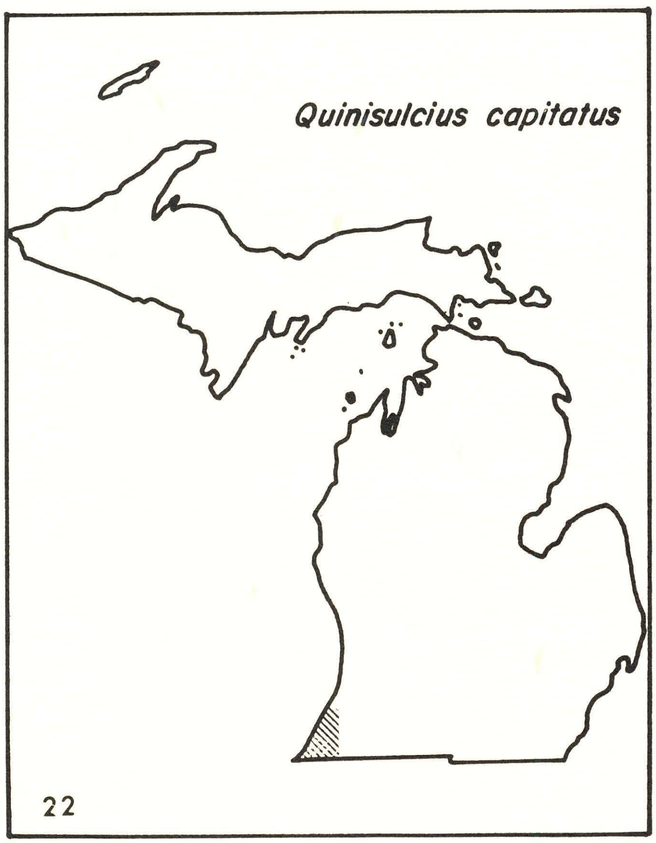

Pratylenchus neglectus
17

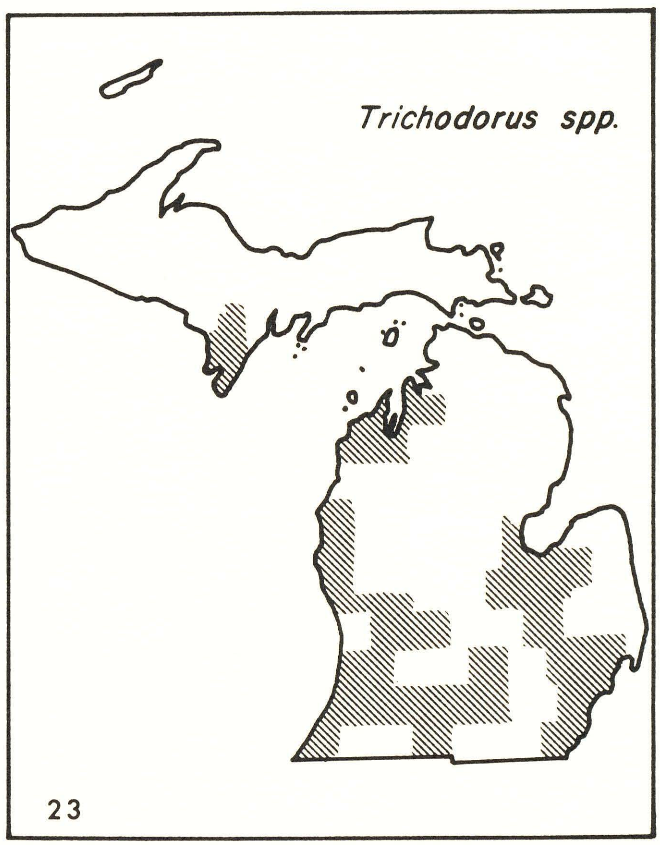

Pratylenchus penetrans
18

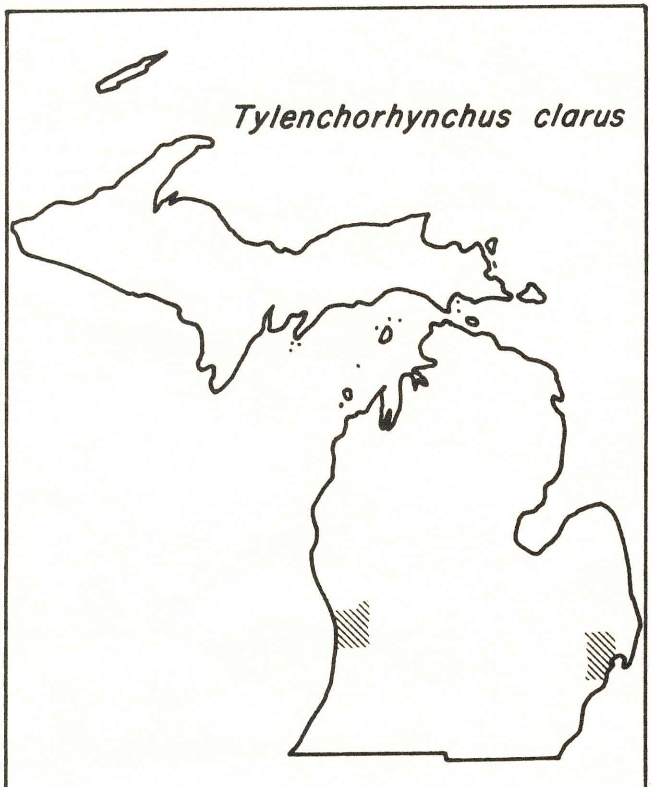

Pratylenchus scribneri
19

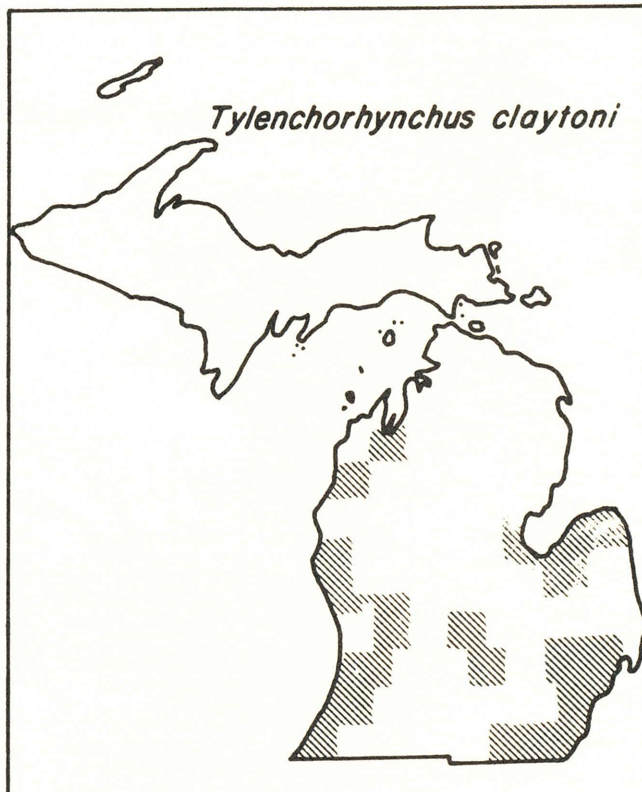

Quinisulcius acti
20

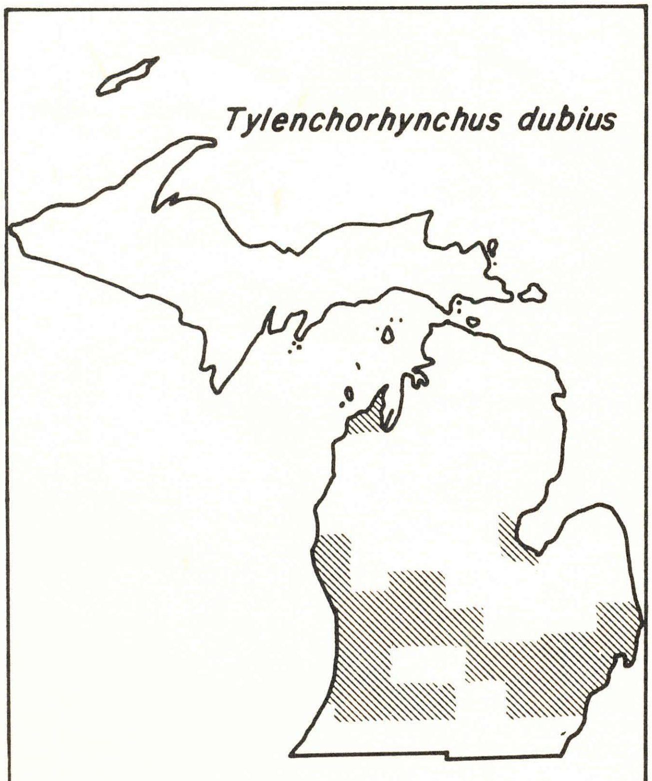

Quinisulcius acutus
21


Quinisulcius capitatus
22


Trichodorus spp.
23


Tylenchorhynchus clarus
24


Tylenchorhynchus claytoni
25


Tylenchorhynchus dubius
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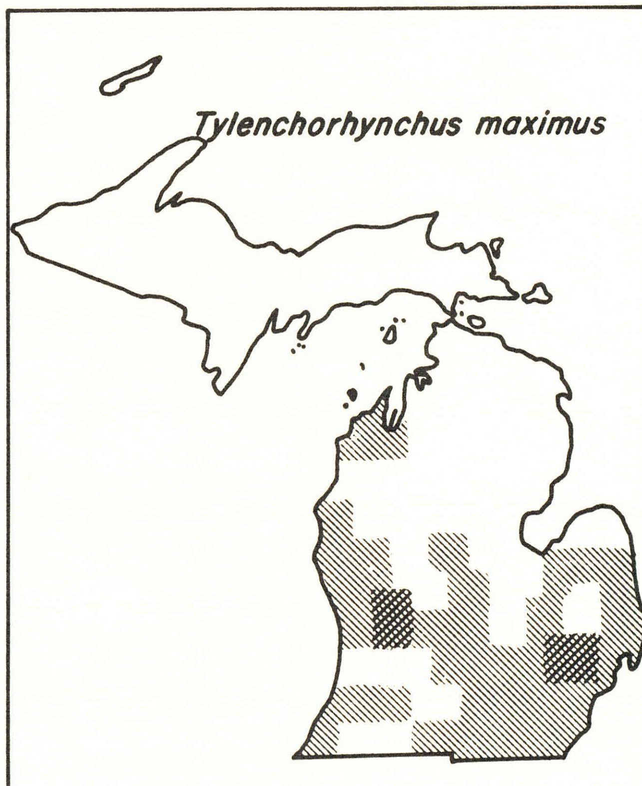
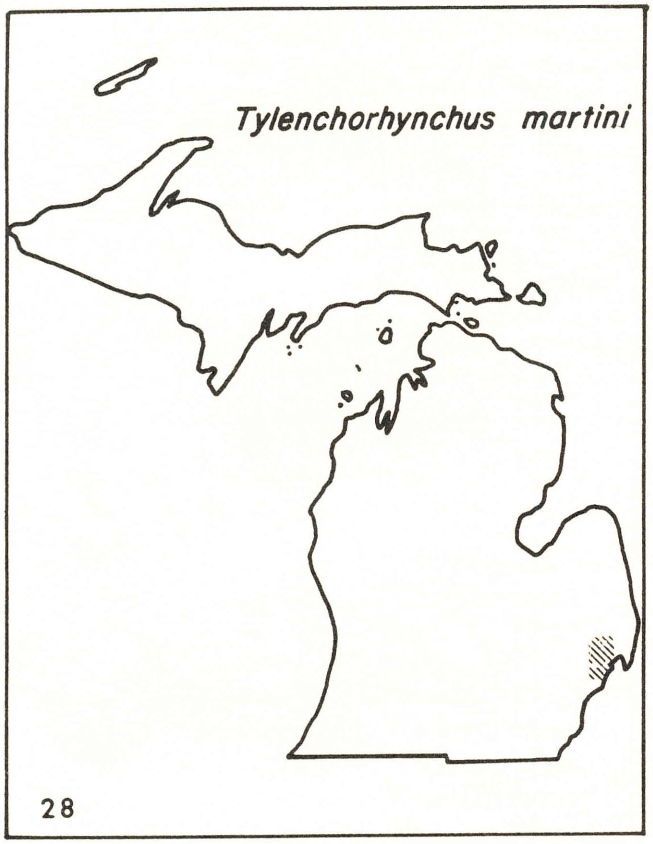
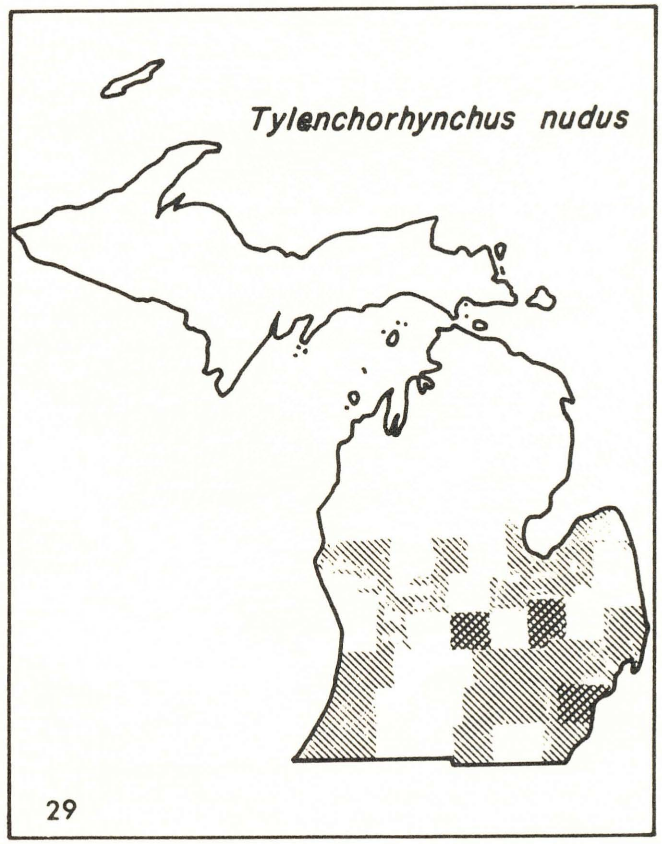
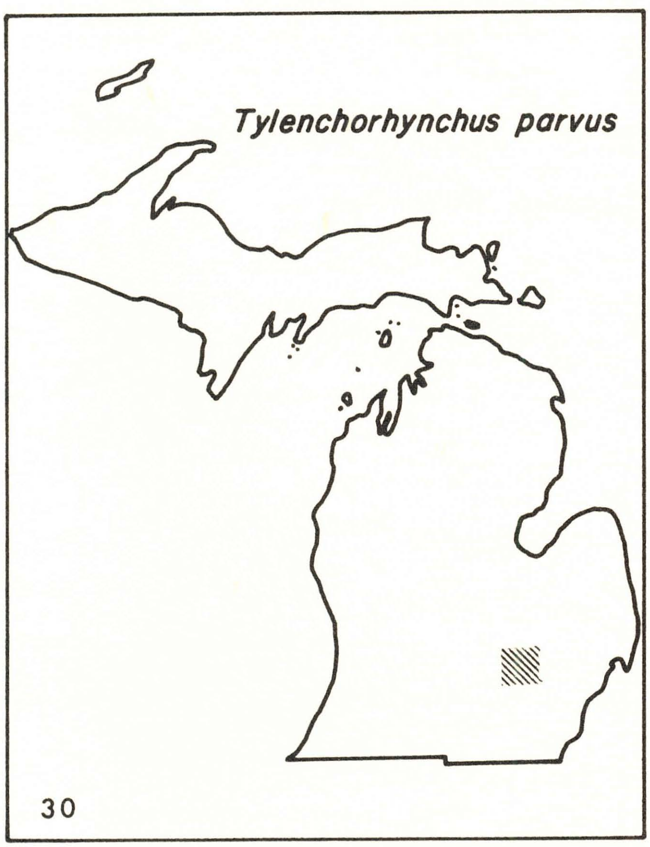
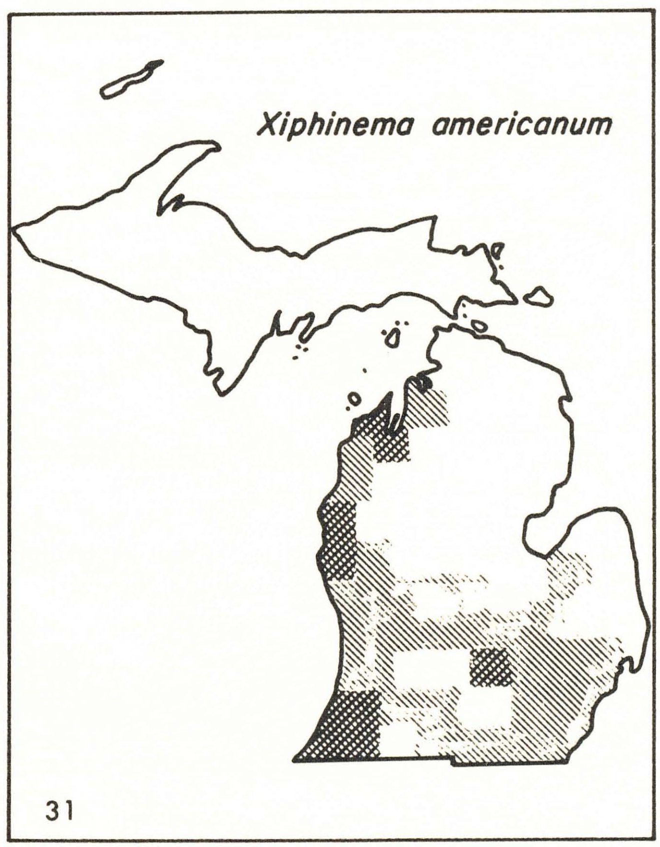

Tylenchorhynchus maximus
27


Tylenchorhynchus martini
28


Tylenchorhynchus nudus
29


Tylenchorhynchus parvus
30


Xiphinema americanum
31

Key To Females Of *Macroposthonia* DeMan, 1880 In Michigan

1. Submedian lobes rounded, less than ½ of the labial disc breadth 2
   Submedian lobes broader than ⅔ of the labial disc, flattened anteriorly resulting in a truncated head end. Tail terminus folded, mostly directed upwardly dorsal, consisting of two telescopic folded annules resulting in a blunt or truncate head and terminus.
   L = 343-578μm. St. = 50-60μm. R = 81-107
   . . . . *rustica* (Micoletzky, 1915) (Taylor, 1936) deGrisse and Loof, 1965
2. Vagina sigmoid 3
   Vagina not sigmoid 4
3. Tail conoid rounded, terminus rounded. L = 400-720μm. St. = 58-86μm. R = 84-120
   . . . . *xenoplax* (Raski, 1952) deGrisse and Loof, 1965
   Tail sharply conical, terminus sharply pointed. L = 360-460μm. St. = 51-62μm. R = 104-112.
   . . . . *reedi* (Diab and Jenkins, 1966) deGrisse and Loof, 1965
4. Submedian lobes prominent, labial plates visible. Tail and head rounded, no spines on anterior vulval lip but two lobes on vulva in ventral view only. St. = 47-67μm. R = 78-110
   . . . . *curvata* (Raski, (1952) deGrisse and Loof, 1965
