Technical Bulletin 225

Interactions of Nematodes with Other Pathogens Attacking Plants in The Western States

Edward L. Nigh, Jr., *Editor*

Published by

Western Regional Research Project W-56
(1963-1973)

and

Agricultural Experiment Station
The University of Arizona
Tucson, Arizona

Technical Bulletin 225

Interactions of Nematodes with Other Pathogens Attacking Plants in The Western States

Edward L. Nigh, Jr., *Editor*

Published by

Western Regional Research Project W-56 (1963-1973)

and

Agricultural Experiment Station • The University of Arizona

Tucson, Arizona 85721

1975 **1500**

Written by TECHNICAL COMMITTEE W-56

Edited by Edward L. Nigh, Jr.

Jack Altman	1963-73	Colorado
Glenn B. Bergeson	1969-73	Indiana
C. Eugene Dallimore	1963-66	Idaho
O. Joe Dickerson	1970-73	Kansas
Lin R. Faulkner	1963-73	Washington
Gerald D. Griffin	1963-73	Utah (ARS)
Oliver V. Holtzmann	1963-73	Hawaii
O. Joe Hunt	1963-73	Nevada
Harold J. Jensen	1963-73	Oregon
Edward C. Jorganson	1963-68	Utah (ARS)
Ben F. Lownsberry	1963-69	California (Davis)
Fred D. McElroy	1970-73	Vancouver, B.C.
Edward L. Nigh, Jr.	1963-73	Arizona
Bill Orchard	1968-69	Victoria, B.C.
Dewey J. Raski	1969-73	California (Davis)
Harold W. Reynolds	1963-68	Arizona (ARS)
Jerald W. Riffle	1967-73	New Mexico (U.S.F.S.)
Ivan J. Thomason	1963-64	California (Riverside)
Seymore D. Van Gundy	1963-73	California (Riverside)
John M. Webster	1970-73	Vancouver, B.C.

Administrative Advisors

Joe A. Asleson	1963-65	Montana State Univ.
Lloyd C. Ayres	1965-73	Univ. of Wyoming
John F. Fulkerson	1963-74	CSRS, USDA, Wash., D.C.

CONTENTS

Introduction

Synergistic associations of nematodes and other organisms were noted as early as 1892, when Atkinson (1) reported that *Fusarium* wilt of cotton was more severe in cotton plants infected with root-knot nematodes, *Meliodogyne* spp. Nearly thirty years passed before additional observations further indicated the influence of nematodes on the severity of *Fusarium* wilt of cotton and other crops (2,4).

In 1953 Dr. G. Steiner, then Chief of the Division of Nematology, A.R.S., U.S.D.A., saw the importance of studying the association of nematodes and other plant diseases and in writing on "Changes in Basic Concepts in Plant Nematology (5), said: "It concerns the fact that soil-borne plant diseases are at least in some instances of complex character and that nematodes quite frequently are members of such complexes, acting as either initiators, cooperators, synergists and aggravators, or otherwise. Here must be considered not only the plant parasitic types of nematodes but the whole array of forms".

The following year, Holdeman (3) pointed out that there were very few published results that definitely demonstrated the influence of nematodes in other diseases. He reviewed the literature to that time. Since 1954, the role of nematodes in disease complexes has been positively demonstrated numerous times.

Three regional projects were initiated (W-56, S-19, and NE 34) to study the importance of nematodes as plant parasites and in root disease complexes. These projects and the introduction of new nematicides that were effective advanced the research and knowledge of nematodes as plant pathogens.

Nematodes were proven to be associated with bacterial and fungus diseases. They were found to vector viruses of plants. Single species and combinations of nematode species were found to be pathogenic and frequently synergetic. In many instances their exact role has not been established. Most frequently nematodes have been found associated with fungus diseases. Since the plant host grows in a biosphere composed of a complex society of potential parasites, it is only appropriate that the interrelationships and ultimate effects of these complexes upon the host be thoroughly investigated.

REFERENCES

1. Atkinson, G.F. 1892. Some diseases of cotton. Alabama Agr. Exp. Sta. Bull. 41:66 pp.
2. Barker H.D. 1938. Relation of nematodes to wilt. Association South Agr. Workers Proc. 39:147.
3. Holdeman, Q.L. 1954. Nematodes as possible members of disease complexes involving other plant pathogens. Plant Disease Reporter Supplement 227:77-79.
4. Smith, A.L. 1941. The reaction of cotton varieties to fusarium wilt and root knot nematodes. Phytopathology 31:1099-1107.
5. Steiner, G. 1953. Changes in basic concepts in plant nematology. Plant Disease Reporter 37(4):203-205.

History of W-56

The need for a regional approach to nematode research in the Western States was recognized in the late 1940's. In 1949 plans for master and contributing projects, centering around phases of research on root knot nematodes, were drafted and submitted as Project W-15, "Plant Nematodes and Their Control". Unfortunately, Federal support was not given to this project and it was not until late in 1956 that another attempt was made to initiate a regional approach to nematode research in the West. At that time, a master plan was drafted for another project entitled, "The Role of Nematodes in Root Diseases of Economic Plants".

W-56 was initiated in 1958, when little was known regarding the kinds of plant parasitic nematodes present in much of the West and their effect on Western crops. Sufficient information was accumulated by 1963 to allow an estimate of the dollar loss caused by nematodes in most of the major crops. Work in this phase of the project resulted in the discovery of new nematodes in areas where they had not been known to exist.

At the end of the five year termination date of the project, significant progress had been achieved towards attaining the objectives in W-56. New knowledge had been developed that added to the understanding of basic biological principles that underlie the interactions between nematodes, their hosts and associated soil-borne organisms.

When revision of the project was considered in 1963 most of the technical committee members had shifted emphasis toward study of the pathogenicity of these plant parasites. Observations of field associations and limited experimental evidence indicated that some of the most important effects of nematodes on crops might be those resulting from the interactions of nematodes with other pathogens, particularly fungi and viruses. Research emphasis therefore was shifted to a study of a large number of such interactions. Because of the known existence of mixed nematode populations associated with plant roots, the effects of one species of nematode or complex populations of nematode were also studied.

The Technical Committee was composed of representatives from Oregon, Washington, Idaho, Utah, Nevada, Colorado, Arizona, New Mexico, Hawaii and 2 nematologists representing the Davis and Riverside Experiment Stations of California. The title of the revised project was, "The Interrelation of Nematodes and Other Pathogens in Plant Disease Complexes". There was but one defined objective: to determine the interrelations of the following in plant disease complexes: 1) Nematode interactions with other nematodes, 2) Nematode-fungus interactions. 3) Nematode-virus interactions, and, 4) The influence of physical factors on nematode interrelationships.

For 5 years the Technical Committee continued to work on the project. Idaho and New Mexico had withdrawn from the Committee. However, they were replaced in 1967 by the association of the U.S. Forest Service nematologist from New Mexico, whose interests involved complexes between nematodes and mycorrhizae of forest trees.

