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NEMATOLOGY IN THE NORTH CENTRAL REGION, 1956-1966


AND ALASKA

Agricultural Experiment Stations of Alaska, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin, and the U. S. Department of Agriculture cooperating.

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NCR-35 Technical Committee on Plant Parasitic Nematodes

Sponsored by the agricultural experiment stations of Alaska, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin, and the U. S. Department of Agriculture, cooperating.

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FOREWORD

There have been many accomplishments in nematology in the North Central Region during the past decade. As a result of the organization of a regional nematology committee, research and teaching in the area have been greatly expanded. New problems of major agricultural significance have been discovered, and some of suspected significance have been revealed. An awareness has developed of a large and important group of animals, many of them plant parasites. Because of sheer numbers alone, nematodes deserve more attention by biologists in all aspects.

In January 1966, the NCR-35 Regional Committee voted to prepare a publication describing nematology in the North Central Region since the inception of a regional nematode committee in 1956. This publication is the result of that decision. Little nematological work has been done in Alaska, and no information from that state is included. Also, data from Nebraska and Ohio were generally unavailable.

Many people have been involved in the regional project in one way or another. To all we offer our sincere thanks. Special thanks are due the NCA-14 Advisory Committee and Dr. J. A. Callenbach, Administrative Advisor for NCR-35, for their encouragement and support.

NCR-35 Publication Committee

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CONTENTS

Nematology in the North Central Region, 1956-1966

Nematodes have been recognized as plant parasites since the mid-to-late 18th century. Although the seed gall, root-knot, stem and bulb, and cyst nematodes received considerable attention up to 1950, the science was manned by only a handful of personnel up to that time. Because of their microscopic size and evasiveness as positive factors in root deterioration, the plant parasitic nematodes were largely neglected by scientists for many decades. The nematological explosion shortly after World War II and its impact on agriculture in some areas of the United States are well documented. To a great extent, the impact has been brought about through the uncovering of new agricultural problems. These problems have necessitated increased training and additional positions in several disciplines, including nematode morphology, taxonomy, ecology and physiology. Studies in these and related areas do and should include basic work. As has often been true, one doesn't know what is economically important until the nematode or situation is studied. The roles of nematodes in water pollution and in soil and marine microbiology are largely untouched. Yet, these nematodes most certainly play important roles in their respective areas. Although much has been done in nematology in the United States, the potential in the field is so great that some phases are far behind others, and few, if any, phases are adequately supported. From a purely zoological view point, investigations of this group, the most numerous of the Metazoa, seem unlimited.

Nematology was started late in the North Central Region as compared with other regions in the United States for several reasons. Experimental evidence and field observations have shown that root-knot nematodes, other than *Meloidogyne hapla*, are not a continuous problem when the mean January temperature is 30° F or below. Thus, most root-knot nematodes are of little, if any, importance over two thirds of the North Central Region. However, *M. hapla* manifests itself in the Great Lakes area and in other localized areas in the region. Early detection of genera peculiar to regions of the United States (such as the sting nematode in the Southeast; the citrus nematode in California, Arizona and Florida; the burrowing nematode in Florida; the sugar beet nematode in the West; and the golden cyst nematode in New York) added impetus to nematology in those areas.

Lacking paramount recognition of problems and with soils not easily fumigated, the North Central Region had to await the stimulus provided by the discovery of *Ditylenchus destructor* in Wisconsin and of *Heterodera glycines* in Missouri and Illinois. Whereas spectacular nematode problems were not uncovered in the North Central Region as compared with other regions, less noticeable but equally important problem areas were neglected. We are now aware of many of these, and new problems are continually being uncovered. Agriculture in the North Central Region is, to a large extent, field crops oriented, thus making the problems more extensive, if less concentrated, than with the high-cash-per-acre crops such as citrus and many vegetables. In many cases, however, the relative damage per plant is no less in field crops than in the higher-cash-per-acre crops. As the trend continues toward concentrated agriculture in the Midwest, it can be expected that the influence of nematodes will become more pronounced.

Part of the problem has been the lack of personnel to investigate existing situations, but once investigated, the importance of nematodes is often revealed. This has been true of forage legumes in the Midwest. Another case was with woody nursery plants, which constitute one of the important recognized nematode problem areas in the region. But, nematodes associated with woody plants are not restricted to ornamentals. There are reasons to implicate the nematodes as a factor in forest tree decline. Some of the highest nematode populations per given quantity of soil are recovered in forested areas, and much needs to be learned of nematode biology in these habitats. The faunistics of nematodes in wooded areas in the region are relatively unknown. What little has been done has revealed many new species of nematodes. Nematodes reported from woodlands of the North Central Region have been hitherto reported only from foreign countries or once or twice from distant areas in the United States.

Nematological research in the North Central Region began on an organized basis in 1956 with the formation of the NCT-28 Technical Committee, "Biology and Control of Plant Parasitic Nematodes." Before that time, work in nematology (not including the parasitological aspects) was, on the whole, fragmentary, with only an occasional publication or thesis resulting. As an outgrowth of NCT-28, NC-39 was activated July 1, 1957, with the project bearing the same title as NCT-28. The following states had contributing projects for at least part of the 5 years that the regional project was in operation: Illinois (M. B. Linford, leader), Minnesota (D. P. Taylor, leader), Nebraska (M. L. Schuster, leader), Ohio (J. D. Wilson, leader) and Wisconsin (G. Thorne, leader). During this period, Wisconsin was designated as a primary station. Considerable time was spent there assembling a collection of nematological slides and in assisting other persons in identification of their material.

The NC project was terminated in 1962, but continued regional cooperation was provided by the establishment of NCR-35, under which the project has operated until now. In 1963, a project on the population dynamics of *Xiphinema americanum* was carried out, and committee members in most states contributed information concerning population fluctuations of this nematode associated with a given plant species in their states.

Although the regional research committee provided an impetus for nematology in the region, other workers have conducted nematological research in the area. Some states have had more than one professional person working in nematology, at least on a part-time basis. In some instances, cooperative projects were undertaken with workers in other disciplines, especially agronomy and horticulture. Also, most states have personnel of the Plant Pest Control Division, United States Department of Agriculture, making surveys for the golden and soybean cyst nematodes.

Although much has been accomplished in nematology in recent years, great tasks lie ahead. In the following pages, some of the immediate problems, accomplishments and needs pertinent to the North Central Region are summarized. Hopefully, they will provide new insights to scientists and educators and, in turn, to the people.

EDUCATION

Although a regional technical committee is primarily a research organization, education is an important aspect of its activities. Except for the work of the late Dr. M. B. Linford of Illinois, teaching and research in nematology in the North Central Region before 1956 were isolated. Formal courses in nematology were not offered at that time. Plant diseases caused by nematodes were usually discussed briefly, if at all, in plant pathology courses. Soil or plant parasitic nematodes received similar treatment in zoological courses. Regional training schools have not been sponsored or promoted by the North Central Regional Nematology Committee, although one is being planned. Nematological training of the state representatives has been 1) as a result of participation in special training schools sponsored by other regional projects in the United States, 2) by graduation from an institution where formal training in nematology has been offered, or 3) both. By 1966, at least one formal course in nematology was offered in most states in the region. In all instances, these were taught in state universities and affiliated with agriculture. By Dec. 31, 1966, an equivalent of 15 full-time professional persons were engaged in nematological research in the region, and 19 persons were working toward advanced degrees. Since 1956, 17 M.S. and 23 Ph.D. degrees have been conferred with theses in nematology.