   Submedian lobes not prominent, labial plates lacking or very low, head not rounded, two spines on anterior vulva lip 5
5. Labial plates lacking or very low, body annules smooth, tail terminus mostly deeply folded. L = 338-523μm. St. = 48-56μm. R = 86-93
   . . . . *ornata* (Raski, 1958) deGrisse and Loof, 1965
   Labial plates visible, body annules crenated, tail terminus not folded. L = 320-530 μm. St. = 51-60μm. R = 42-54
   . . . . *axesta* (Fassuliotis and Williamson, 1959) deGrisse and Loof, 1965

St = stylet length
L = body length
R = number of body annules

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Key To Females Of *Criconema* Hofmänner and Menzel, 1914 In Michigan

1. Spines on body annules slender, elongate, with bluntly rounded ends arranged in continuous horizontal rows 2
   Spines on body annules scale-like or triangular plates arranged in longitudinal rows 3
2. Stylet 96-130 μm; spines in mid-body region numbering 52-70; first head annule with a fringe of spines
   . . . . *menzeli* (Stefanski, 1924) Taylor, 1936
   Stylet 95-96 μm; spines in mid-body region numbering 40-52; first head annule with crenate margin
   . . . . *fimbriatum* Cobb in Taylor, 1936
3. Stylet length 54-60 μm; body annules 65-75; body with 8 longitudinal rows of scales, broad, triangular, slightly retrorse
   . . . . *octangulare* (Cobb, 1914) Taylor, 1936
   Stylet length 69-96 μm; body annules 61-64; body with 16 longitudinal rows at mid-body of plain triangular backward-pointing scales or spines with serrated edges
   . . . . *cobbi* (Micoletzky, 1925) Taylor, 1936

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Characteristic Females Of The *Xenocriconemella* deGrisse and Loof, 1965 Species In Michigan

1. Head of two annules, smaller than body annules, rounded, not retrorse. Stylet very long and thin (more than ⅓ of body length), vulva at 11th annule in front of terminus. L = 227-300 μm. St. = 82-110 μm. R = 101-120
   . . . . *X. macrodora* (Taylor, 1936) deGrisse and Loof, 1965.