In 1968, W-56 was revised for the second time with the entire emphasis being placed on the interactions of nematodes and fungi. While the title remained the same the objectives were broadened: 1) To determine nematode-fungus interactions in crop diseases of the region where etiology is uncertain, 2) To ascertain the effects of nematode-fungus interactions on plant growth and on the interacting organisms and, 3) To determine the effects of the environment on nematode-fungus interactions in plant diseases. The Committee recognized the need for additional study to evaluate physiological changes which occurred in the host which in turn could alter the biology of interacting organisms. Information was at last available that permitted the more basic aspects of the nematode-fungus relationships to be explored and these aspects were to be emphasized by those members who had established associations between specific nematodes and fungi. Climate, crops and soils of the Western States were important environmental factors that still require study in these disease complexes.

The Technical Committee of W-56 was enlarged by accepting nematologists from Kansas, Indiana, and British Columbia who were involved in research that met the objectives of the project.

During the active years of W-56, the Technical Committee presented three seminars with proceedings published from each. In Hawaii the first seminar concerned the application of nematicides followed by an equally successful effort in Riverside on the subject of root-knot nematode. The third seminar dealing with alfalfa nematodes, was held in Prosser, Washington. It, like the others, was well attended by interested growers highly appreciative of the Committee's efforts to relay needed information on nematodes.

Title and Objectives of First W-56 Regional Project 1956-1963

Title: The Role of Nematodes in Root Diseases of Economic Plants.

Objectives: a. To determine the plant parasitic nematodes present in the root disease complexes in the Western States and Hawaii and their economic importances.

b. To investigate the specific and collective pathogenicity of nematodes and associated organisms, and their ecological relationships in the root disease complexes of economic plants.

c. The identification and assembling of representative nematode specimens associated with the important root disease complexes, and their preservation in permanent mounts.

d. Based on the information obtained through the studies outlined above, control measures will be devised and tested.

Title and Objectives of Second W-56 Regional Project 1963-1968

Title: The Interrelation of Nematodes and Other Pathogens in Plant Disease Complexes.

Objective: Determine the interrelations of the following in plant disease complexes.

1. Nematode interactions with other nematodes.
2. Nematode-fungus interactions.
3. Nematode-virus interactions.

Title and Objectives of Third W-56 Regional Project 1968-1973

Title: The Interrelation of Nematodes and Other Pathogens in Plant Disease Complexes.

Objectives: a. To determine nematode-fungus interactions on plant growth and on the interacting organisms.

c. To determine the effects of environment on nematode-fungus interactions in plant diseases.

This Western Regional Research publication is a completion of the research efforts of W-56. It is a vehicle by which negative results may be reported to the research world. Too frequently only positive data appear in the literature. The members of the Technical Committee hope it will be useful to those researchers who are involved in the study of nematodes in complex with other plant pathogens.

The Technical Committee of Western Regional Research Project W-56 feel that it is fitting to express their appreciation to Drs. Joe Aseleson and Lloyd Ayers for the support and guidance during the years the project has been active. Thanks are also due the Directors of various Experiment Stations who had the foresight to fund this important area of research, particularly at the time it was in its infancy. Above all the members of the Committee wish to recognize the outstanding guidance provided by Dr. John Fulkerson, Plant Pathologist, C.S.R.S., U.S.D.A. His suggestions and encouragement vitally assisted in making this regional project profitable to nematology and plant pathology.

Nematode-Fungal Interactions

A. Discussion

As early as 1892 Atkinson reported Fusarium wilt of cotton to be more severe in fields where root-knot nematodes were present. Many years lapsed before serious study was initiated to determine the causal effects of the disease complex. Holdeman and Graham (2), in 1954, reported that the sting nematode also was responsible for increase of Fusarium wilt in cotton. By then, nematology was developing rapidly and the association of nematodes with other pathogens, particularly fungi, was receiving attention after 62 years of obscurity since Atkinson's published observation. A literature review on the subject was published by Powell in 1963 (7) containing 96 references. Two years later Pitcher's review (6) cited 136 references pertaining to the association of nematodes with fungi. Bergeson (1) in his review of the concepts of nematode-fungus associations in plant disease complexes, cites over 100 references involving these interactions. In 1972 Jatala and Jensen (4) listed more than 700 references pertaining to nematode interactions with other organisms.

As more observations were made, researchers began to seriously investigate the role of parasitic nematodes with fungal pathogens.

Some of the earliest observations indicated that disease resistance was greatly reduced or "broken" in the presence of various nematodes parasitizing the same host. Later research demonstrated the capability of the nematode to significantly modify the hosts' physiology and mineral composition, a factor significant in altering the mechanisms of resistance. Where mechanical barriers are the nature of resistance, it is easy to understand that the penetration of endoparasitic forms and the continuous puncturing caused by the ectoparasitic feeders, can serve as wounding agents. Through such wounds other parasites may enter that cannot enter without a portal of entry. There would be certain exudates emitting from such wounds which may serve to attract fungi or to enrich the soil microflora in the rhizosphere.

Nematode infection may also slow host growth that leaves it more subject to infection by some fungi. Further, vascular plugging which prevents nutrient and water uptake, can reduce host vigor making it more susceptible to invasion by other parasites. Root exudates can also be affected, such as an increase in release of amino acids and reducing compounds that influence the microflora of the rhizosphere.

It has been stated that plant parasitic nematodes may serve as vectors of various fungal spores. However, there is little data to support these reports. Jensen and Siemer (4) were able to demonstrate that in some saprophagus nematodes, spores of *Verticillium* spp. and *Fusarium* spp. were ingested and viable after passing the alimentary tract. They were also protected from the action of fungicides while within the gut of the nematode. The oral aperture of most plant parasite forms of nematodes is too small to ingest even the smaller of the fungal spores, although they could possibly adhere to the cuticle and be transported in this manner. The subject has received so little quantitative study that it is impossible to say with certainty what the role of the nematode is as a vector of plant parasitic fungi.

The influence of fungi on nematodes has received less attention than the reverse situation. Increases in CO_2 are reported in loci of infection by various fungi and at these points, increased populations of nematodes may be found. Infection courts (syncytium) are frequently attacked by fungi where they become quickly established in the nutrient-rich areas. In such cases, the nematode usually succumbs to the fungal competitor. Additional research will eventually determine the true relationship.

REFERENCES

1. Bergeson, G.B. 1972. Concepts of nematode-fungus associations in disease complexes: A review. Expt. Parasitol. 32:301-314.
2. Holdeman, Q.L. and T.W. Graham. 1954. Effect of the sting nematode on expression of Fusarium wilt in cotton. Phytopathology 44: 683-685.
3. Jatala, P. and H.J. Jensen. Sept. 1972. Bibliography of nematode interactions with other organisms in plant disease complexes. Department of Botany and Plant Pathology. Oregon State University, Corvallis, Oregon.
4. Jensen, H.J. and S.R. Siemer. 1971. Protection of *Fusarium* and *Verticillium* propagules from selected biocides following ingestion by *Pristionchus lheritieri*. J. Nematology 3:23-27.
5. Jorgenson, E.C. 1970. Antagonistic interaction of *Heterodera schachtii* Schmidt and *Fusarium oxysporum* (Woll.) on sugarbeet. J. Nematology 2:393-398.
6. Pitcher, R.S. 1965. Interrelationships of nematodes and other pathogens of plants. Helminthological Abstracts 34:1-17.
7. Powell, N.T. 1963. The role of plant-parasitic nematodes in fungus diseases. Phytopathology 53:28-35.