Because of the diversity and scope of nematology, increased training and constant review are a necessary part of this expanding discipline. Thus, whereas education in nematology has made substantial progress in the North Central Region, the field as a whole is still in its infancy, and education must keep pace with its potential growth. This is true not only for agricultural aspects, but also for nonagricultural aspects, applied and basic.

Table 1. Staff, courses and degrees in nematology in the North Central Region, 1956-1966.

	Ill.	Ind.	Iowa	Kan.	Mich.	Minn.	Mo.	N. Dak.	S. Dak.	Wis.	Total
Full-time professional persons	4	3	1.1	1	1	1	1		1.7	1.5	15.3
Regularly scheduled nematology courses[a]	1	2	1	2	1	1	1	1	1	2	13
Number of other courses including nematology	4	4	3	3	1	1	1	1	2	2	22
M.S. degrees since 1956	5		4		2	3	2			1	17
Ph.D. degrees since 1956	5	2	2	2		2				10	23
Man-years in extension nematology per year		0.1	0.1	0.1	0.5						0.8
Present graduate students (1966-67)	4	3	3	2	1	1			1	4	19

[a] In addition, most schools offer special topics or special problems in nematology.

EXTENSION WORK AND POPULAR PUBLICATIONS IN NEMATOLOGY

Extension education is essentially a teaching discipline and has the primary objective of disseminating information. There are no extension nematologists as such in the North Central Region, and relatively little work is devoted to nematology by extension personnel (table 1). This is somewhat surprising in view of the many problems pointed out by research in the past decade. Such a deficiency should be overcome as more agricultural personnel obtain knowledge and receive training in nematology.

In many states, considerable extension work is done by nematologists through participation in short courses, meetings of industry, radio and TV appearances, and by writing popular publications. Conversely, there has been a trend for extension personnel to do applied research. Many of their tests have been directed toward nematode control and have usually been in cooperation with research specialists.

Considerable time is taken in most states to process soil samples submitted to plant disease clinics or directly to the nematologist for evaluation as to the role of nematodes in plant decline. Michigan is the only state that extensively advertises and furnishes this service.

Extension specialists are often overburdened and to assume additional responsibilities would dilute the effectiveness of existing programs. This situation has been alleviated or avoided by some western and southern states by creating positions in extension nematology. This is a natural and necessary development in disciplines of economic importance.

A listing follows of extension or other popular publications in nematology in the North Central Region. Portions of publications on related topics often include sections concerning nematodes.

Elmer, O. H. 1963. Plant parasitic nematodes. Kan. St. Univ. Agr. Exp. Sta. Cir. 365. pp. 1-37.

Ferris, J. M. 1961. Plant parasitic nematodes, a recently recognized problem facing flower growers. Ind. Florists Newsletter 2 (5): 3-5.

__________ 1963. Nematodes and nursery crops. Trees Magazine 23 (5): 18.

Johnson, H. G., and D. P. Taylor. 1959. Nematode control on established plants. Minn. St. Florist's Bul. Feb. 1, 1959. pp. 8-9.

Knierim, J. A. 1956. Nematodes affecting ornamental plants. Mich. St. Nursery Notes 10: 1-3.

__________ 1958. The nematode situation in Michigan. Proc. Shell Nematol. Workshop (Toledo). pp. 1-5.

Linford, M. B. 1959. Biological control of plant parasitic nematodes. Ill. Res. 1 (2): 10-11.

McGuire, J. 1963. Plant parasitic nematodes in South Dakota. S. Dak. Farm and Home Res. 14 (3): 14-16.

Norton, D. C., and G. Worf. 1962. We are learning more about nematodes, hidden plant destroyers. Iowa Farm Sci. 17 (1): 9-10.

__________, R. C. Lambe and C. P. Wilsie. 1965. Nematodes and fungi are cutting hay yields. Iowa Farm Sci. 20 (3): 3-4.

Pepper, E. H. 1964. The nematode menace. N. Dak. Farm Res. 23 (12): 30-33.

Shurtleff, M. C., D. P. Taylor, J. W. Courter and H. B. Petty, Jr. 1964. Soil disinfestation. Methods and materials. Univ. Ill. Circ. 893. pp. 1-23.

Taylor, D. P. 1957. Plant parasitic nematodes - a threat to Minnesota crops. Minn. Farm and Home Sci. 14 (3): 5,9.

__________ 1957. Where plant parasitic nematodes may be found: nurseries and orchards. Proc. Shell Nematol. Workshop (St. Louis). pp. 19-23.

__________ 1958. Nematodes, a potential threat to the flax industry. Proc. 28th Flax. Inst. pp. 20-21.

__________ 1958. Nematodes and nursery crops. Minn. Nurseryman's Newsletter 6 (5-6): 1-3; (7-8): 3-4.

__________ 1959. Nematodes as garden pests. Minn. Horticulturist 87: 42-43.

__________ 1959. Root knot, a nematode disease of plants. Minn. Farm and Home Sci. 16 (3): 13.

__________ 1961. Destructive nematodes accompany southern azaleas. Minn. St. Florist's Bul. Feb. 1, 1961 pp. 8-9.

__________ 1961. Nematodes can make soil-borne diseases worse. Minn. Farm and Home Sci. 18 (3): 10,17.

__________ 1962. Nematodes and nursery production. Ill. St. Nurserymen's Assn. Bul. 52. pp. 1-2.

__________ 1963. Those pesky nematodes. Contract Crops 2 (5): 19-22.

__________ 1964. Nematodes - are they everywhere? Ill. St. Florist's Assn. Bul. 253. pp. 5-7.

__________, and C. F. Hodges. 1965. Root knot nematode attacks bent-grass on putting greens. Ill. Res. 7 (4): 18.

Willis, W. G., and O. J. Dickerson. 1964. Soil fumigation guide for nematode control. Kan. Agr. Ext. Serv. Plant Dis. Leaf. 171: 1-4.

RESEARCH

In any expanding scientific discipline, inquiry is probably the most important element, closely followed by teaching and extension. But, without inquiring minds, stagnation develops and greatly lessens the effectiveness of the whole program. Many problems of expanding disciplines are the result of grossly unbalanced programs. As one phase of a discipline expands, it is both dependent on and limited by the knowledge developed in closely related phases. Thus, research and development and training in several areas should be complementary. This desired goal has not always been so in nematology. Research is needed in all phases of nematology, applied and basic, agricultural and nonagricultural.

The results presented here are largely from the initial stages of research and reflect past accomplishments and problems for the future. To solve these problems and to increase our knowledge of nematodes and their role in nature, basic work is necessary on many phases of nematology. Investigations in morphology, taxonomy, ecology, physiology, genetics and virus transmission are just some of the broad areas needing intensive study.

Surveys

General surveys have probably received less emphasis in the North Central Region than in other areas, but some have been made in most states. Frequently, these have been conducted to investigate the presence of nematodes associated with a certain crop or a group of crops in which decline is evident. Despite certain criticisms, surveys do provide the initial impetus to research by revealing associations of nematodes with a disease situation. In many instances, results of surveys have directed nematologists' attention to problems not known to exist or previously attributed to other causes.