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Key To Females Of *Lobocriconema* deGrisse and Loof, 1965 In Michigan

1. Twelve regularly arranged, scale-like outgrowths on body annules. Head annule smaller than second annule, separated from each other by a neck annule. R = 34-38. St. = 83-96 μm. L = 437-635 μm.
   . . . . *serratum* (Khan and Siddiqi, 1963) deGrisse and Loof, 1965.

   No outgrowths on body annules. Second head annule wider than the first. Neck annule well differentiated. R = 46-51. St. = 85-97 μm. L = 480-640 μm
   . . . . . . *thornei* Knobloch and Bird, 1978.

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Key To Females Of *Nothocriconema* deGrisse and Loof, 1965 In Michigan

1. All body annules with a lateral curve 2
   Body annules lacking a lateral curve 3
2. Body annules laterally forward curved. R = 50. L = 548 μm. St. = 75 μm. Neck annule as high as first head annule and narrower than second
   . . . . *petasum* (Wu, 1965) deGrisse and Loof, 1965

   Body annules laterally backward curved. R = 50-64. L = 350-570 μm. Stylet long and slender, 86-115 μm. Neck annule not as high as first head annule, often sloping to the borders of this annule
   . . . . *princeps* (Andrassy, 1962) deGrisse and Loof, 1965
3. Head annule narrower than first retrorse body annule 4
   Two head annules equal or unequal in width 5
4. Annules smooth, tail annules smooth, tail rounded conical, terminus folded with no terminal knob. R = 45-70. L = 232-580 μm. St = 45-70 μm
   . . . . *mutabile* (Taylor, 1936) deGrisse and Loof, 1965
5. Two head annules about equal in width, anterior lip of vulva projecting over posterior lip. L = 270-400 μm. St = 77-102 μm. R = 75-87
   Tail sharply conical, not folded
   . . . . *permistum* (Raski and Golden, 1966) deGrisse, 1967

   Second head annule larger than first head annule, anterior lip of vulva not projecting over posterior lip. L = 250-440 μm. St = 88-119 μm. R = 76-86
   . . . . *sphagni* (Micoletzky, 1925) deGrisse and Loof, 1965 (syn; *Criconemoides grassator* Adams and Lapp, 1967)

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Key To Females Of *Hemicycliophora* deMan, 1921 In Michigan, Fig. 4

1. Vulval lips modified. 2
   Vulval lips not modified. 3
2. Cuticular sheath marked by about 290-307 annules and tightly surround body. Lip region with two annules, labial disk large, rounded. Head end rounded. Vulval lips greatly modified, elongated. Tail concave-conoid. *Stylet = 90-104 µm.* Body length posterior to vulva *5.3-6.4 × body width at vulva.*
   . . . . *similis* Thorne, 1955
   Cuticular sheath marked by about 338-348 annules and loosely surrounds body. Lip region with two annules, labial disc rectangular. Head truncate. Vulval lips modified, vulval sleeve short. Tail end attenuated, usually slightly offset. *Stylet = 112-122 µm.* Body length posterior to vulva *6.6-7.8 × body width at vulva*
   . . . . *vidua* Raski, 1958
3. Cuticular sheath marked by 276-303 annules and clings closely throughout length of body. Lip region smooth, rounded. Labial disc large. Vulval lips not modified. Body ending in a uniformly conoid, tapering tail with finely rounded terminus. *Stylet = 86 (82-91) µm.*
   . . . . *uniformis* Thorne, 1955
   Cuticular sheath marked by 304-363 annules and fits tightly throughout body length. Lip region with two annules. Head truncate. Labial disc rounded, large. Vulval lips not modified, posterior one may be bulging. Body ending in a convex-conoid attenuated tail which becomes very slender near the pointed terminus. *Stylet = 95-112 µm*
   . . . . *vaccinium* Reed and Jenkins, 1963

Hemicycliophora similis was found in wooded area around white birch *Betula papyrifera* in Douglas Lake area in Northern Michigan. It was also found in Rose Lake Wildlife Areas in Bath township and in wooded areas at Michigan State University in East Lansing.

H. vidua was found in Sanford Wood lot and in the East Lansing Sewage Project in the woods, both locations at Michigan State University.

H. uniformis was found in wooded areas at Douglas Lake and in wooded areas at Michigan State University.

H. vaccinium was found around high bush blueberry *(Vaccinium corymbosum)* in Ottawa County.

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Key To Females Of *Paratylenchus* Micoletzky, 1922 In Michigan, Fig. 13

1. Lip region truncate, striated, stylet 27 (25-30) µm; tail digitate rounded, males absent or if present without stylet
   . . . . *projectus* Jenkins, 1956
   Lip region rounded, smooth, stylet 30 (27-34) µm; tail rounded conoid, males with stylet present
   . . . . *hamatus* Thorne and Allen, 1950

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Key To Females Of *Gracilacus* Raski, 1962 In Michigan

1. Vulva with conspicuous lateral membranes, males common. Tail with clawlike process at tip varying at times, but always ending in a sharp point. St. = 51 (48-55) μm; V% = 81.6(79.4-83); 4 incisures in lateral field
.... *straeleni* (deConinck, 1931) Raski, 1962 (n.syn. *Paratylenchus audriellus* Brown, 1959) Raski, 1976

Vulva without lateral membranes, males rare. Tail conoid with rounded tip. St. = 67(61-69) μm; V% = 70(68.3-73.5); 3 incisures in lateral field
.... *aciculus* (Brown, 1959) Raski, 1962

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Key To Females Of *Rotylenchus* Filipjev, 1934 In Michigan

1. Lateral field incompletely areolated, hemispherical lip region with 6-7 annules set off from body, spermatheca present with elongated sperm, males present; L = 1.22-1.87 mm; St. = 44-50 μm
.... *robustus* (deMan, 1876) Filipjev, 1934
Lateral field areolated only anteriorly, hemispherical lip region with 4-5 annules not set off from body, spermatheca inconspicuous without sperm, males absent; L = 0.92-1.31 mm; St. = 34-38 μm.
.... *buxophilus* Golden, 1956

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Key To Females Of *Helicotylenchus* Steiner, 1945 In Michigan, Fig. 3

1. Female tail hemispherical with a rounded terminus or with a slight ventral projection, less than two tail annules long............................ 2
Female tail with a pronounced ventral projection (projection two or more tail annules long) 3
2. St. = 28-32 μm; tail terminus hemispherical, 9-17 annules; phasmids 2 annules posterior to anus to 6 annules anterior to level of anus
.... *platyurus* Perry in Perry, Darling and Thorne, 1959
St. = 24-28 μm; tail more curved dorsally, usually with slight ventral projection, 4 to 10 annules
.... *digonicus* Perry in Perry, Darling and Thorne, 1959
3. Pronounced ventral projection of tail usually hemispherical. Tail not indented terminally, 7 to 12 annules. Inner lines of lateral field not fused in posterior third of tail. Phasmids 2 to 7 annules anterior to anus level. Spermatheca offset without sperm. St. = 27-30 μm, males unknown
..... *pseudorobustus* (Steiner, 1914) Golden, 1956
Pronounced ventral projection of tail sharply pointed. Tail indented terminally, 8 annules. Inner lines of lateral field fused in posterior third of tail. Phasmids 4 to 6 annules anterior to level of anus. Spermatheca inconspicuous without sperm. St. = 24-28 μm, males unknown
.... *crenacauda* Sher, 1966
Female tail with annulation on distal dorsal portion narrower than other tail annules. Ventral projection of terminus usually hemispherical or irregularly hemispherical. Phasmids 2 annules anterior to level of anus. St. = 24-27 μm. Round spermatheca with sperm, males present
.... *californicus* Sher, 1966

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Key To Females Of *Pratylenchus* Filipjev, 1934 In Michigan, Figs. 15-19

1. Males present, females with functional spermatheca 2
   Males absent, females without functional spermatheca 3
2. Lip region rounded, with 3 annules, round spermatheca, post uterine branch undifferentiated. Tail broadly rounded with smooth terminus. V% = 75-84.
   . . . . *penetrans* (Cobb, 1917) Filipjev and Schuurmans-Stekhoven, 1941
   Lip region with 4 annules (some specimens have been found with 3), spermatheca oblong, post uterine branch with rudimentary ovary. Tail tapering to narrowly rounded tip with smooth terminus. V% = 78-82
   . . . . *vulnus* Allen and Jensen, 1951
3. Tail tip often spatulate, coarsely and distinctly annulated. Spermatheca absent. Lip region with 3 annules. V% = 78-86 and usually more than 80%. Body annulation prominent
   . . . . *crenatus* Loof, 1960
   Tail tip rounded with smooth terminus. Spermatheca absent. Lip region with 2 annules, anterior margin of apical annules convex. Second annule wider than first, but sides not "stepped." V% = 76-88. Body annulation inconspicuous
   . . . . *neglectus* (Rensch, 1924) Filipjev and Schuurmans-Stekhoven, 1941

Pratylenchus penetrans, the most common species of the genus in Michigan is found on many crops. Some hosts are sour cherry, potato, rye, strawberry, peaches, onions, corn, lettuce, rose, asparagus, blueberry, apple, snap beans, and Damson plums. It is found mainly in mineral soils, but is present also in muck.

Pratylenchus neglectus has been found on potato, sour cherry, wheat, sugar beet, peaches, rye, strawberry, peach and in hayfields.

P. crenatus has been found mainly in wooded areas and on corn. Many times it is found in mixed populations with *P. penetrans* on corn and peach.