B. Research Results

Scientist(s)	Location	Date	Nematode	Fungus	Host	Location	Observation	Bibliography
Aytan and Dickerson	Kansas	1968	*Meloidogyne naasi*	*Fusarium moniliforme*	Sorghum	Laboratory	Positive association	-*
Dickerson and Browder	Kansas	1971	*Meloidogyne incognita*	*Puccinia recondita f. tritici*	Wheat	Glasshouse	Negative association	-
Dickerson and Browder	Kansas	1972	*Meloidogyne hapla*	*Puccinia recondita f. tritici*	Wheat	Glasshouse	Negative association	-
Falkner, et al.	Washington	1965-69	*Pratylenchus minyus*	*Verticillium dahliae*	Peppermint	Field	Positive association	1,2
Golden and Van Gundy	California	1972	*M. incognita*	*Rhizoctonia solani* *Thielaviopsis basicola*	Tomato	Glasshouse	Positive association	3
Holtzmann and Santo	Hawaii	1969-71	*Pratylenchus zeae*	*Pythium graminicola*	Sugarcane	Glasshouse	Independent but additive	4
Jensen and Vaughan	Oregon	1972	*M. hapla* *P. penetrans* *Helicotylenchus nannus* *Longidorus elongatus*	*Plasmodiophora brassicae*	Cabbage	Glasshouse	Synergistic response	5
Jorgensen	Utah	1968	*Meloidogyne* spp	Various soil fungi	Various	Field and glasshouse	Positive observations	6
Jorgensen	Utah	1970	*Heterodera schachtii*	*Fusarium oxysporum*	Sugarbeet	Greenhouse	Positive association	7
Khoury and Alcorn	Arizona	1973	*M. incognita*	*Verticillium albo-atrum*	Cotton	Glasshouse	Wilt increase with larger nema populations	8
Nigh and Alcorn	Arizona	1968	*M. incognita*	*V. albo-atrum*	Cotton	Field	Indirect relation described	9
Nigh and Eshtiaghi	Arizona	1969	*M. incognita* *Tylenchorhynchus cylindricus* *Aphelenchoides sp.* *Aphelenchus avenae*	*Phymatotrichum omnivorum*	Cotton	Field	Nematodes feed on fungus. No relationship observed with parasitic nema spp.	10
Polychronopoulos	California	1969	*H. schachtii*	*R. solani*	Sugarbeet	Greenhouse	Positive	11
Riffle	New Mexico	1971	*A. cibolensis*	*Poria weirii* *Armillaria mellea* *Leptographium* *Polyporus schweinitizii* *Fomes annosus*	Pine	Laboratory	Nematodes feed on fungi. Growth, fungi reduced, *A. mellea* killed	-
Riffle	New Mexico	1973	*Aphelenchoides cibolensis* *Aphelenchoides composticola*	*Armillaria mellea*	Pine	Laboratory	Nematodes reduced seedling mortality due to root rot	-
Sindhu and Webster	British Columbia	1974	*M. incognita*	*F. oxysporum*	Tomato	Glasshouse	Nema breaks wilt resistance	13
Yorston	Oregon	1969	*P. penetrans* *L. elongatus*	*V. dahliae*	Mint et al.	Glasshouse	Additive	15

* Unpublished data

C. Bibliography

1. Fulkner, L.R. and W.J. Bolander. 1969. Interaction of *Verticillium dahliae* and *Pratylenchus minyus* in *Verticillium* wilt of peppermint: Effect of Soil Temperature. Phytopathology 59:868-870.
2. Faulkner, L.R. and C.B. Skotland. 1965. Interactions of *Verticillium dahliae* and *Pratylenchus minyus* in *Verticillium* wilt of peppermint. Phytopathology 55:583-586.
3. Golden, J.K. and S.D. Van Gundy. 1972. Influence of *Meliodogyne incognita* on root rot development by *Rhizoctonia solani* and *Thielaviopsis basicola* in tomato. (Abstr.) J. Nematology 4:225.
4. Holtzmann, O.V. and G.S. Santo. 1971. Effect of temperature on the interrelationship of *Pratylenchus zeae* and *Pythium graminicola* on sugar cane. Phytopathology 61:1321.
5. Jensen, H.J. and E.K. Vaughan. 1972. Interactions of various nematodes with the club-root organism of cabbage. (Abstr.) Phytopathology 62:1104.
6. Jorgenson, E.C. 1968. Root-knot and soil fungus interactions. Symposium: Root-knot nematode in the Western States, Riverside, California.
7. Jorgenson, E.C. 1970. Antagonistic interaction of *Hererodera schachtii* Schmidt and *Fursarium oxysporum* (Woll.) on sugarbeet. J. Nematology 2:393-398.
8. Khoury, F.Y. and S.M. Alcorn. 1973. Effect of *Meliodogyne incognita acrita* on the susceptibility of cotton plants to *Verticillium albo-atrum*. Phytopathology 63:485-490.
9. Nigh, E.L. and S.M. Alcorn. 1968. The incidence of *Verticillium* wilt in field grown upland cotton infected with *Meliodogyne incognita acrita*. P. Series, Cotton, A College of Agriculture Report.
10. Nigh, E.L. and H. Eshtiaghi. 1969. Nematodes associated with upland cotton infected by *Phymatotrichum omnivorum*. (Abstr.) Phytopathology 59:1042.
11. Polychronopoulos, A.G., B.R. Houston and B.F. Lownsbery. 1969. Penetration and development of *Rhizoctonia solani* in sugar beet seedlings infected with *Herterodera schachtii*. Phytopathology 59:482-485.
12. Santo, G.S. 1969. Studies on the interrelationship between *Pythium graminicola* and *Pratylenchus zeae* and sugarcane growth. M.S. Thesis, Department of Plant Pathology, University of Hawaii.
13. Sidhu, Gurmel and J.M. Webster. 1973. Genetic Control of Resistance in Tomato. I. Identification of genes for host resistance to *Meloidogyne incognita*. J. Nematology 1:546-550.
14. Soudah, Clemense. 1964. Incidence of *Rhizoctonia* infection in alfalfa as effected by root knot nematode, *Meliodoygne incognita acrita*. M.S. Thesis, Department of Plant Pathology, University of Arizona.
15. Yorston, John. 1969. The interactions of *Pratylenchus penetrans* with host plants, *Longidorus elongatus* and *Verticillium dahliae*. Ph.D. Thesis, Oregon State University, Corvallis. 55 pp.