A list of the nematodes found in association with plants in the North Central Region is presented in table 2. This is a biased list, however, and often reflects the assignment or interest of the investigator. At the same time, it reflects the widespread occurrence of certain species. In some instances, the more uncommon nematodes or those especially taxonomically difficult were classified only to genus. A reasonable complete list of the nematodes associated with plants would require far more time than is available to the existing personnel in the region.

Although the compilations in table 2 reveal the strengths or interests of personnel in the various states within the region, they also reveal gaps in our knowledge of nematodes on important crops within the region. Since table 2 is merely a faunistic list, it should be considered in light of information presented in the subsections on "Principal Associations" and "Economic Problems."

Table 2. Plant parasitic or suspected plant parasitic nematodes found within the North Central Region and their observed abundance. 1=abundant, 2=common, 3=uncommon, 4=rare.

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	Minn.	Mo.	N. Dak.	S. Dak.	Wisc.
Anguina spp.				4					4	3
A. agropyronifloris				4					4	
Aphelenchoides spp.	3	3		2	1			2	3	3
A. blastophthorus				4						
A. composticola				4						
A. fragariae	4	4		4						
A. limberi				4						
A. parietinus			2		3				3	
A. pseudoparietinus				4						
A. ritzemabosi	3	4	3		4					3
A. subtenius					3					
Aphelenchus avenae	1	2	1	2	1			2	1	3
A. eremitus				4						
Boleodorus clavicaudatus				2						
B. thylactus	3		2	2	3				1	
Criconema spp.	4								4	3
C. fimbriatum			3							
C. octangulare			3							
Criconemoides spp.	3	2	3	2	2	2			4	3
C. curvatum			3							
C. macrodorum			3							
C. sphaerocephalum					3					
C. xenoplax		3	3	2					3	
Ditylenchus spp.	2	3	3	2		2			2	
D. destructor		4								3
D. dipsaci	3			3	3					
D. myceliophagus				4						
Dolichodorus spp.			4							
D. heterocephalus					4					4
Helicotylenchus spp.	1	1	1	3	1	1		3	2	2
H. digonicus			3	1					4	3
H. dihystera		2	3	3					3	
H. erythrinae				3		2				
H. platyurus	3		3	2					3	3
H. pseudorobustus	1	1	1	2	3	3			4	
Hemicycliophora spp.		3				3			4	3
H. gigas			4							
H. membranifer		4								
H. rotundicaudata		4								
H. similis			2		2					
H. uniformis			3		2					
H. vaccinium					2					
H. vidua			3		3					
Heterodera spp.				3	3	2			3	
H. cacti	2					3			3	
H. glycines	2						1			
H. punctata								2		
H. schachtii				1	2			4		3
H. trifolii	3	2	2			3	3			
H. weissi	1	3	3	3					3	3
Hirschmaniella spp.			4	4					4	
Hoplolaimus spp.						2		3		
H. galeatus	2	2	1	2	3				2	
H. tylenchiformis				3						
Hypsoperine sp.										4
H. graminis				4						

Table 2 (Cont'd).

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	Minn.	Mo.	N. Dak.	S. Dak.	Wisc.
Longidorella parva				4						
Longidorus spp.	4	3	4						3	3
L. elongatus					2					
Meloidogyne spp.				4		2				2
M. hapla	2	2	2	2	1	2	3		3	2
M. incognita (group)	4	3		1				4		
M. incognita acrita					4		1			
Metaphelenchus micoletzkyi				4						
Neotylenchus spp.									4	
N. affinis	3			4						
N. arcuatus				4						
Nothotylenchus spp.	4			4					4	
N. affinis				4						
N. acris				4	2				4	
N. cylindricollis				4						
N. drymocolus				4						
Paraphelenchus spp.	3								2	
P. amblyurus				4						
P. myceliophthorus				4						
P. pseudoparietinus				4					3	
Paratylenchus spp.	1	1		2	1	1		2	2	2
P. aciculus		4			3					
P. aculentus			3		3					
P. audriellus			3		3				4	
P. curvitatus			3		4					
P. elachistus			3							
P. hamatus		2			2					
P. intermedius				4						
P. macrophallus		2								
P. microdorus			4							
P. nanus			3							
P. projectus	2	2	2		4				1	
P. tenuicaudatus			3							
Pratylenchoides spp.		3								
Pratylenchus spp.	2	1				1			2	1
P. alleni	3						3			
P. brachyurus									2	
P. coffeae			3						4	
P. crenatus		3			1					3
P. hexincisus	1	3	2			2			1	
P. neglectus	2	2		3	1					
P. penetrans	2	1	2	2	1	2				2
P. pratensis	2	3				4				
P. scribneri	1	2		1		4			1	
P. subpenetrans		4								
P. thornei		4								
P. vulnus		4		3	4	3				
P. zeae		4								
Psilenchus spp.	2	3				3			2	
P. aberrans				3						
P. clavicaudatus				3						
P. gracilis				4						
P. hilarulus		3	1	3					1	
P. magnidens				3						
Radopholus neosimilis				4						
Rotylenchus buxophilus		4		4						
R. goodeyi				4						
R. robustus				4						
Rotylenchulus reniformis				4						
Scutellonema brachyurum		4								
S. bradys	4									
Tetylenchus joctus		3			3			4	4	
Trichodorus spp.	4	3		3				4	3	2
T. christiei		3	4	4	1					
T. proximus				4						
Trophurus spp.		4								
T. minnesotensis									3	
Tylenchorhynchus spp.	1	2		3	1	1			2	2
T. acutus	2	2	2	1		3		2	1	
T. agri	3		3							
T. brevicaudatus			3							
T. brevidens		4				4			4	
T. capitatus	2	2								
T. clarus				4						
T. claytoni		4		4	1			2		
T. cylindricus		4						2		
T. dubius				3		4				

Table 2 (Cont'd).

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	Minn.	Mo.	N. Dak.	S. Dak.	Wisc.
T. ewingi					3					
T. lamelliferus				3						
T. latus		4				2			4	
T. leptus			3						4	
T. martini	2	2	2			3			3	
T. maximus	3	3	3	3	2	4			2	3
T. microphasmis					4					
T. nudus		2	2	4		1			2	2
T. parvus				2	2					
T. silvaticus	3		3	2						
T. striatus				3		4				
T. tessellatus				4						
Tylenchus spp.	1	1	1	3		1		2	1	
T. agricola				3						
T. costatus		3	2	3	1			2	2	
T. davainii		3	2	3	2				4	
T. duplexus				4						
T. exiguus			2						1	
T. filiformis			2	2	4				2	
T. thornei				2	3					
Xiphinema spp.				4		1		2	4	2
X. americanum	1	1	1	1	1	1		2	1	2
X. chambersi		4	3							
X. diversicaudatum	4	3			4					
X. index				4						

The free-living nematodes have been studied much less than the plant or suspected parasitic ones, but in some instances, many identifications have been made (table 3). Parasites of insects found in Indiana are *Blatticola blattae* (2), *Hammerschmidtiella diesingi* (3), *Leidynema appendiculata* (3), *Mermis* spp. (2), *Sphaerularia bombi* (1), *Tetradonema plicans* (4), *Agamermis decaudata* (3). Parasites of insects found in Kansas are *Leidynema appendiculata* (3), *Mermis* spp. (3), *Agamermis decaudata* (3). Numbers in parenthesis indicate observed abundance: 1=abundant, 2=common, 3=uncommon and 4=rare.