P. vulnus was found only on privet and around maple trees.

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Key To Females Of *Tylenchorhynchus* Cobb, 1913 In Michigan, Fig 24-30

1. Tail terminus annulated 2
   Tail terminus smooth 4
2. Body length 0.98-1.40 mm, stylet 21-24 μm with very slender shaft, no spermatheca, no males present
   . . . . *maximus* Allen, 1955
   Body length 0.57-0.78 mm, stylet 16-19 μm with strong shaft, spermatheca present, males present
   3
3. Lip region well set off, tail subcylindrical, tail terminus subhemispherical, tail with 46-48 annules . .
   . . . . *dubius* (Bütschli, 1873) Filipjev, 1936
   Lip region continuous, tail cylindrical, tail terminus hemispherical, tail with 35-48 annules
   . . . . *parvus* Allen, 1955
4. Lip annules 2-3. 5
   Lip annules 4-7. 6
5. Lip annules 2, spermatheca present, males present, tail with 18-20 annules
   . . . . *nudus* Allen, 1955
   Lip annules 3, spermatheca absent, males absent, tail with 15-23 annules. . . . .
   . . . . *martini* Fielding, 1956
6. Body with no longitudinal striae. 7
   Body with longitudinal striae 8
7. Lip region continuous bearing 4-5 annules: basal

esophageal bulb with a lobe overlapping intestine, tail with 8-15 annules

. . . . *clarus* Allen, 1955

Lip region set off bearing 3 annules, basal bulb not overlapping intestine or if so, very slightly, tail with 18-26 annules

. . . . *agri* Ferris, 1963

8. Lip region well set off bearing 6-7 annules, phasmids very small and inconspicuous

. . . . *microphasmis* Loof, 1960

Lip region slightly set off bearing 3-4 annules, phasmids prominent. . . . .

. . . . *claytoni* Steiner, 1937

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Key To Females Of *Quinisulcius* Siddiqi, 1971 In Michigan, Figs. 20-22

1. Anterior surface of stylet knobs inclined laterally, lip region with 8 annules, tail with 42 annules, tail terminus hemispherical

. . . . *acti* (Hopper, 1959) Siddiqi, 1971

(syn. *milgiriensis* Seshadri *et al*, 1967)

Anterior surface of stylet knobs inclined anteriorly or posteriorly, lip region with 6 annules, tail with 15-33 annules, tail terminus not hemispherical. . . 2

2. Anterior surface of stylet knobs inclined posteriorly, tail with 26-33 annules, tail conoid with smooth terminus

. . . . *capitatus* (Allen, 1955) Siddiqi, 1971

Anterior surface of stylet knobs inclined anteriorly, tail with 15-23 annules, tail conoid with smooth, subacute terminus

. . . . *acutus* (Allen, 1955) Siddiqi, 1971

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Key To Females Of *Merlinius* Siddiqi, 1970 In Michigan, Figs. 9-12

1. Body with longitudinal striae, tail terminus annulated, tail with 21-40 annules, stylet 18-20 μm long

. . . . *tessellatus* (Goodey, 1952) Siddiqi, 1970

Body without longitudinal striae, tail terminus smooth, tail with 42 annules, stylet 12-15 μm long

. . . . 2

2. Tail acute with rounded terminus

. . . . *joctus* (Thorne, 1949) Sher, 1973

Tail subcylindrical with rounded terminus. 3

3. Cephalic framework lightly sclerotized, lip region with 4-6 annules, males common. Spermatheca with bilobed structure, minute punctuations between incisures sometimes making it appear to have more than 6 incisures

. . . . *microdorus* (Geraert, 1966) Siddiqi, 1970

Cephalic framework moderately sclerotized, lip

region with 6 annules, males rare, spermatheca not seen, no minute punctuations between incisures
. . . . *brevidens* (Allen, 1955) Siddiqi, 1970

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Characteristics of Females of *Geocenamus* Thorne & Malek, 1968 Species in Michigan

1. Longitudinal body and lip striations, enlarged phasmids. Cuticle in 2 layers; 6 incisures. Lip region broadly hemispherical, well set off, with 6 or 7 labial annules and a conspicuous perioral disk. Labial annules divided into 6 segments by 6 longitudinal striae, cephalic framework weak. Spear slender, 56-65 μm long. Spermathecae bilobed. Vulva with double epiptygma and lateral membranes
. . . . *longus* (Wu, 1969) Tarjan, 1973

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Key To Cysts of *Heterodera* Schmidt, 1871 And *Punctodera* Mulvey and Stone, 1976 In Michigan
Key To Cyst Groups, Fig. 5

1. Cysts without posterior protuberance, mostly rounded or pear-shaped. . . . . Group 1
Cysts with posterior protuberance, mostly lemon-shaped 2
2. Vulval opening very short (6-19 μm). 3
Vulval opening longer (>30 μm) 4
3. Vulval cone circumfenestrate . . . . Group 2
Vulval cone bifenestrate. 3
4. Bullae present in all species, small to large, underbridge generally well developed 4
Bullae rarely present, underbridge either absent or slender 5

GROUP 1

Cyst without posterior protuberance, rounded or pear-shaped, vulval slit very short (<15 μm in length), underbridge rarely present, bullae present or absent, circumfenestrate.

Vulval and anal fenestra of nearly equal size—*Punctodera punctata* (Thorne, 1928) Mulvey and Stone, 1976.

Type host-*Triticum aestivum* L. (wheat and grasses).

GROUP 2

Cyst with posterior protuberance, spherical to lemon-shaped, vulval slit short (20 μm long), generally circumfenestrate, bullae present or absent, underbridge absent.

Cysts lemon-shaped to nearly spherical, slightly longer than wide, bullae absent, circumfenestral area with cuticular punctuations, cysts mostly lemon-shaped, cuticular punctuations large—*Heterodera weissi* Steiner, 1949.

Type host-*Polygonum pennsylvanicum* L. (knot weed).

GROUP 3

Cyst with posterior protuberance, lemon-shaped, vulval slit short (< 16 μm long), bifenestrate, bullae and underbridge present or absent.

Semifenestra not widely separated, vulval bridge (< 18 μm wide), bullae strongly developed, underbridge present—*Heterodera iri* Matthews, 1971.

Type host-*Agrostis tenuis* Sibth (brown top grass).

GROUP 4

Cysts with posterior protuberance, lemon-shaped to spherical, vulva slit long (< 35 μm), underbridge and bullae generally strongly developed, ambifenestrate.

1. Underbridge weakly to strongly developed without dorsoventral finger-like projections, bullae few to many on peripheral cone wall, cysts lemon-shaped, posterior protuberance long-short, anal bullae distinctly molar-shaped
 . . . . *H. schachtii* Schmidt, 1871.
2. Underbridge weakly to strongly developed without dorsoventral finger-like projections, bullae few to many on peripheral cone wall, cysts lemon-shaped, posterior protuberance long-short, *anal bullae* to molar shaped, and not in form of strobiloid protrusions, underbridge depth 30-62 μm, length 70-130 μm, underbridge (80-130 μm), generally heavy (15-30 μm side), underbridge depth 33-38 μm, body length second-stage larvae 430-547 (average 500) μm, stylet length 25-30 (average 28) μm
 . . . . *H. trifolii* Goffart, 1932.

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Key To Species Of *Meloidogyne* In Michigan Based on Posterior Cuticular Patterns, Fig. 8

1. Arch high, pattern roughly oval. Pattern almost identical to that of *M. incognita*. Striae of the posterior cuticular pattern very wavy to zigzag and more widely spaced than in *M. incognita*.
 Lateral fields not obvious but marked by breaks in the striae, the broken ends often forked. Has an area of striae interruption above the anus which is not present in *M. incognita*
 . . . . *microtyla* Mulvey, Townshend and Potter, 1975
 Arch low and rounded or flattened 2
2. Pattern with a distinct fold over the anus, large phasmids below the surface, a little closer together than the vulval length, and broken striae between the phasmids at right angles to the dorsal arch.
 The pattern on a slight prominence on the spherical body
 . . . . *naasi* Franklin, 1965
 Posterior cuticular pattern roughly circular, the smooth striae forming a low arch; lateral fields usually not marked but the striae at the level of the vulva may form a loop or wing which the dorsal striae meet almost at right angles. The tail end has few striae but *there is a stippled area*. The anus is usually covered by a fold of cuticle; phasmids fairly widely spaced
 . . . . *hapla* Chitwood, 1949

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Franklin, M. T. (1965). A root-knot nematode, *Meloidogyne naasi* n.sp. on field crops in England and Wales. Nematologica 11(1):79-86.

Mulvey, R. J., J. L. Townshend and J. W. Potter (1975). *Meloidogyne microtyla* sp. nov. from southwestern Ontario, Canada. Can. J. Zool. 53:1528-1536.

Key To The *Trichodorus* and *Paratrichodorus* Species In Michigan, Fig. 23

1. Cuticle does not swell strongly after fixation. Dorsal oesophageal gland nucleus posterior. Subventral oesophageal glands non-overlapping. Didelphic females with strong vaginal sclerotization and pair of lateral pores within one body width from vulva. Males numerous caudal alae absent, spicules arcuate and three evenly spaced supplements (two anterior to spicules), suspension muscles conspicuous. Usually 2 or 3 ventro-median cervical pores 2
 Cuticle swelling strongly after fixation. Didelphic females lacking lateral pores within one body-

width of weakly sclerotized vulva. Male caudal alae present and suspensor muscles inconspicuous. Two supplements in caudal alae region with third well-separated or only one supplement. Rarely more than one ventro-median cervical pore 4

2. No ventro-median cervical papillae in onchiostyle region of male. Female body greater than 1 mm. . . . . *T. proximus* Allen, 1957
One or two ventro-median cervical papillae in onchiostyle region of male 3

3. Gubernaculum at level with or ventral to spicules, convex anteriorly. Three pairs of female lateral pores . . . . *T. primitivus* (deMan 1876) Micoletzky, 1922
Male onchiostyle 38-42 μm. Female vulva sclerotization large and trapezoid. Gubernaculum not as above . . . . *T. similis* Seinhorst, 1963

4. Nuclei of posterior ventro-sublateral glands close to oesophageal-intestinal junction, dorsal nucleus anterior. Excretory pore near or posteriad to base of oesophagus. Males rare and with only one supplement. Spicules long. No cervical pores. One pair of ventro-submedian papillae near termini . . . . *P. (N.) christiei* Allen, 1957
Posterior ventro-sublateral oesophageal glands non-overlapping. Short dorsal overlap in some species. Posterior ventro-sublateral gland nuclei anterior to oesophageal-intestinal junction and close to dorsal nucleus. Males with 2 pairs of large ventro-submedian postcaudal papillae. Females with subterminal pores 5

5. Onchiostyle 64 μm or more. One pair of subventral pores behind vulva . . . . *P. (N.) atlanticus* Allen, 1957
Onchiostyle less than 60 μm 6

6. Two pairs of ventro-median pores near vulva. Two male supplements in spicule range. Spicules 36-39 μm . . . . *P. (N.) porosus* Allen, 1957
No subventral or ventro-median pores near vulva. Three male supplements, one well anterior to head to retracted spicules. Spicules longer than 40 μm . . . . *P. (N.) pachydermus* Seinhorst, 1954

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Redescriptions Of The Most Common Species Of Michigan *Tylenchorhynchinae* (Nematoda)

In processing about 6,000 soil samples at Michigan State University, 20% were found to contain nematodes of the genera *Tylenchorhynchus* and *Merlinius*. Most of the samples were from agricultural areas of the state and included both organic and mineral soils but a few were taken from uncultivated soil.