Nemotode-Nematode Interactions

A. Discussion

Seldom does a single plant-parasitic nematode species occur singly in the absence of other nematodes in an agricultural soil. Usually mixed populations of two or more species occur in any given crop field. Community structure of plant parasitic nematodes in 14 soybean fields of Illinois and Indiana showed five fields each containing three plant parasitic nematode species, three fields with 4 species, two fields each, with two species, and with five species, and one field each with one species and with six species (2). In these complex groups of nematodes, mobility ranges from migratory species that feed for a short time then move on to a new site to the sedentary species that remain at a selected feeding site. In addition, many plant parasitic nematodes show a preference for feeding or entry at a specific stage in root ontogeny. Some species prefer the meristem, some the zone of elongation, and others the region of maturation (3). Considerable emphasis has been given to the parasitism of plants by single species; however, parasitism by more than one nematode has received little attention. Since more than one nematode is the more natural situation it seems important to know more about the interactions of nematode species on each other and on plant growth.

In general, it appears that populations of one nematode species are enhanced in the presence of another species if the host is relatively resistant to the second species. Conversely, populations of a species will be suppressed in the presence of another species if the host is relatively susceptible to the second species (1). It is therefore important to know what plant-parasitic nematodes are present and which ones are most aggressive to the crop grown.

REFERENCES

1. Gay, C.M. and G.W. Bird. 1973. Influence of concomitant *Pratylenchus brachyurus* and *Meloidogyne* spp. on root penetration and population dynamics. J. Nematology 5:212-217.
2. Ferris, V.R., J.M. Ferris, R.L. Bernard, and A.H. Probst. 1971. Community structure of plant parasitic nematodes related to soil types in Illinois and Indiana soybean fields. J. Nematology 3:399-407.
3. Kirkpatrick, J.D., S.D. Van Gundy, and W.F. Mai. 1964. Interrelationships of plant nutrition, growth, and parasitic nematodes. Plant Analysis and Fertilizer Problems. IV. 189-225.

B. Research Results

NEMATODE-NEMATODE INTERACTIONS

Scientist(s)	Location	Date	Nematode	Nematode	Host	Location	Observation	Bibliography
Griffin	Utah	1972	*Meloidogyne hapla*	*Ditylenclus dipsaci*	Alfalfa	Field	Increased Pathogenicity	1
Jatala and Jensen	Oregon	1972	*M. hapla*	*Heterodera schachtii*	Sugarbeet	Greenhouse	Positive	2,3, 4,5,6
Lownsbery	California	1964	*Xiphinema americanum*	*Criconemoides xenoplax*	Various	Field	Cropping influenced nema populations	7
Tait	Utah	1965	*Pratylenchus neglectus*	*M. hapla*	Cherry	Greenhouse	Positive	8
Van Gundy and Kirkpatrick	California	1966	*Meloidogyne javanica* *P. scribneri* *Trichodorus christiei* *H. arenaria*	All combinations	Tomato	Greenhouse	*M. javanica* most aggressive pathogen	Annual Report
Yorston	Oregon	1970	*P. penetrans* *Longidorus elongatus*	*Verticillium dahlai*	Peppermint	Glasshouse	Positive	9

C. Bibliography

1. Griffin, G.D. 1972. Interaction of *Meloidogyne hapla* and *Ditylenchus dipsaci* on root-knot resistant alfalfa. (Abstr.) Phytopathology 62:1103.
2. Jatala, P. 1972. Interrelationships of *Meloidogyne hapla* Chitwood, 1949 with *Heterodera schachtii* Schmidt, 1971 on *Beta vulgaris* L. Ph.D. Thesis. 91 pp.
3. Jatala, P. and H.J. Jenson. 1972. Histopathological interrelationships of *Meloidogyne hapla* and *Heterodera schachtii* on *Beta vulgaris*. (Abstr.) Phytopathology 62:1103-1104.
4. 1972. Interrelationships of *Meloidogyne hapla* and *Heterodera schachtii* populations on *Beta vulgaris*. (Abstr.) J. Nematology 4:226.
5. 1972. Self-interactions of *Meloidogyne hapla* and *Heterodera schachtii* on *Beta vulgaris*. (Abstr.) J. Nematology 4:226-227.
6. Jatala, P. and H.J. Jensen. 1972. Effects of *Meloidogyne hapla and Heterodera schachtii* interrelationships on carbohydrates and mineral content of *Beta vulgaris*. Proc. 2nd I.C.P.P. (1973). Abstract No. 0403.
7. Lownsbery, B.F. 1974. Effects of cropping on population levels of *Xiphinema americanum* and *Criconemiodes xenoplax*. Plant Disease Reporter 48(3):218-221.
8. Tait, Bernard Al. 1965. Host-parasite relationships between *Prunus mahaleb* and the parasitic nematodes *Pratylenchus neglectus* and *Meloidogyne hapla*. M.S. Thesis. Utah State University.
9. Yorston, J.M. 1970. The interactions of *Pratylenchus penetrans* with host plants, *Longidonus elongatus* and *Verticillium dahliae*. Ph.D. Thesis (54 pp.) Oregon State University.

Nematode -Viral Interactions

A. Discussion

Soil-borne plant viruses represent a unique group of diseases for which the means of transmission was unknown until 1958. At that time it was discovered that grape fanleaf disease was transmitted by the nematode, *Xiphinema* index. This was one of several soil-borne viruses which were characterized by the fact that infective soils lost infectivity when the soils were dried. Subsequent studies have shown that many diseases, some of major economic importance to crops such as potato, peach, raspberry, strawberry, cherry, leek, lettuce, pea, sugarbeet, etc., are transmitted only by nematodes belonging to four genera, *Xiphinema, Longidorus, Trichodorus,* and *Paratrichodorus*. The other major group of soil-borne viruses, the soils of which retain infectivity upon drying, have been found to be transmitted by fungal vectors.

Plant viruses which nematode vectors fall into two groups based on the size and shape of the virus particles. Those with a polyhedral shape about 30 um in diameter (so-called nepoviruses) are transmitted only by nematode species of *Xiphinema* and *Longidorus* of the Dorylaimina. The tobraviruses with straight tubular particles are transmitted by members of *Trichodorus* and *Paratrichodorus* of the *Diphtherophorina*.

Subsequent detailed studies on the transmission processes of these viruses have dealt with efficiency of transmission which increases with increasing times of access to infected source plants and to healthy bait plants. Acquisition of virus can occur in less than one hour of feeding and transmission can be accomplished by adults or juveniles. The virus is not retained through the molting process or passed on to future generations through eggs. Persistence of the virus in nematode vectors has been observed to exceed several weeks and infective nematodes may survive for years in soils from which grapevines infected with fanleaf have been pulled leaving roots that also survive for long periods.

Determination of the nature of these nematode-vectored virus diseases of plants has clarified the problem of control. The most direct and effective control at present is by an expensive soil fumigation treatment, that is at best only a temporary solution. Longer-lasting possibilities may be found in plant varieties resistant to nematode feeding or to the virus transmission and multiplication in the plants.