Table 3 . Free-living nematodes found within the North Central Region and their observed abundance. 1=abundant, 2=common, 3=uncommon, 4=rare.

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	N. Dak.	S. Dak.
Achromadora spp.				4			
A. pseudomicoletzkyi				3			
A. ruricola		4		4			
A. semiarmata				4			
A. terricola				4			
Acrobeles spp.	3	2	2	4	1	1	1
A. ciliatus				4			
A. complexus				1			1
A. ctenocephalus				2			2
A. elaboratus				4			4
A. ornatus				4			
Acrobeloides spp.				3	1		1
A. apiculatus				4			
A. buetschlii			3	4			1
A. minor				4			1
Alaimus spp.	4	2	3	4	3		4
A. primitivus				3			
A. proximus				4			
Amphidelus spp.				4			4
A. dolichurus				4			
A. hyans				4			
A. pusillus				4			

Table 3 (Cont'd).

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	N. Dak.	S. Dak.
Anaplectus spp.				2			4
A. granulosus				3			
Aporcelaimus spp.		2		3			2
A. conicaudatus				4			
A. minor				4			
A. paraconicaudatus				4			
A. parvus				4			
A. vorax				4			
Axonchium spp.			4	3			3
A. amplicolle				4			
A. choristum				4			
A. micans				4			
A. solitare				4			
Belondira spp.				4			4
B. apitici				3			
B. caudata		4					
B. ortha				4			
Bunonema spp.			4		3		4
Butlerius spp.	4	4			4		
Campydora demonstrans				3			4
Carcharolaimus spp.				4			3
C. dentatus		4					
Cephalobus spp.	2	2	2	4		2	4
C. persegnis				3			
Cervidellus spp.							3
Chiloplacus spp.			2	3			1
C. lentus				4			
C. quadricarinatus				2			
C. symmetricus			4	4			
Chronogaster longicolles		4					
Cobbonchus spp.				4			
Cylindrolaimus obtusus				3			3
Diphtherophora spp.				4	2		2
D. brevicolle				4			3
D. obesus				2			2
Diplogaster spp.	1	2		4			2
Diplogasteritus nudicapitatus				3			
Diploscapter spp.	1			4			4
Discolaimium spp.				3			2
D. conura				4			2
D. cylindricum				3			2
D. gracile		3		4			2
D. latum				4			4
D. tenuidons				4			
Discolaimoides spp.							4
Discolaimus spp.	3	2		4			2
D. major				3			
D. similis		3		4			2
D. texanus		3	3	2			2
Dorylaimellus spp.				4			4
D. aequalis				4			3
D. occidentalis				4			
D. parvulus				3			
D. porosus				4			4
D. striatus				4			
D. tenuidens				4			4
D. virginianus		3		3			
Dorylaimoides spp.			3				2
D. elegans				4			2
Dorylaimus spp.					2		4
Doryllium spp.					3		
Enchodelus spp.				4			4
E. arcuatus				4			
E. hopedorus				4			
E. macrodorus				4			
E. teres				4			
E. vesuvianus				4			
Eucephalobus spp.				4			
E. elongatus				4			
E. laevis				3			
E. latus				4			
E. oxyuroides				2			1
E. striatus				3			
E. teres				4			4
Eudorylaimus spp.		2		3			1
E. acuticauda				4			2

Table 3 (Cont'd).

Nematodes	Ill.	Ind.	Iowa	Kan.	Mich.	N. Dak.	S. Dak.
E. alpinus				4			
E. amylovorus		2		4			2
E. angulosus				4			
E. arcus (group)		2		4			4
E. brachycephalus				4			
E. brevidens				4			
E. capitatus				3			3
E. carteri (group)		2		3			2
E. centrocercus				4			
E. curvatus				3			
E. diadematus				4			
E. ettersbergensis				4			
E. humilis				4			
E. incisus				4			
E. iners				4			
E. intermedius (group)		2		4			3
E. irritans				4			
E. junctus							
E. krygeri (group)		2					
E. longidens		2					
E. minor				4			
E. minutus		2					
E. miser				3			2
E. monohystera		2		4			1
E. niditus				4			
E. nodus				4			4
E. nothus		2		3			3
E. obesus				4			4
E. obscurus		2		4			1
E. obtusicaudatus				3			
E. papillatus				4			
E. paraobtusicaudatus				4			
E. parvus				3			
E. pratensis				3			3
E. productus				3			
E. propinquus				3			
E. sublabiatus (group)		2		4			2
E. tritici				4			
E. unformis				4			
Iotonchus similis				4			
Ironus spp.		2		4			
I. longicaudatus				4			
Isolaimium spp.				4			
Labronema spp.				4			
L. ferox		2					4
L. ruttneri				4			
L. uniforme		3					
Leptonchus spp.				4			3
L. granulosus	3	2		3			2
Mesodiplogaster lheritieri				4			
Mesodorylaimus spp.		2		3			2
M. bastiani		2		3			2
M. biroi				4			
M. filicaudatus				3			
M. subtilis				4			
Mesorhabditis spp.				3			
M. monhystera				3			
Miconchus exilis				2			
M. rapax				4			
Monhystera spp.				3			4
Monhystrella spp.				3			
Monochoides				4			
Mononchus spp.	1	2	1			2	3
M. papillatus			1	2	1		2
M. parvus				3			4
M. truncatus				4	1		
M. tunbridgensis				4			
Mylonchulus spp.			2	3			2
M. brachyurus				2	1		
M. lacustris				2	3		
M. subsimilis				4			
Nygolaimus spp.		2		3			1
N. amphigonicus				3			
N. aquaticus				4			4
N. dubius				4			3
N. hartingii				4			3
N. laevis				3			
N. obtusus				4			
N. tenuis				4			
N. vulgaris				4			2
Onontolaimus chlorurus				4			
Oncholaimus spp.		3					
Oxydirus oxycephalus		3					
Panagrolaimus spp.		2				2	3
P. rigidus				4			
P. subelongatus			3	2			3
Paroigolaimella coprophaga				4			
Pelodera spp.				3	2		
Plectus spp.	2	2		3	1		2
P. acuminatus				4			
P. armatus				3			
P. assamilis				3			
P. parietinus				2	2		1
P. rhizophilus				3			
P. varians				4			
Prismatolaimus spp.		3			2		3
P. dolichurus				4			
P. intermedius				3			
Protorhabditis spp.				4			
Pungentus spp.			4	3			
P. brevidentatus				4			
P. intertaxtus				4			
P. monohystera				4			2
P. parvus				4			
P. pungens		2		3	3		4
P. sparsus				4			
Rhabditis spp.	1	2	1	2	1	2	2
Sectonema spp.		2					4
Seinura spp.	4	3					4
S. oahuensis				4			
Thalassoalaimus aquaedulcis				4			
Tobrilus spp.				4			3
Triplonchium spp.							3
Tripyla spp.		2		4			3
T. affinis					2		
T. arenicola				3			
T. setifera				3			
Tylencholaimellus spp.					3		2
T. affinis				4			
T. cinctus				3			
T. coronatus				4			
T. diplodorus				4			
T. striatus		2		3			2
Tylencholaimus nanus				4			3
T. proximus				3			2
T. stecki				4			
T. teres		2					
Tyleptus							4
Tylolaimophorus cylindricum				4			
Tylopharynx spp.				4			
Vasastoma spp.				4			
Wilsonema spp.							2
W. auriculatus				3			2
W. otophorum					1		3