METHODS

Descriptions of species are based on both living and preserved specimens. Measurements were made on specimens which had been heat relaxed, fixed in F.A. 4:10, preserved and mounted according to the glycerol-ethanol method of Seinhorst (1959).

All measurements were made with 100 X oil immersion objective and 10X ocular. The following symbols are used in this paper in descriptions:

- MB = position of the median bulb expressed as percentage of the oesophageal length; the median bulb is measured to the end of the bulb;
- Kn = width of knobs in micrometers;
- m = percentage of conus to total stylet length;
- o = distance from knobs to dorsal oesophageal gland outlet expressed in percentage of total stylet length;
- T/ABW = ratio of length of tail to anal body width;
- sp = length of spicules in microns;
- g = length of gubernaculum in microns.

Tylenchorhynchus dubius (Bütschli, 1873) Filipjev, 1936, (Fig. 32, 1-4)

Females (6): L = 0.67 (0.57-0.76) mm; a = 26 (22-29); b = 5.3 (4.7-5.9); c = 13 (12-15); V = $^{25}55^{25}$ ($^{23-32}55\text{-}57^{20-32}$); spear = 17 (16-18) μm; MB = 56 (51-58); Kn = 4.0 (3.2-4.4); m = 54 (52-58); o = 14 (14-19); T/ABW = 2.4 (2.3-2.7).

Males (6): L = 0.63 (0.55-0.73) mm; a = 28 (24-32); b = 4.7 (4.2-5.5); c = 12 (11-13); T = 68 (62-74); spear = 16 (16-17) μm; MB = 58 (56-59); Kn = 3.6 (3.2-4.4); m = 50 (42-61); o = 13 (11-15); T/ABW = 2.6 (2.1-3.0); sp = (24.3-27.6); g = 13.0 (8.59-16.4).

Female: Body cylindrical. Lip region rounded, set off from body, bearing 7 annules. Labial framework lightly sclerotized. Spear with rounded knobs slanting posteriorly. Orifice of dorsal oesophageal gland about 2.7 μm posterior to knobs (Fig. 32.1). Excretory pore opening opposite anterior end of oesophageal bulb; hemizonid just anterior to pore. Basal bulb pyriform, slightly overlapping intestine on all sides. Cardia small, hemispherical.

Cuticle finely annulated; lateral field with 4 incisures. Fine striations appear on cuticle around vulval openings. Oocytes in single row except for region of multiplication near distal end; spermathecae with spermatozoa. Size of uterine egg about 84 μm x 27 μm. Tail cylindrical with bluntly rounded terminus; annulation extending around terminus. Phasmids conspicuous, slightly anterior to middle of tail. Post anal intestinal sac present (Fig. 32.2).

Male: Spicules tylenchoid; gubernaculum slightly curved at proximal end. Phasmids about middle of tail (Fig. 32.4).

Habitat: mineral soil around phlox, bent grass on golf courses, grass in fields and lawns, apple and prune orchards, rye, wheat, alfalfa, taxus, spirea, and iris.

Distribution: Counties—Kent, St. Clair, Muskegon, Oakland, Ingham, Ottawa, Ionia, Wayne, Clinton, Allegan, Oceana, Calhoun, Bay, Leelanau, Montcalm, Macomb, Livingston, Van Buren, and Kalamazoo (Fig. 26).

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Tylenchorhynchus maximus Allen, 1955, (Fig. 32, 5-7)

Females (6): L = 1.2 (1.1-1.3) mm; a = 42 (36-46); b = 7.6 (7.4-7.9); c = 19 (17-22); V = $^{21}50^{18}$ ($^{18-23}49\text{-}52^{17-20}$); spear = 23 (22-24) μm; MB = 58 (56-60); Kn = 2.8 (2.5-3.1); m = 57 (55-61); o = 11 (9-12); T/ABW = 3.0 (2.6-3.5).

Female: When relaxed, cylindroid body lies in a loose spiral shape. Lateral field with 4 incisures. Lip region slightly set off from body bearing 7 annules. Labial framework lightly sclerotized extending posteriorly 3

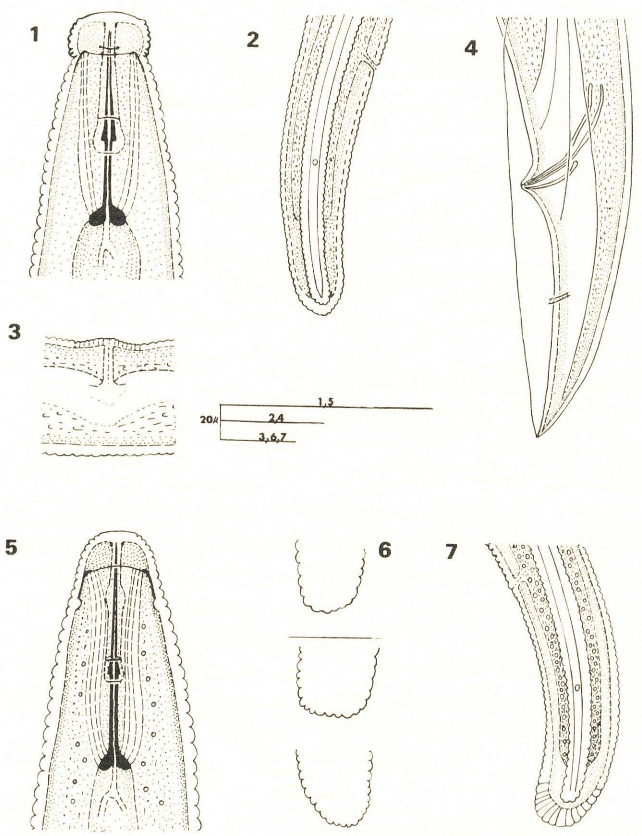

Figure 32,1-3. Drawings of *Tylenchorhynchus dubius*. Female head, tail and vulval region. 4. Male tail. 5-7. *Tylenchorhynchus maximus*. Female head, and variations in tails.

annules. Anterior cephalids conspicuous, at base of cephalic sclerotization on 4th annules. Spear 23 μm long, very slender, with small posteriorly sloping knobs. Opening of dorsal oesophageal gland about 2.7 um behind spear knobs (Fig. 32.5). Excretory pore conspicuous, about opposite anterior end of bulb; hemizonid 2 annules wide, just anterior to excretory pore. Basal bulb pyriform; cardia hemispherical. Ovaries outstretched with oocytes in single file; no spermathecae seen. Tail terminus broadly rounded, annulated; about 36-38 annules on tail. Post anal intestinal sac present (Fig. 32.7).

Habitat: Mineral soil around yew, vinca, peach, cherry, grass, rye, willow, apple, golf course bent grass, and maple.

Distribution: Counties—Kent, Washtenaw, Van Buren, Wayne, Berrien, St. Clair, Ionia, Genesee, Clinton, Allegan, Ingham, Montcalm, Leelanau, Benzie, Grand Traverse, Mason, Oceana, Newago, Isabella, Tuscola, Sanilac, Muskegon, Gratiot, Ottawa, Eaton, Livingston, Oakland, Macomb, Jackson, Kalamazoo, Branch, Hillsdale, Lenawee, and Monroe (Fig. 27).

A soil sample from a lawn in Branch County, Michigan contained several hundred females of *Tylenchorhynchus maximus* Allen, 1955. A male of this species was found and described.

REFERENCE

Allen, M. W. (1955). A review of the nematode genus *Tylenchorhynchus*. Univ. Calif. Publ. Zool. 61(3): 129-165.

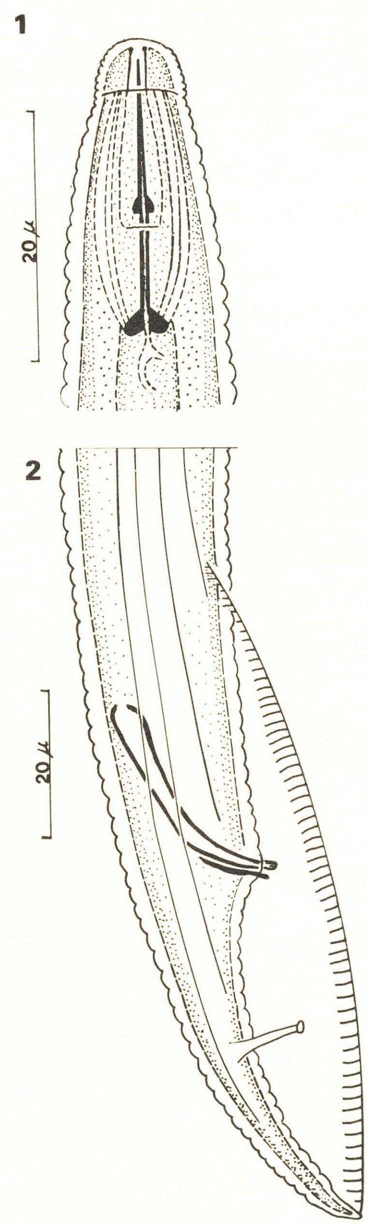

Figure 33, 1-2. *Tylenchorhynchus maximus*. Male head and tail region.

Tylenchorhynchus maximus
Allen, 1955, (Fig. 27, 33, 1-2)

Male (1): L = 1.0 mm; a = 47; b = 5.4; c = 18; T = 51%; stylet = 22µm; spicules = 34µm; gubernaculum = 11µm.

Body cylindrical, lying in a loose spiral when killed by gentle heat. Lip region rounded, continuous with body contour and bearing 7 annules. Cephalic sclerotization light. Stylet delicate, 22µm in length with small knobs directed posteriad. Orifice of dorsal esophageal gland 2µm behind base of spear (Fig. 33.1). Cephalids and deirids not observed. Lateral field with 4 incisures. Esophagus tylenchoid. Basal esophageal bulb pyriform, cardia large, conoid. Phasmids slightly anterior to middle of tail. Spicules tylenchoid, about 34 µm long. Gubernaculum about 11µm long. Bursa crenate, enveloping tail (Fig. 33.2).