B. Research Results

Scientist(s)	Location	Date	Nematode	Virus	Host	Location	Observation	Bibliography
Ayala	California	1965	*Trichodorus* spp.	Tobacco rattle	Tobacco	Greenhouse	Positive transmission	1
Betto and Raski	California	1966	*Xiphinema index*	Fanleaf virus	Grape	Laboratory	Negative micro-inoculation of nematode	2
Das, Raski, et al.	California	1967	*X. index*	Grape fanleaf	Grape	Greenhouse and field	Positive transmission	3,4,5
Griffin	Utah	1971	*Trichodorus* sp.	Tobacco rattle	Tobacco	Field and greenhouse	Transmission from potato field to tobacco	-*
Griffin	Utah	1973	*Trichodorus* sp.	Tobacco rattle	Potato	Field and greenhouse	Positive	-
Hanson, et al.	British Columbia	1973	*Xiphinema americanum*	Cherry rasp leaf	Various	Field	Association	6
Jensen, and Allen	Oregon	1964	*Trichodorus allius*	Tobacco rattle	Tobacco	Greenhouse	Positive transmission	7,8
Jensen, Koepsell, and Allen	Oregon	1974	*Trichodorus teres* *T. allius*	Tobacco rattle (3 isolates)	Several hosts	Field and Greenhouse	Positive transmission	9
Koepsell, Allen and Jensen	Oregon	1974	*T. allius*	Tobacco rattle	Potato	Field	Positive transmission	10
Lownsbery	California	1964	*X. americanum*	Fanleaf	Grape	Greenhouse	Influence temperature on transmission	11
Miller and Jensen	Oregon	1965	*X. americanum* *Longidorus elongatus*	Several viruses	Straw-berry	Greenhouse	Negative reaction	12
Nigh and Allen	Arizona		*L. elongatus*	Exocortis	Citrus	Field and greenhouse	Negative field association; negative transmission	13
Paulus, et al.	California	1963	*Trichodorus* sp.	Pepper virus	Pepper	Field	Positive trans-mission with nemas from in-fected peppers	14
Raski and Hewitt	California	1963	*X. index*	Fanleaf	Grape	Field	Positive transmission	15
Raski, et al.	California	1954-71	*X. index*	Fanleaf	Grape	Field	Control, observa-tions on vector and virus	16,17 18,19
Roggen	California	1966	*X. index*	Fanleaf	Grape	Greenhouse	Nemamorphology from virus in-fected grape	20
Taylor and Raski	California	1964	*X. index*	Fanleaf	Grape	Greenhouse	Positive transmission	21
Teliz, et al.	California	1964-67	*X. americanum*	Various	Various	Field and Greenhouse	Positive results	22,23
Teliz, et al.	California	1966	*X. americanum*	Tomato, ring-spot, peach yellow bud mosaic, grape yellow vein	Cucumber	Greenhouse	Positive trans-mission from peach to cucumber	24,25
Teliz, et al.	California	1967	*X. americanum*	Peach yellow bud mosaic	Cucumber, Glasshouse peach, apricot plum		Positive, however virus did not move from roots to top in plum	26

* Unpublished data

C. Bibliography

1. Ayla, A. 1965. Transmission of California tobacco rattle virus by three species of the nematode genus *Trichodorus* Cobb, 1913. Ph.D. Thesis, University of California, Davis.
2. Betto, E. and D.J. Raski. 1966. Attempts to inoculate *Xiphinema index* with grape fanleaf virus by microinoculation. J. Nematology. 12:453-461.
3. Das, S. 1966. Virus-vector relationships of grape fanleaf virus and its nematode vector *Xiphinema index* Thorne and Allen, 1950. Ph.D. Thesis, Dept. of Nematology, Univ. of California, Davis. Diss. Abstr. 27B(6):1690-1691.
4. Das, S. and D.J. Raski. 1968. Vector-efficiency of *Xiphinema index* in the transmission of grapevine fanleaf virus. J. Nematology 14:55-62.
5. Das, S. and D.J. Raski. 1969. Effect of grapevine fanleaf virus on the reproduction and survival of its nematode vector, *Xiphinema index* Thorne and Allen. J. Nematology 1:107-110.
6. Hanson, A.S., G. Nyland, T.H. McElroy and R. Stace-Smith. 1974. Origin, cause, host range and spread of cherry rasp leaf disease in North America. Phytopathology 64:721-727.
7. Jensen, H.J. and T.C. Allen, Jr. 1964. Transmission of tobacco rattle virus by a stubby-root nematode, *Trichodorus allius*. Plant Dis. Reporter 48:333-334.
8. Jensen, H.J. and T.C. Allen, Jr. 1974. *Trichodorus allius*, a potential nematode vector of tobacco rattle virus. (Abstr.) Phytopathology 54:1434.
9. Jensen, H.J., P.A. Koepsell, and T.C. Allen. 1974. Tobacco rattle virus and nematode victors in Oregon. Plant Dis. Reporter 58: 269-271.
10. Koepsell, P.A., T.C. Allen and H.J. Jensen. 1974. Tobacco rattle virus in Oregon potatoes. OSU Extension Circular 844. 6 pp.
11. Lownsbery, B.F. 1974. Some temperature reactions of *Xiphinema americanum* and implications to virus transmission. Plant Dis. Reporter 48:222-224.
12. Miller, P.W. and H.J. Jensen. 1965. Non-transmission of certain strawberry viruses by nematodes. Plant Dis. Reporter 49:509-511.
13. Nigh, E.L., Jr., and R.M. Allen. 1967. Failure of nematodes to transmit citrus exocortis virus. (Abstr.) Phytopathology 57:100-101.
14. Paulus, A.O., I.J. Thomason and L.G. Weathers. 1963. A soilborne virus disease of pepper in California. (Abstr.) Phytopathology 53:885-886.
15. Raski, D.J. and W.B. Hewitt. 1960. Experiments with *Xiphinema index* as a vector of fanleaf of grapevines. Nematologia 5:166-170.
16. Raski. D.J. and W.B. Hewitt. 1963. Plant-parasitic nematodes as vectors of plant viruses. Phytopathology 53:39-47.
17. Raski. D.J., W.B. Hewitt, A.C. Goheen, C.E. Taylor and R.H. Taylor. 1965. Survival of *Xiphinema index* and reservoirs of fanleaf virus in fallowed vineyard soil. Nematologica 11:349-352.
18. Raski, D.J., W.B. Hewitt, R.V. Schmitt. 1971. Controlling fanleaf virus—dagger nematode disease complex in vineyards by soil fumigation. Calif. Agriculture 25(4): 11-14.
19. Raski, D.J., W.B. Hewitt, C.E. Taylor and R. Taylor. 1965. Survival of *Xiphinema index* and fanleaf virus in fallowed vineyard soil. (Abstr.) Nematologica 11: 44-45.
20. Roggen, D.R. 1966. On the morphology of *Xiphinema index* reared on grape fanleaf virus invected grapes. Nematologica 12: 287-296.
21. Taylor, C.E. and D.J. Raski. 1964. On the transmission of grape fanleaf by *Xiphinema index*. Nematologica 10:489-495.
22. Teliz, D. 1966. *Xiphinema americanum*, a vector of grape yellow vein virus. Proc. Int. Conf. on virus and vector on perennial hosts with special reference to *Vitis*. University of California, Div. Agr. Sci. Spec. Publ. 363 pp.
23. Teliz, D. 1967. Effects of nematode extraction method, soil mixture, and nematode numbers on the transmission of tobacco ringspot virus by *Xiphinema americanum*. Nematologica 13:177-185.
24. Teliz, D., R.G. Grogan and B.F. Lownsbery. 1966. Transmission of tomato ringspot, peach yellow bud mosiac and grape yellow vein viruses by the nematode *Xiphinema americanum*. Phytopathology 56:658-683.
25. Teliz, D., B.F. Lownsbery and R.G. Grogan. 1966. Transmission of tomato ringspot virus by *Xiphinema americanum*. (Abstr.) Phytopathology 56:151.
26. Teliz, D., B.F. Lownsbery, R.G. Grogan and K.A. Kimble. 1967. Transmission of peach yellow bud mosaic virus to peach apricot, and plum by *Xiphinema americanum*. Plant Dis. Reporter 51:841-843.