Principal Associations

Plant parasitic nematodes are so closely associated with plants that one can hardly divorce the two, even though at times seemingly unrelated investigations are made. Many things should be considered in discussing principal associations. The associations are among the first impressions made upon a nematologist, but actually they are the end result of many complex and interrelated phenomena. Nematode ecology, physiology, genetics, crop management, climatological and edaphic factors (biological and physical) are all involved in what appears to be a principal association. Some factors may be more important in one situation than another, but they all play a part. The lack of a close nematode-plant relationship is also the result of interactions of these same factors, although operating in different ways and proportions. To agricultural economics, adequate knowledge of these conditions may be as important as the principal associations themselves.

As a result of survey or other research, many nematodes in the North Central Region have been noticed frequently in association with specific plants. These are presented as principal associations, but probably reflect partly the assignment or interest of the people involved. Because not all plants or crop areas were investigated equally, many other "principal associations" remain to be discovered. Thus, the associations presented here are probably only a few that have been discovered. They have, however, formed the basis of existing research.

Aphelenchoides

In the states from which *Aphelenchoides* was reported, the bud and leaf species were usually listed as uncommon or rare. They are occasionally severe on chrysanthemums.

Criconemoides

Although *Criconemoides* are not as widespread as many plant parasitic nematodes, they are common in specific habitats, such as lawns in Kansas, bluegrass in Illinois and blueberries and tree fruits in Michigan.

Ditylenchus spp.

Ditylenchus destructor. This species was found infesting 1,200 acres of potatoes in Wisconsin, but now is under control.

Ditylenchus dipsaci has been associated occasionally with alfalfa in Kansas and with onion in Illinois and Michigan.

Helicotylenchus

Helicotylenchus spp. have been found commonly associated with turf in Indiana, Illinois, Iowa, Kansas, Michigan, South Dakota and Wisconsin and with roses and field crops in Minnesota. Besides being common in turf in Indiana and Iowa, *H. pseudorobustus* is commonly associated with corn and soybeans in those states and in Illinois.

Heterodera

Heterodera gylcines is associated with soybeans in southeast Missouri, southern Illinois and Indiana. *Heterodera schachtii* is often associated with sugar beets in Kansas and Michigan and with red table beets and cabbage in Wisconsin. *Heterodera trifolii* is frequently associated with clover in most states in the region and probably generally occurs wherever white clover is grown. Unidentified *Heterodera* cysts have been found frequently associated with range grasses in Iowa, North Dakota and South Dakota.

Hoplolaimus

Hoplolaimus is frequently associated with lawns in Kansas. *Hopolaimus galeatus* was found a principal associate around trees in Iowa, in nurseries in Illinois and Indiana, and with corn, sorghum and grasses in South Dakota.

Hypsoperine

Hypsoperine graminis occurs occasionally around Zoysia grass in Kansas. A new species of *Hypsoperine* has been found on canary grass in Wisconsin.

Meloidogyne

Probably the most widespread species of *Meloidogyne* in the North Central Region is *M. hapla*. It probably is present in all states and is commonly associated with vegetables, strawberries, nurseries, home gardens and ornamentals in most areas of the region where these crops are grown. *Meloidogyne incognita* is a principal associate of melons in southern Indiana, and along with *M. arenaria*, it occurs around sweet potatoes and vegetables and in home gardens in Kansas. *Meloidogyne incognita acrita* is common around cotton, soybeans, melons and other truck crops in southeastern Missouri. This species often is associated with greenhouse crops as in Michigan.

Panagrolaimus

A species of *Panagrolaimus* has been associated, along with *Helminthosporium vagans* Drechsler, with a melting out of bluegrass in North Dakota.

Paratylenchus

Although species of *Paratylenchus* are very common in the region, their importance must still be investigated. They commonly are associated with mint in Indiana and Wisconsin, vegetables in Wisconsin, soybeans and clover in Illinois and Indiana, turf in Iowa and Kansas, roses and field crops in Minnesota and celery in Michigan. *Paratylenchus projectus* is common around field crops, range grasses, apples and pine in South Dakota.

Pratylenchus

Species of *Pratylenchus* are probably generally distributed throughout the region. They have been especially associated with vegetables and corn in Wisconsin, lawns in Kansas, and roses and field crops in Minnesota. *Pratylenchus brachyurus* is common around wheat and range grasses in South Dakota. *Pratylenchus coffeae* is a principal associate around chrysanthemums in South Dakota. *Pratylenchus hexincisus* is frequently associated with alfalfa in Iowa, corn in Illinois and South Dakota, soybeans in Illinois, Indiana, Iowa and South Dakota and with pasture grasses in South Dakota. *Pratylenchus penetrans* seems general in Iowa and Wisconsin; common in Michigan; a principal associate around onion, spearmint, peppermint, corn, apple, and soybeans in Indiana; strawberry in Illinois, Michigan and Kansas; and nursery crops in Illinois and Michigan. *Pratylenchus scribneri* is a principal associate of corn, cantaloupe, tomato, strawberry, watermelon and chrysanthemums in South Dakota; corn and soybeans in Illinois and Indiana; and to some extent in all field crops in the western part of Kansas. *Pratylenchus vulnus* has been associated with greenhouse roses in Indiana and Michigan.

Trichodorus

Trichodorus is a principal associate around mint in Wisconsin and onion in Michigan.

Tylenchorhynchus

Species of *Tylenchorhynchus* are common throughout the region. They are often associated with corn in South Dakota; soybean in Illinois, Indiana, Minnesota and South Dakota; apple in Indiana; turf in Illinois, Iowa, Kansas, Michigan and South Dakota; and forage grasses in North Dakota. They are also common around roses in Minnesota. *Tylenchorhynchus* spp. including *T. martini* are common around roots of small grains in Minnesota.

Xiphinema

Xiphinema americanum is one of the most commonly encountered plant parasitic nematodes in the North Central Region. It is especially common around perennials, but is not restricted to them. It is a common associate of orchard crops, forest trees and nursery crops in Wisconsin; orchard crops in Indiana, Iowa and Michigan; trees in Iowa and North Dakota; roses in Minnesota; alfalfa, red clover and white clover in Iowa; strawberries and nursery crops in Illinois; mint in Indiana; soybeans in Indiana, Iowa and Minnesota; lawns in Kansas; and generally distributed in Missouri and South Dakota.

Xiphinema diversicaudatum is sometimes associated with greenhouse roses in Indiana, Illinois and Michigan.

Economic Problems

Economic problems involving plant parasitic nematodes are often revealed when significantly improved quality or increased yield results with the elimination of nematodes. This has not always been as easy to prove as it has been with some other diseases and disorders of plants and animals. But, in some cases, where absolute proof is wanting, evidence from several different sources has been rather convincing and control measures have been initiated, often with gratifying results. As our procedure improves, the soundness of our control measures will improve.