Tylenchorhynchus claytoni
Steiner, 1937, (Fig. 34, 1-4)

Females (6): L = 0.62 (0.57-0.67) mm; a = 23 (20-28); b = 4.6 (4.1-5.2); c = 14 (12-18); V = $^{24}56^{24}$ ($^{16-30}55-58^{13-33}$); spear = 19.8 (19-20.6) µm; MB = 55 (52-59); Kn = 3.8 (3.2-5.0); m = 53 (51-57); T/ABW = 2.0 (1.7-2.4).

Males (6): L = 0.60 (0.57-0.63) mm; a = 24 (21-26); b = 4.4 (4.0-4.7); c = 13 (12-15); T = 62 (61-67); spear = 18.6 (18.0-19.5)µm; MB = 51 (50-54); Kn = 3.6 (3.2-4.4); m = 53 (50-56); T/ABW = 2.3 (1.5-2.5); sp = 27.9 (26.3-29.6); g = 13.9 (13.1-15.7).

Female: Body cylindrical, tapering at both ends. Lip region rounded, bearing 3 annules, slightly set off from body. Cephalic framework lightly sclerotized. Spear delicate with well developed rounded knobs. Dorsal oesophageal gland orifice usually about 1.4µm behind spear knobs (Fig. 34.1). Excretory pore opens at level of upper part of basal bulb; hemizonid 2 annules wide just anterior to pore. Cardia hemispherical. Ovaries outstretched; spermathecae with spermatozoa present. Cuticle in squares; about 20 longitudinal striations divide cuticle into segments; lateral fields plain. Tail terminus smooth, variable in shape. Phasmids prominent, opening anterior to middle of tail (Fig. 34, 2-3).

Male: Testis outstretched. Phasmids anterior to middle of tail. Bursa coarsely crenate (Fig. 34.4).

Habitat: soil around strawberries, Arbor-vitae, spruce, rhododendron, peach, azaleas, and blueberry.

Distribution: Counties—Van Buren, Ingham, Muskegon, Oakland, Macomb, Monroe, Wayne, Manistee, Berrien, Tuscola, Grand Traverse, Oceana, Kent, Clinton, Bay, Huron, Lenawee, and Allegan (Fig. 25).

REFERENCE

Steiner G. (1937). Opuscula miscellanea nematologica, V. Proc. Helminth. Soc. Wash. (4):33-38.

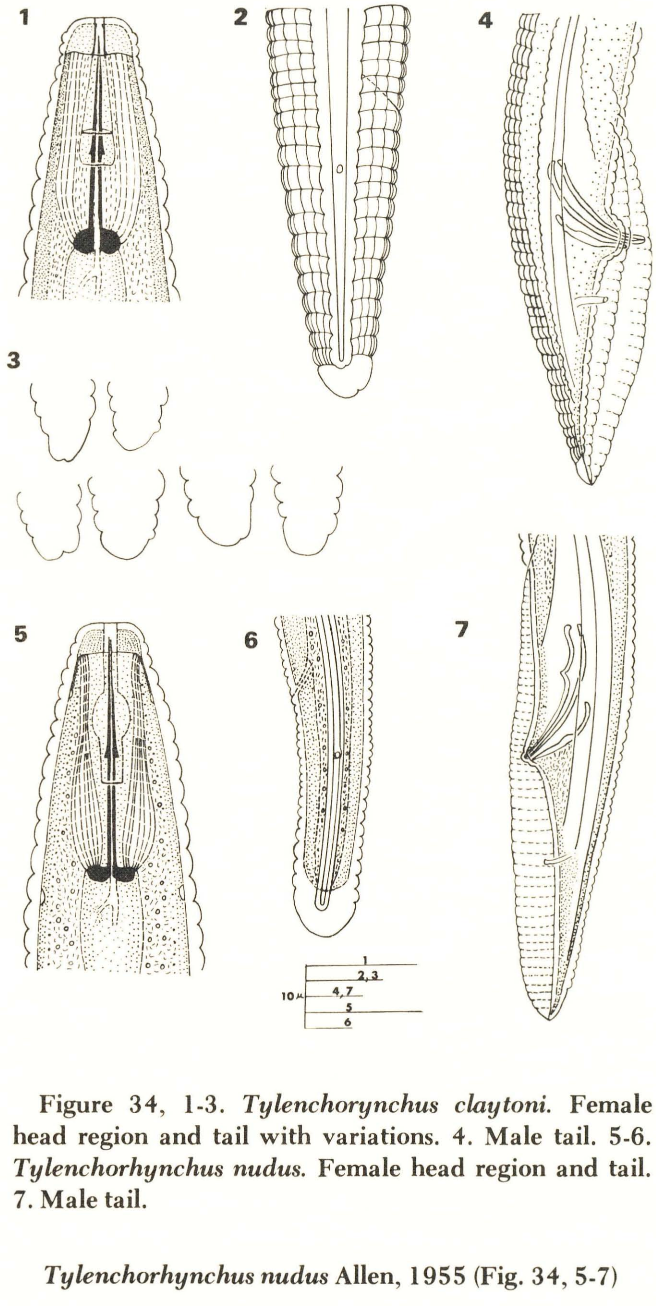

Figure 34, 1-3. *Tylenchorynchus claytoni*. Female head region and tail with variations. 4. Male tail. 5-6. *Tylenchorhynchus nudus*. Female head region and tail. 7. Male tail.

***Tylenchorhynchus nudus* Allen, 1955 (Fig. 34, 5-7)**

Female (6): L = 0.78 (0.72-0.86) mm; a = 32 (30-34); b = 5.3 (4.8-5.6); c = 16 (15-19); V = $^{22}53^{21}$ ($^{21-24}51-55^{21-23}$); spear = 21 (20-22) µm; MB = 54 (52-60); Kn = 4.6 (3.8-5.0); m = 52 (50-55); o = 11 (10-14); T/ABW = 2.5 (2.2-2.8).

Males (6); L = 0.76 (0.69-0.79) mm; a = 34 (30-37); b = 5.1 (4.18-5.7); c = 15 (15-17); T = 61 (59-68); spear = 21 (19-20.7) µm; MB = 52 (44-56); Kn = 4.7 (4.3-5.4); m = 49 (48-51); o = 11 (10-12); T/ABW =

2.7 (2.4-3.2); sp = 26.4 (26.3-26.9); g = 13.3 (13.1-15.7).

Female: Body cylindrical, ventrally arcuate when relaxed by gentle heat. Lip region not set off, bearing 2 annules. Labial framework lightly sclerotized, extending posteriorly 2 annules. Spear 21μm long with knobs slightly cupped. Dorsal oesophageal gland opening about 3.3μm behind spear knobs (Fig. 34.5). Cuticle coarsely annulated; lateral field with 4 incisures. Excretory pore about opposite anterior end of bulb; hemizonid 2 annules wide just anterior to pore. Anterior cephalids on 3rd annule. Posterior cephalids 12 annules from cephalic framework. Basal bulb pyriform, slightly overlapping intestine on all sides; cardia rounded, small. Ovaries outstretched; spermathecae with spermatozoa present. Intestine packed with coarse granules; post anal intestinal sac absent. Tail terminus broad and rounded; smooth, not striated (Fig. 34.6).

Male: male with tylenchoid spicules, troughlike gubernaculum (Fig. 34.7).

Habitat: Turf, peach orchards.

Distribution: Counties—Ingham, Macomb, Oceana, Wayne, Kent, Newago, Isabella, Bay, Huron, Tuscola, Montcalm, Saginaw, Genesee, Clinton, St. Clair, Oakland, Livingston, Allegan, Van Buren, Jackson, Washtenaw, Berrien, Cass, Hillsdale, and Monroe (Fig. 29).

REFERENCE

Allen, M. W. (1955). A review of the nematode genus *Tylenchorhynchus*. Univ. Calif. Publ. Zool. 61(3):129-165.

Tylenchorhynchus agri Ferris, 1963 (Fig. 35, 1-3)

Females (8): L = 0.76 (0.65-0.87) mm; a = 29 (24-35); b = 5.7 (5.1-6.8); c = 14 (10-17); V = $^{20}52^{19}$ ($^{18-23}51$-55^{17-23}); spear = 20.3 (19-22) μm; MB = 54 (52-56); Kn = 4.7 (4.3-4.8); m = 50 (47-54); o = 12 (10-13); T/ABW = 2.7 (2.4-3.0).

Female: Body ventrally arcuate when relaxed; tapering both ways to extremities. Cuticle marked with transverse striae which are finest in the oesophageal region (about 1.6 micrometers) to fairly coarse striae (about 2.5 micrometers) on the tail. Lateral field with 4 incisures. Lip region set off from body bearing 3 annules (2 annules plus labial disk). Labial sclerotization inconspicuous. Spear about 20 micrometers long with well developed, slightly cupped knobs. Anterior cephalids located at about 4th annule behind the lip region. Posterior cephalids on 15th body annule. Orifice of dorsal oesophageal gland 2 to 3 micrometers behind spear base (Fig. 35.1). Excretory pore opens opposite anterior end of bulb. Hemizonid just anterior to excretory pore, about 2 annules long. Basal bulb large, pyriform, with basal portion extending slightly over anterior end of intestine; cardia rounded, sometimes indistinct because intestine is filled with large coarse, refractive granules (Fig. 35.2). Ovaries outstretched with oocytes in a single row; uterine egg measures 18 × 45.6 μm. There seems to be a great variation in the number of tail annules; usually between 19-22; 28 have been counted in a few specimens. Terminus smoothly rounded. Phasmids conspicuous, anterior to middle of tail. Post anal intestinal extension present (Fig. 35.3).