Nematode-Bacterial Interactions

A. Discussion

One of the earliest reports of nematodes associated with another plant pathogen involved *Pseudomonas solanacearum* and nematode infested soil (2). The work illustrated that nematodes were capable of influencing the tomato host in some manner that made it susceptible to the bacterial disease. Since then, various reports (1,4) indicate that nematode attack must predispose the host before a particular bacterium is capable of causing disease. As pointed out by Pitcher (3), the nematode may act as a vector by the introduction of the bacterium to the meristematic tissue such as in the case of *Cornybacterium insidiosum* and *Anguina tritici*. Cauliflower disease of strawberry appears to be caused by the interaction of *Aphelenchoides ritzemabosi* and *Cornybacterium fascians* (4). When the nematode attacks the foliage without the bacterium, feeding damage is noted on expanded leaves of normal size. However, when the two organisms are combined, leaf curling and thickening occurs which is typical of the symptoms of cauliflower disease.

Species of ectoparasitic nematodes have not been reported to be involved in disease complex with soil-borne bacteria. Apparently, the wounds produced by these parasites are insufficient to allow the entry of bacteria cells or that their feeding causes sufficient physiological changes that pre-dispose the host to infection.

Relatively few investigations concerning nematode-bacterial interactions were undertaken during the duration of this regional project. This may have been as a result of the few economic bacterial disease problems confronting agriculture in comparison with the known incidences of fungal and viral infections that cause serious crop losses. Another projection previously made has been that the majority of plant infecting bacteria are above ground while the majority of nematode parasites attack the root systems.

REFERENCES

1. Carne, W.M. 1926. Earcockle (*Tylenchus tritici*) and a bacterial disease (*Pseudomonas tritici*) of wheat. J. Dept. Agr. West. Austr. 3:508.
2. Hunger, F.W.T. 1901. Een bacterie—ziekte dess tomaat. S. Lands. Plantentiuin, Meded. 48:4-57.
3. Pitcher, R.S. 1963, Role of plant-parasitic nematodes in bacterial diseases. Phytopathology 53 (1):35-39.
4. Pitcher, R.S. and J.E. Crosse. 1958. Studies in the relationship of eelworms and bacteria to certain plant diseases. II Further analysis of the strawberry Cauliflower disease complex. J. Nematology 3:244-256.

NEMATODE-BACTERIAL INTERACTIONS

B. Research Results

Scientist(s)	Location	Date	Nematode	Bacteria	Host	Location	Observation	Bibliography
Chantanao	Oregon	1968	*Pristionchus lheritieri*	*Agrobacterium tumefaciens*		Laboratory	Transmission of bacteria & phage	1
Chantanao & Jensen	Oregon	1969	*P. lheritieri*	*A. tumefaciens* *Erwinia amylovora* *E. carotovora* *Pseudomonas phaseolicola*		Laboratory	Passed thru alimentary canal in viable condition	2,3
Griffin et al.	Utah	1968	*Meloidogyne hapla*	*A. tumefaciens*	Rasp-berry	Greenhouse	Positive interaction	4
Griffin & Hunt	Utah	1972	*M. hapla*	*Corynebacterium insidiosum*		Greenhouse	Positive complex affected by time and temperature	5
Hawn, E.J.	Canada	1963	*Ditylenchus dipsaci*	*C. insidiosum*		Greenhouse	Positive interaction	6
Hawn, E.J. et al.	Canada	1967	*D. dipsaci*	*C. insidiosum*		Field	Positive interaction	7
Hunt, et al.	Nevada	1971	*M. hapla*	*C. insidiosum*		Greenhouse	Positive interaction	8
Jatala & Jensen, et al.	Oregon	1974	*P. lheritieri*	*Rhizobium japonicum*		Laboratory	Transmitted *R. japonicum* to bean	9
Jensen & Gilmour	Oregon	1967	*Saprozoic* spp.	*Streptomyces* phage		Laboratory	Positive transmission	10
Lownsbery, et al.	California	1972	*Criconemoides* spp.	*Pythium* spp. & *Pseudomonas syringae*		Greenhouse	Positive inter-action between 3 pathogens	11
Nigh	Arizona	1966	*Meloidogyne javanica*	*Agrobacterium tumefaciens*		Greenhouse	Interaction dependent upon number nemas	12
Nigh	Arizona	1966	*M. javanica*	*Rhizobium* sp.		Greenhouse	*Rhizobium* nodule reduc-tion as nema population increased	13