Nursery and Ornamental Plants

The nursery industry is one of the important agricultural enterprises in the North Central Region. It is in this area that nematodes were early recognized as an important problem, and nurseries today are giving active support to nematological research (fig. 1). Because of the time factor in perennials, nematodes have ample time to build up over a period of years, and damage is often multiplied several fold as compared with some annuals.

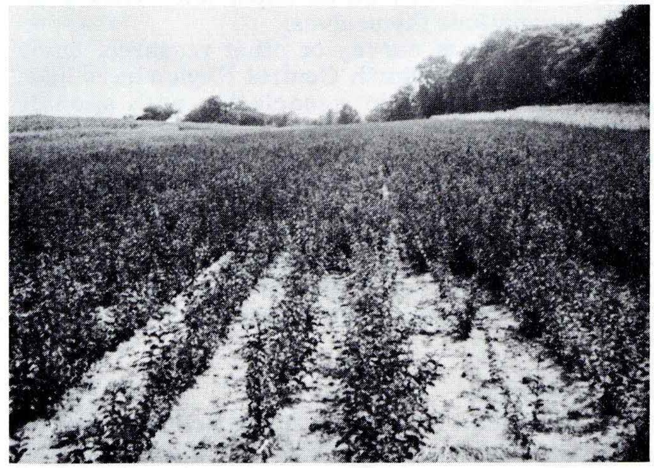

FIGURE 1. Nematode damage in an ornamental nursery. Soil in the foreground was not fumigated; that in the background was fumigated to control nematodes. Source: Minnesota Agricultural Experiment Station.

Because of the vast amount of shipping of nursery plants, many nematodes not indigenous to an area may be introduced. Some nematodes may not survive the environment into which they are introduced, but others may become established and spread to surrounding areas. Thus, the problem of nematodes in nurseries is not just one of monetary loss to the individual grower.

Thousands of dollars worth of nursery stock are discarded each year because of root-knot nematode infections, principally *Meloidogyne hapla.* This nematode is a serious pathogen on peony and other ornamentals in Iowa. Many nurserymen in the North Central Region use some type of control in seedbeds, potting soil and in the field to reduce the number of root-knot nematodes. *M. ovalis* is a recently discovered nematode known to attack sugar maple, white ash and American elm in Wisconsin.

Other genera important to the nursery industry include *Aphelenchoides, Xiphinema, Pratylenchus, Helicotylenchus* and, possibly, *Criconemoides.* Several foliar nematodes *(Aphelenchoides* spp.) cause damage to plant leaves in nurseries and gardens in Indiana and Wisconsin. In North Dakota, *X. americanum* is associated with dieback of weeping birch. *Pratylenchus coffeae* has caused a serious problem on nursery chrysanthemums in South Dakota.

All states in the region report large numbers of nematodes associated with turf grasses. In Wisconsin, a form of summer dormancy of bluegrass is caused by several species of *Helicotylenchus.* Nematologists in Kansas have found that *Hypso-*

perine graminis causes extensive damage to Zoysia lawn grass (fig. 2). This species probably was introduced into the region on commercial lawn grasses. It has the potential of becoming a serious economic problem because it reproduces on most of the lawn and field crop grasses grown in Kansas. Another nematode genus, *Tylenchorhynchus,* may be involved in turf, pasture and range grass decline in South Dakota and North Dakota and in azalea production in Wisconsin. Fumigation tests at a Minnesota nursery convinced the management that nematode control resulted in better plant growth and a higher percentage of cuttings that rooted.

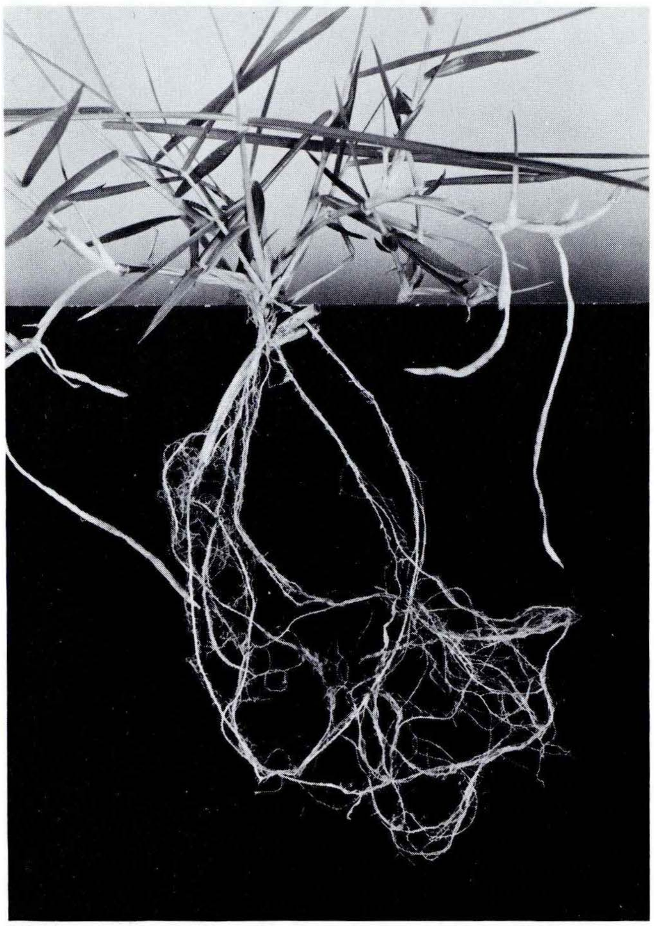

FIGURE 2. Hypsoperine graminis infected roots of Zoysia japonica. Note swelling and lack of lateral roots of the newer adventitious roots. Source: Kansas Agricultural Experiment Station.

Greenhouse Crops

Greenhouse crops can suffer heavily from nematode damage unless adequate control measures are practiced. In spite of their sometimes severe damage, nematodes in the greenhouse are among the easiest to control. Good horticultural practices, of which sanitation is extremely important, will control or eliminate most of the problems. Management is the key to the problem. In one greenhouse, it may be difficult to detect any potential nematode problems, while in another nearby greenhouse in which identical or similar plants are grown, plants may be so severely infested that losses become limiting. Most commercial operators treat their greenhouse beds with chemicals or heat at regular intervals to control root-knot nematodes (principally *M. incognita).* Failure to apply measures that reduce the nematode population causes yield and quality reduction as a result of injury by root-knot nematodes. Virtually every crop grown under glass is attacked by this group of nematodes.

Another species, *X. diversicaudatum,* causes striking injury to greenhouse-grown roses. This species and possibly several species of *Paratylenchus* and *Pratylenchus* markedly shorten the productive life of greenhouse rose plants.

Fruit and Vegetable Crops

Fruit and vegetable production varies greatly in the region, but is most concentrated in the eastern part. Vegetable production, however, has increased markedly in some western areas due to increased irrigation during the past decade. Nematode problems on annual vegetables are more noticeable in the southern part of the region, but they can be severe in the northern areas, such as in muck soils in Ohio, Indiana and Iowa.