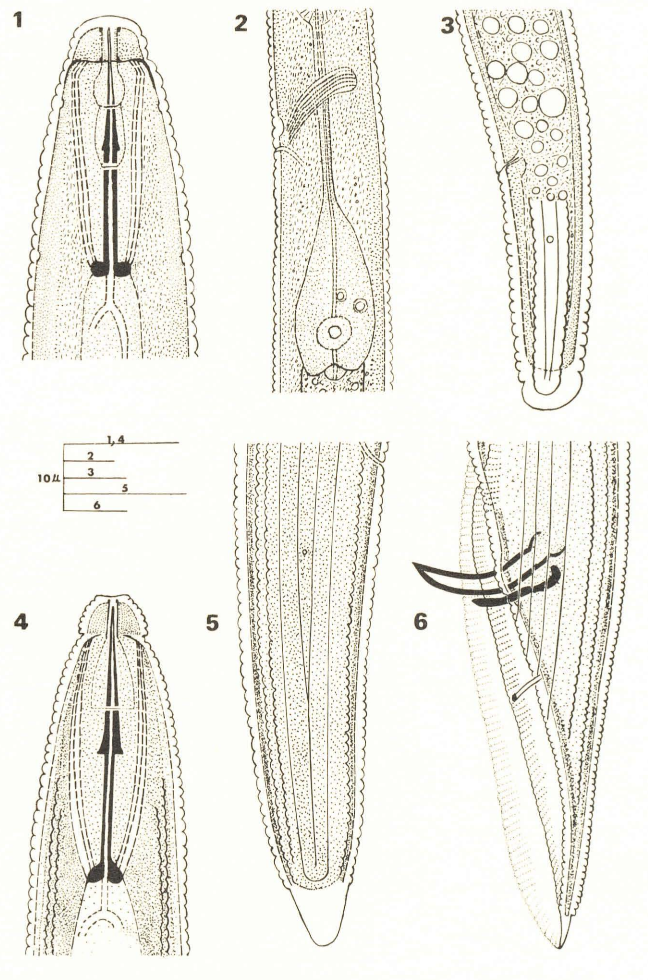

Figure 35, 1-3. *Tylenchorhynchus agri*. Female head, cardiac region and tail. 4-5. *Tylenchorhynchus microphasmis*. Female head and tail. 6. Male tail.

Habitat: Dark loam soil around roots of Arctic Blue willow *(Salix purpurea L.)*, in the Rose Lake Conservation Area.

Distribution: Clinton County.

REFERENCE

Ferris, Virginia, R. (1963). *Tylenchorhynchus silvaticus* n.sp.

and *Tylenchorhynchus agri* n.sp. (Nematoda: Tylenchida). Proceedings Helminth. Soc. Wash. 30:165-168.

Tylenchorhynchus microphasmis Loof, 1959 (Fig. 35, 4-6)

Females (4): L = 0.97 (0.96-0.98) mm; a = 30-37; b = 5.3-5.8; c = 13-14.9; V = $^{21-24}50\text{-}55^{21-24}$; spear = 26-26.6 μm.

Males (2): L = 0.73-0.84 mm; a = 28-32; b = 5.0-5.2; c = 11-13; T = 52-57; spear = 24-25 μm.

Female: Body forming an open "C" when relaxed. Cuticle marked by fine transverse striae which are divided into segments by 16-20 longitudinal striae. Lateral field with 4 incisures. Lip region, set off by constriction, bearing 6-7 annules. Cephalic sclerotization obscure. Spear slender with rounded knobs. Orifice of dorsal oesophageal gland about 3 μm behind spear base (Fig. 35.4). Median oesophageal bulb varies from round to ovate; basal bulb pyriform. Cardia hemispherical, inconspicuous. Excretory pore opening opposite anterior end of basal bulb; hemizonid inconspicuous, one to four annules anterior to excretory pore. Ovaries paired, outstretched; oocytes in single file. Spermathecae round with spermatozoa present. Tail conoid; terminus rounded, not annulated. Phasmids inconspicuous, anterior to middle of tail (Fig. 35.5).

Male: Spicules arcuate; gubernaculum curved at proximal end. Phasmids in upper third of tail; bursa enveloping tail (Fig. 35.6).

Habitat and distribution: A rare species in Michigan, found around roots of peach trees near Washington and Macomb Counties.

REFERENCE

Loof, P. A. A. (1959). Miscellaneous notes on the genus *Tylenchorhynchus* (Tylenchinae: Nematoda). Nematologica 4:294-306.

Tylenchorhynchus longus Wu, 1969

Females (11): L = 1.10 (0.967-1.25) mm; a = 26 (23-32); b = 5.4 (4.5-5.9); c = 17 (15-24); V = $^{28}54^{28}$ $(^{25-34}51\text{-}58^{26-33})$; spear = 58 (55.3-65.2) μm; MB = 59 (51-69); Kn = 5.8 (5.4-6.5); m = 58 (55-62); o = 4.6 (4.1-4.9); T/ABW = 2.0 (1.8-2.2).

Males (11): L = 1.03 (0.86-1.15) mm; a = 27 (23-30); b = 5.3 (4.0-5.9); c = 14 (12-16); spear = 56 (53.2-62.4) μm; Kn = 5.6 (5.4-5.9); m = 57 (55-59); o = 5.3 (4.0-5.9); T/ABW = 2.4 (1.9-2.8).

Female: See amended description in Nematologica 17:602-603.

Distribution: Counties—Emmet, Isabella.

REFERENCE

Wu, Liang-Yu. (1969). Three new species of the genus *Tylenchorhynchus* Cobb, 1913 (Tylenchidae: Nematoda) from Canada. Can. J. Zool. 47:563-567.

Merlinius microdorus (Geraert, 1966) Siddiqi, 1970 (Fig. 36, 1-5)

Females (10): L = 0.6 (0.53-0.71) mm; a = 27 (22-31); b = 5.1 (4.5-5.3); c = 12 (11-13); V = $^{28}53^{28}$ $(^{25-34}51\text{-}55^{24-32})$; spear = 14 (13-15.9) μm; MB = 50 (49-53); Kn = 3.0 (2.7-3.8); m = 54 (50-60); o = 8 (7-10); T/ABW = 3.1 (2.9-3.6).

Males (6): L = 0.6 (0.56-0.68) mm; a = 27 (22-35); b = 5.2 (4.7-5.6); c = 12 (10-14); T = 41 (31-52); spear = 14 (13.0-15.7) μm; MB = 5 (51-54); Kn = 2.9 (2.7-3.8); m = 57 (55-61); o = 9 (7-11); T/ABW = 2.9 (2.8-3.7); sp = 22.6 (21.7-23.0); g = 7.1 (6.5-8.5).

Female: Body almost straight but with a slight ventral curve when relaxed. Cuticle with fine striae about 0.6 μm apart on middle of body. Lateral field with 6 incisures. There appear to be more than 6 incisures which Geraert (1966) attributed to rows of punctuations between incisures. Lip region rounded, continuous with body or set off by a very slight depression, bearing 4 annules. Labial framework very lightly sclerotized except where lateral margin extends posteriorly. Spear with well developed knobs. Anterior cephalids small, at about third annula behind lip region. Posterior cephalids conspicuous at about 10th body annual.

Orifice of dorsal oesophageal gland about 1.6 μm behind spear base (Fig. 36.1). Hemizonid 3 annules long, 1 to 3 annules anterior to excretory pore which opens about opposite anterior end of bulb; deirids anterior to excretory pore, opposite hemizonid. Median bulb ovoid, basal bulb elongate-pyriform. Cardia hemispherical, inconspicuous. Ovaries paired, outstretched; oocytes arranged in single file except for short region of multiplication. Spermathecae appear bilobed; spermatozoa present (Fig. 36.2). Vulva with double epiptygma and lateral membrane (Fig. 36.4). Tail subcylindrical, terminus blunt, not annulated. Phasmids conspicuous, slightly posterior to middle of tail (Fig. 36.3).

Male: Testis single, outstretched. Spicules tylenchoid. Gubernaculum small, troughlike; tail arcuate, bursa crenate (Fig. 36.5).

Habitat and distribution: A perennial flower garden of sandy loam soil around unthrifty Madonna lilies, *Lilium candidum L.* in Lansing, Ingham County (Fig. 11).

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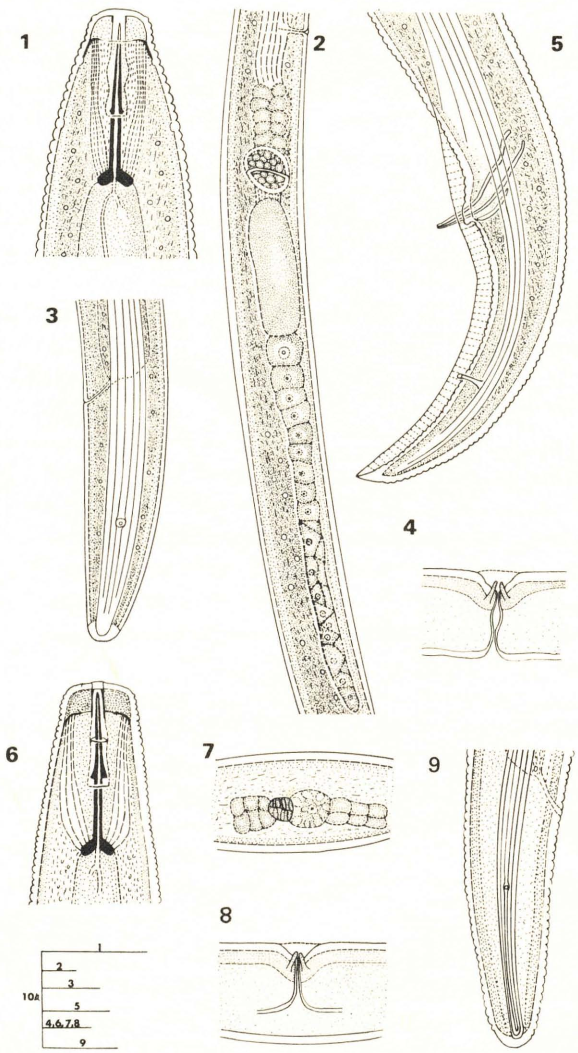

Figure 36.1-4. ***Merlinius microdorus.*** **Female head region, reproductive tract, tail, and vulval region. 5. Male tail. 6-9.** ***Merlinius brevidens.*** **Female head, spermatheca, vulval region, tail.**

Merlinius brevidens (Allen, 1955) M. R. Siddiqi, 1970 (Fig. 36, 6-9)

Females (6): L = 0.55 (0.48-0.58) mm; a = 27 (25-39); b = 5.2 (4.6-5.6); c = 12 (12-14); V = $^{22}54^{21}$ ($^{21-25}53\text{-}55^{20-23}$); spear = 15.9 (15.7-16.2)μm; MB = 42 (42-52); Kn = 3.5 (3.2-3.8); m = 54.7 (53-57); o = 8 (7-10); T/ABW = 2.3 (2.3-3.0).

Female: Body cylindrical; when heat relaxed body lies straight or slightly ventrally arcuate. Lip region continuous with body contour, bearing 6 annules. Labial framework moderately sclerotized, the more heavily sclerotized lateral margins extending posteriorly about 2 annules. Spear length around 16μm, the knobs rounded and slanting posteriorly (Fig. 36.6). Excretory pore about opposite anterior end of basal bulb; hemizonid just anterior to pore, 3 annules wide. Basal oesophageal bulb set off from intestine; cardia hemispherical. Cuticle finely annulated; lateral field with 6 incisures. Ovaries paired, outstretched; oocytes in single file except for short region of multiplication; spermathecae without spermatozoa, difficult to see in most specimens (Fig. 36.7). Vulva with double epiptygma and lateral membranes (Fig. 36.8). Anus obscure; tail terminus rounded, smooth (Fig. 36.9).