C. Bibliography

1. Chantanao, Aroon. 1968. Transmission of Plant Pathogenic Bacteria and a Bacteriophage of *Agrobacterium tumefeciens* (Smith and Townsend). Conn. by a saprozoic nematode, *Diplogaster lheritieri.* Maupas, 1919. Oregon State University, Corvallis. 74 numb. leaves (Ph.D. Thesis).
2. Chantanao, Aroon, and H.J. Jensen. 1969. Techniques for controlling bacterial flora of *Pristionchus lheritier*. J. Nematology 1:277.278.
3. Chantanao, Aroon and H.J. Jensen. 1969. Saprozoic nematodes as carriers and disseminators of plant pathogenic bacteria. J. Nematology 1:216-218.
4. Griffin, G.D., J.L. Anderson and E.C. Jorgenson. 1968. Interaction of *Meloidogyne hapla* and *Agrobacterum tumefaciens* in relation to raspberry cultivars. Plant Dis. Reptr. 52:492-493.
5. Griffin, G.D. and O.J. Hunt. 1972. Effect of temperature and inoculation timing on the *Meloidogyne hapla / Corynebacterium insidiosum* complex in alfalfa. J. Nematology 4:70-71.
6. Hawn, E.J. 1963. Transmission of bacterial wilt of alfalfa by *Ditylenchus dipsaci* (Kuhn). Nematologica 9:65-68.
7. Hawn, E.J. and M.R. Hanna. 1966. Influence of stem nematode infestation on bacterial wilt reaction and forage yield of alfalfa varieties. Can. J. Plant Sci. 47:203-208.
8. Hunt, et al. 1971. The effects of root knot nematodes on bacterial wilt in alfalfa Phytopathology 61:256-259.
9. Jatala, P., H.J. Jensen, and S.A. Russell. 1974. *Pristionchus lheriteri* as a carrier of *Rhizobium japonicum*. J. Nematology 6:130-131.
10. Jensen, H.J. and C.M. Cilmour. 1968. Saprozoic nematodes transmit *Streptomyces* phage. Plant Dis. Reptr. 52:3-4.
11. Lownsbery, B.F., W.H. English, E.H. Moody, and F.J. Schick. 1972. Development of stem cankers in peach trees inoculated with ring nematodes, *Pythium* spp., and *Pseudomonas syringae.* (Abstr.) Phytopathology 56:150.
12. Nigh, E.L., Jr. 1966. Incidence of crown gall infection in peach as affected by the Javanese root-knot nematode. (Abstr.) Phytopathology 56:150.
13. Nigh, E.L., Jr. 1966. *Rhizobium nodule* formation of alfalfa as influenced by *Meloidogyne javanica*. (Abstr.) Nematologica 12:76.

Nematode-Mycorrhizal Interactions

A. Discussion

The mycorrhizal condition of tree roots is the rule rather than the exception in forested areas. Many nematode species occur in the root zone of forest trees in nurseries, plantations, and natural stands. These rhizospheric environments provide many opportunities for interactions among nematodes, mycorrhizal fungi, and mycorrhizae.

Various nematode species in the genera *Aphelenchus, Aphelenchoides, Ditylenchus, Paurdontoides, Paraphelenchus* and *Bursaphelenchus* are parasitic on fungi (2). These nematodes can reduce or stop the growth of root inhabiting fungi. Some species are also capable of causing death of their fungal hosts. The nematodes may feed on hyphae, conidia, and other survival structures. During the feeding process, cytoplasmic streaming may be inhibited, and frequently cytoplasm is altered by secretion of digestive enzymes into hyphal cells. These enzymes affect the penetrated cells and adjacent cells several times removed from the point of feeding. Hyphal cells may shrink as a result of nematode feeding, and upon withdrawal of the stylet cellular contents have been observed to move out through stylet punctures.

Investigations to determine effects of mycophagous nematodes on growth of mycorrhizal fungi in pure culture indicate that these nematodes have a wide fungal host range. *Aphelenchoides cibolensis*, for example, fed and reproduced on 50 to 53 ectomycorrhizal fungi and killed 16 of them in a 40-day period. Nematodes concentrate in large numbers around the advancing margin of the colonies, and as their populations increase and their feeding activities intensify, diameter growth of the fungal colonies is severely reduced. Continued nematode feeding kills the fungal host. Another mycophagous species, *Aphelenchus avenae*, reduced diameter growth of seven mycorrhizal fungi (6). None of these fungi were killed even through removal of hyphal cytoplasm caused hyphal cells to collapse and hyphal tips to shrivel for some distance on each side of the stylet.

Pure culture studies have shown that mycophagous nematodes suppress development of fungal symbionts and inhibit ectomycorrhizal formation on pine seedlings. The effects of mycophagous nematodes on established ectomycorrhizae, however, are not well known. Sutherland and Fortin (6) showed that *Aphelenchus avenae* prevented formation of *Quillus granulatus* ectomycorrhizae with *Pinus resinosa* seedlings. None of these nematodes were found on or within the mycorrhizae, and they did not alter the morphology of the mycorrhize. Riffle (4) found that *Aphelenchoides cibolensis* and *A. compositicola* suppressed formation of *S. granulatus* ectomycorrhizae with *P. ponderosa* seedlings. These nematodes also reduced width of the fungal mantle 250 μm behind apices of the ectomycorrhizae. Nematodes were not found on or embedded in mantle mycelia or in cortical tissues.

Some plant parasitic nematode species may effect mycorrhizal formation by damaging healthy root tissues required for syntheses of mycorrhizae. Ruehle (5) found that *Tylenchorhynchus claytoni* invaded and damaged cortical tissues of newly emerging short roots of *Pinus taeda* seedlings, preventing normal ectomycorrhizal development.

It has been established that some ectomycorrhizal function as biological deterrents to pathogenic root infections (1). The mechanisms in ectomycorrhizae that prevent infection by fungal pathogens apparently do not prevent infection by plant parasitic nematodes, for the fungal mantle of ectomycorrhizae is readily attacked by these nematodes.

Most nematode species that parasitize ectomycorrhizae of conifers are endoparasites. These include *Heterodera* spp., *Meloidogyne* spp., *M. floridensis*, *Nacobbodera chitwoodi, Criconemoides rusticum, Helicotylenchus dihystera, Rotylenchus pumilis,* and *Hoplolaimus galeatus* (2,3,5).

Hoplolaimus galeatus directly attacked mycorrhizae to become dark brown to black (3). Ruehle (5) reported that ectomycorrhizae of *P. taeda* and *P. echinata* were more favorable feeding sites for *H. galeatus* than non-mycorrhizal roots.

Root knot nematodes, *Meloidogyne* spp., penetrate the fungal mantle of established mycorrhizae of pines at or near the meristematic root apex, or at tissue ruptured by emergence of secondary roots. In *P. ponderosa,* feeding and subsequent development of the females, as well as hypertrophy and hyperplasia of cortical and vascular tissues, severely disorganized vascular tissues, compressed and collapsed cortical tissue with the associated Hartig net, and ruptured the outer fungal mantle of the ectomycorrhizae. Such severe damage may alter the role of ectomycorrhizae as biological deterrents to pathogenic root infections (4).

In summary, nematodes have the potential to inhibit formation of beneficial mycorrhizae, and to severely damage established mycorrhizae. The extent to which nematode damage alters the role of ectomycorrhizae as biological deterrents to pathogenic infection will require more research before it is fully understood. By suppressing formation of mycorrhizae and by destroying established mycorrhizae on plants that have an obligate need for them to maintain optimum growth, nematodes may effect plant growth and development of root diseases more than has been previously recognized.

REFERENCES

1. Marx, D.H. and C.B. Davey. 1969. The influence of ectotrophic mycorrhizal fungi on the resistance of pine roots to pathogenic infections, IV. Resistance of naturally occurring mycorrhizae to infections by *Phytophthora cinnamoni*. Phytopathology 59:559-565.
2. Riffle, J.W. 1971. Effect of nematodes on root-inhabiting fungi, p. 97-113. In E. Hacskaylo (ed.) Mycorrhizae. First North American Conference on Mycorrhizae Proceedings. April 1969. U.S. Dept. Agr., Forest Service. Misc. Publ. 1189. 255 p.
3. Riffle, J.W. 1972. Effect of certain nematodes on the growth of *Pinus edulis* and *Juniperus monosperma* seedlings. J. Nematology 4:91-94.
4. Riffle, J.W. 1973. Histopathology of *Pinus ponderosa* ectomycorrhizae infected with a *Meloidogyne* species. Phytopathology 63: 1034-1040.
5. Ruehle, J.L. 1973. Nematodes and forest trees—types of damage to tree roots. Ann. Rev. Phytopathology 11:99-118.
6. Sutherland, J.R. and J.A. Fortin. 1968. Effect of the nematode *Aphelenchus avenae* on some ectotrophic mycorrhizal fungi and on a red pine mycorrhizal relationship. Phytopathology 58:519-523.