Root-knot nematodes (principally *M. hapla), X. americanum* and several species of *Pratylenchus* are common in strawberry plantings throughout the region. These species are important both from the standpoint of plant injury and plant quarantine regulations. Strawberries, in some instances, have played a major role in the dispersal of these nematodes. Plant inspections to prevent this spread have made growers keenly aware of the need to control nematodes in the field.

An estimate of the monetary loss caused by nematodes in these crops can be obtained from work in Indiana. Surveys indicated that 75 percent of the melon fields are infested with root-knot nematodes *(M. incognita).* Comparison of yields from treated and untreated plots showed average increases of 100-200 bushels per acre when root-knot nematodes were controlled. With melons selling at $2 per bushel, the loss per acre in untreated, infested fields ranges between $200 and $400 per acre.

In the North Central Region, little information is available on the damage plant parasitic nematodes inflict to fruit trees. In Michigan, however, establishing new plantings of cherry and peach and replanting in established orchards is a major problem due to *Pratylenchus penetrans* and *Xiphinema americanum.* Species of *Meloidogyne* and *Pratylenchus* have also been problems in fruit tree nurseries, especially when material is shipped to other states.

Home gardens are frequently infested with root-knot nematodes that cause extensive plant injury. These nematodes also cause crop losses to commercial vegetable growers. *Meloidogyne hapla* damages carrots in muck soils of Iowa, Michigan and Wisconsin. *Meloidogyne incognita* is a limiting factor in sweetpotato production in Kansas. Tomatoes and potatoes are attacked, not only by root-knot nematodes, but also by species of *Pratylenchus.*

Ditylenchus destructor is another important nematode attacking potatoes. In Wisconsin, 1,200 acres of potato land have been found infested with this nematode. Infested fields were taken out of potato production until the nematodes were eradicated. Over 500 acres have been fumigated with ethylene dibromide at a cost of $38-$40 per acre, and *D. destructor* has now been eliminated so that potato production can again be permitted on this land.

Onions have been heavily damaged by *D. dipsaci* in limited areas in Illinois and Michigan. Reductions in onion yield occur when *P. penetrans* is present in large numbers in muck soils in Indiana, even though environmental conditions may not be conducive to complete loss. Under other conditions, this species causes total losses to onions grown from seed. Therefore, Indiana and Michigan growers treat, in late Autumn, land to be planted to onion the following spring. Because of the highly organic type of soil, large amounts of the fumigants are required, resulting in a minimum chemical cost alone of $60 per acre.

Heterodera schachtii is damaging to red table beets in one area of Wisconsin and has also been found on cabbage. This species also injures sugar beets in Wisconsin and Michigan, and is endemic on sugar beets in western Kansas, where losses up to 75 percent are noted in a few fields each year. The only practical control for *H. schachtii* is long term rotation.

Field Crops

Field crops are grown on more acres than any other plant commodity in the North Central Region. Although corn and soybeans are grown on more acres than the other field crops, wheat and forage legumes are major crops in many areas. Nematodes are associated with all, and the damage is considerable (figs. 3 and 4).

Xiphinema americanum is common throughout the North Central Region. Research in Iowa illustrates that this species can be very important in forage-legume production. Greenhouse and field experiments indicate strongly that *X. americanum* can and does cause serious damage in about 10 percent of the alfalfa and red clover fields. Field observations suggest that this species can cause considerable damage to white clover. Another nematode, *Heterodera trifolii,* which attacks clover, probably causes decline of white clover in long-term pastures. In simulated pasture plots, this species caused significant injury to both white and red clover.

The soybean cyst nematode *(Heterodera glycines)* has become a major problem in Illinois, with heavy losses reported from soybeans on light, sandy soils in dry years. In Missouri, the estimated loss caused by this species increased from $50,000 in 1959 to over $2 million in 1965. These increased losses result from a buildup of the nematode population and an increased number of acres infested each year. During 1965, losses from 25 to 60 percent were noted in many infested soybean fields, with a high of 90 percent in one instance.

Although cyst nematodes have received most of the publicity, root-knot nematodes are also a serious problem on soybeans. In breeding programs designed to develop nematode-resistant soybean varieties, resistance to both *Heterodera* and *Meloidogyne* must be included if farmers are to get useful selections, although resistance to one or the other may be valuable in particular circumstances.

FIGURE 3. Nematodes feeding on corn roots. Source: Iowa Agriculture and Home Economics Experiment Station.

In Missouri, root-knot nematodes, principally *M. incognita* in combination with Fusarium wilt, caused a $3-million to $5-million annual loss to cotton. It was learned that a normal cotton crop could be grown by first using a soil fumigant to control the nematodes or by planting a nematode-resistant cotton variety without using a soil fumigant. The wide distribution of root-knot nematodes, combined with the high cost of soil fumigation, has forced farmers to grow only resistant cotton varieties.

Root-knot nematodes cause severe losses to many other field crops. An undescribed species of *Meloidogyne* has been associated with stunted sorghum in a large field in the Kansas River bottomlands.

In greenhouse tests, *Pratylenchus alleni* caused a 25-percent reduction in root weight of soybean

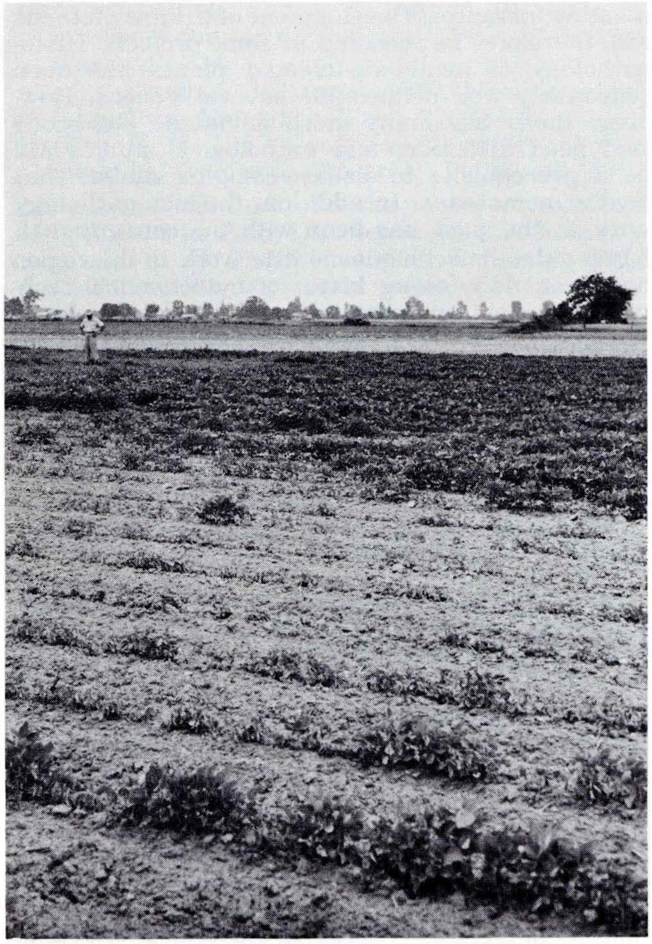

FIGURE 4. Soybean cyst nematode damage such as this is common in Southeast Missouri. Source: Plant Pest Control Division, U. S. Dept. Agr.

plants. This species was originally discovered in an Illinois soybean field. Nematodes of many genera have been isolated from soil samples collected in fields of barley, wheat and forage grass in 19 counties of North Dakota. Similar findings can be cited for other states within the North Central Region. However, more research is required to determine the nature and magnitude of the injury that these plant parasitic nematodes are causing to the different crops attacked.