No male was located in Michigan populations.

Habitat: Sandy soil in open fields, peach orchards, sugar beets, muck soil around onions, celery, potatoes, carrots, clay around navy beans, soil around corn.

Distribution: Counties—Allegan, Macomb, Berrien, Kent, Ionia, Montcalm, Lapeer, Van Buren, Clinton, Ottawa, Tuscola, Muskegon, Genesee, Barry, Jackson, and Oakland (Fig. 9).

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DISCUSSION

The most common Tylenchorhynchinae species in Michigan are *Tylenchorhynchus maximus* Allen, 1955, *T. dubius* (Bütschli) Filipjev, 1936 and *Merlinius brevidens* (Allen, 1955) Siddiqi, 1970. *T. maximus* is found in many turf samples submitted for testing at Michigan State University and in growers' agricultural samples with cover crops grown in the fields throughout the state. It has been reported from various localities in California, Nevada, Utah, Idaho, Colorado, South Dakota, New Jersey, Illinois, Indiana, Iowa, Kansas, Minnesota, Wisconsin, and Canada. It is a common species in the Netherlands.

M. brevidens is numerous in muck, but is also found in mineral soils. It has been reported from California, Nevada, Utah, Idaho, Colorado, New Jersey, Maryland, Indiana, Minnesota, South Dakota, Canada and several localities in the Netherlands. Siddiqi (1961) states that this species was found in districts in India around various crops. The populations examined by him possessed males and the females had spermathecae with spermatozoa. In Michigan, no male has been found, and it is very difficult to see the spermathecae. No spermatozoa have been observed in the obscure, degenerated spermathecae.

T. dubius appears in most turf samples in Michigan. It is common in the Netherlands and in England. It has been reported from New Jersey, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Jersey, New York, West Virginia, Kansas and Minnesota.

Tylenchorhynchus nudus Allen, 1955 is fairly common in Michigan and has been reported from Canada, South Dakota, New Jersey, Indiana, Iowa, Kansas, Minnesota, and Wisconsin. According to Loof (1959), this nematode was also found in Ceylon. The Michigan females all possess spermathecae with spermatozoa which were not seen in specimens of Allen (1955). The two inner lateral incisures in Michigan specimens are separate the whole length of the tail and do not coalesce behind the phasmid as Loof (1959) drew them in the Ceylonese specimens. Many specimens are parasitized on the cuticle with sporozoan parasites, *Duboscquia* sp. as reported by Thorne (1968) in South Dakota specimens.

Tylenchorhynchus claytoni Steiner, 1937, in Michigan was found often in strawberry samples and in azalea plants. Infested azaleas had large populations and showed chlorosis, dieback and stunting. Sher (1958) and Barker, Work and Epstein (1965) found *T. claytoni* involved with similar symptoms in their studies on the decline of azaleas. It is known from the Netherlands, Switzerland, Canada, South Carolina, North Carolina, Alabama, Colorado, Oregon, Arkansas, California, New Jersey, Connecticut, Delaware, Maine, Maryland, Massachusetts, New York, North Dakota, Kansas, Indiana, Pennsylvania, Rhode Island and West Virginia.

Tylenchorhynchus agri Ferris, 1963, was found in Michigan in large numbers around unthrifty Blue Arctic willows. These specimens are very similar to the Illinois species of *T. agri*, but possess a few differences: the lip region bears 3 annules compared to 4 in *T. agri*, has finer body striations (1.6 μm in oesophageal region in Michigan specimens to 2.5 μm in the Illinois specimens). The spear of the Michigan specimens occupies more annules compared to the Illinois specimens.

Males are absent in Michigan populations and the spermathecae could not be seen, perhaps because of the dense refractive intestinal granules. Michigan specimens were found in a mixed population with *T. maximus*. Collections made during various times for several years eventually produced one male. This was found in a population of several thousand females; unfortunately, an accident in the laboratory resulted in the loss of this specimen. Males undoubtedly play a minor role in Michigan populations. *T. agri* is known from Illinois and Iowa.

Merlinius microdorus Geraert, 1966, known from Belgium, was found around unthrifty Madonna lilies in sandy loam soil and always showed a large percentage of males in the populations.

T. microphasmis Loof, 1959 (type locality Boskoop, the Netherlands), was found in Michigan in a peach orchard on July 27, 1966 but has not been found since. In several of the *Tylenchorhynchus* species, a guiding ring could be seen and it showed up clearly in certain processed specimens. It was so distinct and visible it was drawn when observed.

T. longus Wu, 1969, known from soil near *Populus balsamifera L.*, Bow River Forest, Calgary, Alberta, Canada was found in Michigan near a species of White Birch near the mouth of the Maple River, University of Michigan Biological Station, Douglas Lake, Emmet County, Michigan and also around conifers near Mt. Pleasant. Although individual colonies were always small, many specimens were collected throughout these areas. Additional sampling in both agricultural and non-cultivated areas is almost certain to reveal many more species of these genera.

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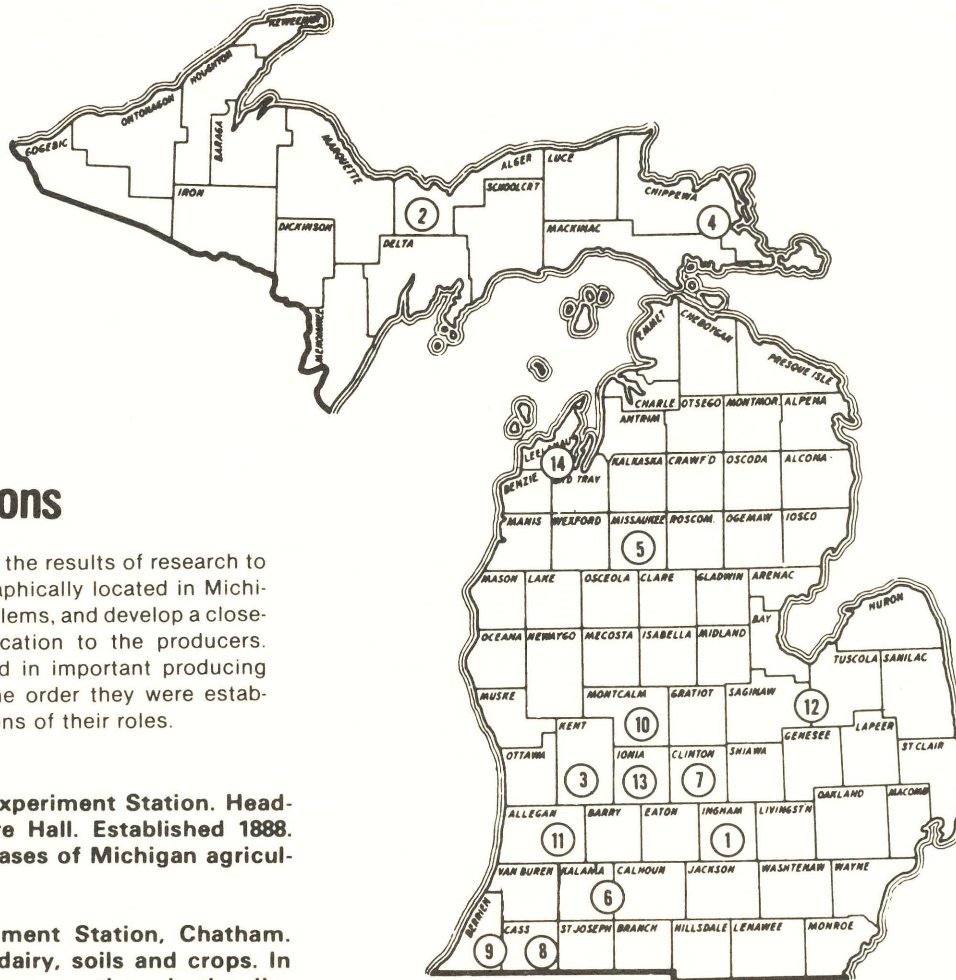

Outlying Field Research Stations

These research units bring the results of research to the users. They are geographically located in Michigan to help solve local problems, and develop a closeness of science and education to the producers. These 14 units are located in important producing areas, and are listed in the order they were established with brief descriptions of their roles.

(1) **Michigan Agricultural Experiment Station. Headquarters, 101 Agriculture Hall. Established 1888. Research work in all phases of Michigan agriculture and related fields.**

(2) **Upper Peninsula Experiment Station, Chatham. Established 1907. Beef, dairy, soils and crops. In addition to the station proper, there is the Jim Wells Forest.**

(3) **Graham Horticultural Experiment Station, Grand Rapids. Established 1919. Varieties, orchard soil management, spray methods.**

(4) **Dunbar Forest Experiment Station, Sault Ste. Marie. Established 1925. Forest management.**

(5) **Lake City Experiment Station, Lake City. Established 1928. Breeding, feeding and management of beef cattle and fish pond production studies.**

(6) **W. K. Kellogg Biological Station Complex, Hickory Corners. Established 1928. Natural and managed systems: agricultural production, forestry and wildlife resources. Research, academic and public service programs.**

(7) **Muck Experimental Farm, Laingsburg. Plots established 1941. Crop production practices on organic soils.**

(8) **Fred Russ Forest, Cassopolis. Established 1942. Hardwood forest management.**

(9) **Sodus Horticultural Experiment Station, Sodus. Established 1954. Production of small fruit and vegetable crops. (land leased)**

(10) **Montcalm Experimental Farm, Entrican. Established 1966. Research on crops for processing, with special emphasis on potatoes. (land leased)**

(11) **Trevor Nichols Experimental Farm, Fennville. Established 1967. Studies related to fruit crop production with emphasis on pesticides research.**

(12) **Saginaw Valley Beet and Bean Research Farm, Saginaw. Established 1971, the farm is owned by the beet and bean industries and leased to MSU. Studies related to production of sugar beets and dry edible beans in rotation programs.**

(13) **Clarksville Horticultural Experiment Station, Clarksville. Purchased 1974. Plots established 1978. Research on all types of tree fruits, small fruits, vegetable crops and ornamental plants.**

(14) **Northwest Michigan Horticultural Research Station. Established 1979. Research and education for cherry and other horticultural crops in northwest Michigan.**

The Michigan State University Agricultural Experiment Station is an equal opportunity employer and complies with Title VI of the Civil Rights Act of 1964.

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