The state reports summarized in this section are, in many cases, based on research that was crop oriented. Thus, it is possible that nematode problems on some crops have been ignored or overlooked because not enough nematologists have worked on all the different crops grown in the region. It is strongly suspected that nematodes are a major factor in the decline of certain crops, but the supporting data are limited. Continued association of nematode species with important crop plants of the region such as those described will inevitably lead to further research.

Principal Research Areas

The formative years in nematology in the North Central Region were, of necessity, spent largely on faunistics, followed by preliminary pathogenicity and fumigation trials. All these are being continued in varying degrees. Today, however, and for the next several years, the emphasis will be on detailed studies of biological phenomena. With the diversified agriculture in the North Central Region, one might expect nematological research to be equally diversified. This is partly true, but even with the diversification necessitated by the agriculture of a state, concentration on a given crop often results in voids in information about other crops. Job assignments sometimes bias the investigation.

An area of endeavor that should receive more consideration is the role of nematodes in disease complexes with bacteria, fungi and viruses. Such work is now being done in the area, but much more is needed. Questions involving the part nematodes play as reservoirs and in transmission, establishment and ultimate disease development with other organisms are largely unanswered.

Knowledge of nutrition, food supply and physiology of plant parasitic and free-living forms is sparse for most nematodes and should be part of programs in the North Central Region. Most of this work is now being or has been done in Indiana and Wisconsin.

With the recent expansion of soybean acreage in the Midwest, it is only natural that there is greater interest in nematodes on this crop. Such programs are now operating in Illinois, Indiana and Iowa. These include pathogenicity, rotation, population dynamics and environmental studies. In spite of the vast corn acreage in the region, relatively little nematological work has been done with this crop. Some work has been done in Illinois and Iowa, but here is an instance where a major crop has been largely neglected.

Vegetables are important in the eastern states within the region and in the irrigated areas of the western states. Although some areas are relatively small, they are in concentrated production, and nematode problems can be great. Among problems on vegetables that have received or are receiving attention are nematodes on muskmelons, onions and potatoes in Indiana; the potato-rot nematode in Wisconsin; root-knot on sweetpotatoes in Kansas; and root-knot on celery in Michigan.

Nursery, greenhouse and turf plants are high income crops and, therefore, losses per acre can be great. Consequently, scientists in most states have been called upon to do some nematological work in these areas.

Field crops, other than corn and soybeans, are important, especially in the western areas of the region. The major work in Iowa has been on forage legumes. Workers in Kansas are investigating *Meloidogyne hapla* in alfalfa.

Important plants on the prairies and plains are those used as windbreaks. They often undergo decline, and *Xiphinema americanum* is a common associate. This problem is being investigated in South Dakota.

Interwoven in all these studies are basic investigations on taxonomy and biosystematies, ecology, physiology and host-parasite relationships. Applied control measures are practiced in varying degrees as the situation warrants. Many basic questions concerning all phases of control are yet unanswered. Very little is known about relationships of nematodes with other soil organisms. Biological control of nematodes will remain a vision until much more is learned about relationships between nematodes and parasitic fungi, bacteria, viruses, protozoa and other organisms, not the least of which are predaceous nematodes. Also, projects designed to explore control of other organisms, such as insects and fungi in association with nematodes, will be or have been activated.

Besides the diverse investigations described, nematodes associated with insects are being studied in Indiana, and the role of nematodes in water pollution is being studied in Illinois.

Lack of greenhouse and laboratory techniques for culture of certain nematodes, especially ectoparasitic ones, has been a perplexing deterrent in many instances. Development of culture methods will, therefore, be included in some projects. Histopathology of nematode-infected plants has been reasonably well defined for several genera. However, there are many more nematode situations that need attention, and pathological studies will be a prerequisite to disease-complex studies that involve nematodes. In addition, the histopathology work in the past has been with the conventional, but restricted techniques. Little work in the region has been done using histo- or cytochemical techniques or electron microscopy.

In recent years it has become obvious that all nematode problems are not agricultural; the biology and significance of nematodes in water systems is a good example.

The preceding research efforts should not be interpreted as definitive. As projects mature and expand and new problems emerge, adjustments will be necessary to serve the needs of the region.

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THE FUTURE

Nematology in the North Central Region has developed markedly during the past decade. Regional projects have done much to foster this development and doubtless can play a major part in the future. One of the benefits of a regional project is to reduce the professional isolation that so often results when there are a limited number of personnel trained in nematology in each state. Thus, the need for such a regional committee is no less now than it was 10 years ago. The future of nematology in the North Central Region will, to a large degree, depend upon solving common problems. In this, a regional project can be very instrumental.

With the opening up of a whole new field to the region in the past decade, problems of major magnitudes were revealed. These findings dictate expanded scientific inquiry into these and related problems. Some areas are now being studied, some need to be expanded, and others have yet to be initiated. Basic studies are needed in most areas. However, so much emphasis has been placed on the spectacular phases of nematology that other equally important aspects have been neglected. The lack of publications concerning nematode relationships to our basic crops is very striking. Many reasons for this could be imagined, but two seem rather obvious and somewhat interrelated. The so-called basic research has in many instances become the easy way out simply because the aims and consequent data are more definitive. Secondly, support has not been available for the mass of data it takes to successfully handle field problems. One needs only to recall that the science of nematology had a token existence, until a practical control was found, to realize that what is basic to the science is essentially that which is not known. A list of the research areas as related to nematological problems pertinent to the North Central Region would be useful. Such a listing follows:

1. Taxonomy and morphology are essential to any biological discipline. Adequate training in these areas is mandatory for all workers in nematology.

2. The biology of all forms of soil nematodes and their role in soil microbiology needs investigation. The soil contains many saprobic and predaceous nematodes in such close association with the plant parasitic forms that all these forms need investigation from a soil microbiological standpoint to understand the process of root deterioration.

3. Ecological studies on nematode distribution and habitat relationships are highly desirable. These should include population dynamics as influenced by macro- and microenvironments.

4. Basic studies are needed on host-parasite relationships, including feeding habits and physiological aspects.

5. Plant pathological investigations on the role of nematodes to plants in the Midwest include: (a) Perennials, including forest trees, fruit crops, nursery crops, forage legumes and (b) Role of nematodes in concentrated agriculture, especially corn and soybeans.

6. The role of nematodes in water pollution is a relatively new field and one that needs much expansion.

7. Interaction studies are needed on nematodes in association with other organisms that may serve as a basis of biological control.

8. Studies on the nature of resistance and accumulation of resistant germ plasm is vital to any breeding program.

9. The discovery of transmission of viruses by nematodes has been a major scientific breakthrough in recent years, and much more work needs to be done.

10. Many areas will need new procedures or more efficient use of known procedures to take full advantage of the opportunities offered in nematology.

These problems should become goals and are consistent with those recommended in the report, "A National Program of Research for Agriculture," October 1966, prepared at the request of the United States Senate. It is recognized that many of the nematology areas just mentioned overlap, emphasizing the importance of broad training and coordinated research.