B. Research Results

NEMATODE-MYCORRHIZAL INTERACTIONS

Scientist(s)	Location	Date	Nematode	Fungus	Host	Location	Observation	Bibliography
Riffle	New Mexico	1966-67	*Aphelenchoides* sp.	*Mycelium radicus atrovirens** *Suillus granulatus*	Pine & juniper	Laboratory	Nematode multiplied and feeding reduced fungus growth viability	1,2
Riffle	New Mexico	1968-71	*Aphelenchoides cibolensis*	53 spp. ectomycorrhizal fungi	Pine	Laboratory	Some fungi destroyed	3,4,5
Riffle	New Mexico	1972	*Xiphinema americanum* *Rotylenchus pumilis* *Hoplolaimus galeatus*	Ectomycorrhizae	Ponderosa pine	Greenhouse	Discolored mycorrhizae	6
Riffle	New Mexico	1972	*Meloidogyne* sp.	Ectomycorrhizae	Ponderosa pine	Field	Directly attacked, severly damaged mycorrhizae	7,8
Riffle	New Mexico	1973	*A. cibolensis* *Aphelenchoides composticola*	*S. granulatus*	Ponderosa pine	Laboratory	Mycorrhizal formation suppressed; mantle thickness reduced	9

* *M. r. atrovirens* is a pseudomycorrhizal fungus

C. Bibliography

1. Riffle, J.W. 1966. Effect of an *Aphelenchoides* species on the growth of a mycorrhizal and a pseudomycorrhizal fungus. (Abstr.) Nematologica 13:151.
2. Riffle, J.W. 1967. Effect of *Aphelenchoides* species on the growth of a mycorrhizal and a pseudomycorrhizal fungus. Phytopathology 57:541-544.
3. Riffle, J.W. 1968. Effect of an *Aphelenchoides* species on the growth of mycorrhizal fungi. (Abstr.) Nematologica 14:14.
4. Riffle, J.W. 1970. *Aphelenchoides cibolensis* (Nematoda: Aphelenchoididae;, a new mycophagous nematode species. Proc. Helminth. Soc. Wash. 37:78-80.
5. Riffle, J.W. 1971. Effect of nematodes on root-inhibiting fungi, p. 97-113, In Mycorrhizae. Proc. First North Amer. Conf. on Mycorrhizae. April 1969. U.S.D.A. Forest Serv. Misc. Publ. 1189. 255 p.
6. Riffle, J.W. 1972. Effect of certain nematodes on the growth of *Pinus edulis* and *Juniperus* seedlings. J. Nematology 4:91-94.
7. Riffle, J.W. 1972. Histopathology of *Pinus ponderosa* ectomycorrhizae infected with a *Meloidogyne* species. (Abstr.) Phytopathology 62:785.
8. Riffle, J.W. 1973. Histopathology of *Pinus ponderosa* ectomycorrhizae infected with a *Meloidogyne* species. Phytopathology 63: 1034-1040.
9. Riffle, J.W. 1973. Formation of *Suillus granulatus* ectomycorrhizae with *Pinus ponderosa* seedlings affected by *Aphelenchoides cibolensis* and *Aphelenchoides compositicola*. (Abstr.) Second International Congress of Plant Pathology, Number 559.

PUBLICATIONS FROM RESEARCH involving the INTERACTION of NEMATODES with OTHER PATHOGENS

1. Altman, J. 1969. Effect of chlorinated C3 hydrocarbons on amino acid production by indigenous soil bacteria. Phytopathology 59:762-766.
2. Altman, J. 1969. Predisposition of sugar beets to damping off with herbicides. (Abstr.) Phytopathology 59:1015.
3. Altman, J. 1970. Increased and decreased plant growth responses resulting from soil fumigation. Symposium Vol. II on Ecology of Soilborne Diseases. Univ. of Calif. Press. pp. 216-221.
4. Altman, J. and B.J. Fitzgerald. 1960. Late fall application of fumigants for the control of sugar beet nematodes, certain soil fungi and weeds. Plant Dis. Reporter 44(11):868-872.
5. Altman, J. and R.G. Gilbert. 1966. Ethanol extraction of free amino acid from soil. Plant and Soil 24:229-238.
6. Altman, J. and S. Lawlor. 1964. The effects of six chlorinated hydrocarbons on certain soil bacteria. Phytopathology 54:886.
7. Altman, J. and M. Ross. 1965. Plant pathogens as a possible factor in unexpected preplant herbicide damage in sugar beets. (Abstr.) Phytopathology 55:1051.
8. Altman, J. and M. Ross. 1967. Plant pathogens as a possible factor in unexpected preplant herbicide damage in sugar beets. Plant Dis Reporter 51:86-88.
9. Altman, J. and I. Thomason. 1971. Nematodes and Their Control in Advances in Sugarbeet Production (Principles and Practices, Iowa State Univ., Ames, Iowa. Chapter 11, pp. 335-370.
10. Altman, J. and K.M. Tsue. 1965. Changes in plant growth with chemicals used as soil fumigants. Plant Dis. Reporter 49:600-601.
11. Aytan, S. and O.J. Dickerson. 1969. *Meloidogyne naasi* on sorghum in Kansas. Plant Dis. Reporter 53:737.
12. Chantanao, A.A. and H.J. Jensen. 1969. Transmission of an *Agrobacterium tumefaciens* phage by *Pristionchus lheritieri.* J. Nematology 1:116-168.
13. Chantanao, A.A. and H.J. Jensen. 1969. Techniques for controlling bacterial flora of *Pristionchus lheritieri.* J. Nematology 1:277-278.
14. Chantanao, A.A. and H.J. Jensen. 1969. Saprozoic nematodes as carriers and disseminators of plant pathogenic bacteria. J. Nematology 1:216-218.
15. Dallimore, C.E. 1966. Culture of *Ditylenchus destructor* on asceptic potato plugs. (Abstr.) Phytopathology 56:874-875.
16. Dallimore, C.E., J.G. Garner, and R.E. Ohms. 1967. Control of early dying of potatoes by soil fumigation. Idaho Current Information Series, No. 52, 3 pp.
17. Dickerson, O.J., R.T. Robbins, and J.K. Greig. 1969. Sweet potato protected from root-knot nematode infection by chemical treatment of transplant beds. J. Nematology 1:284-285.
18. Fisher, J.M. and D.J. Raski. 196 . Feeding of *Xiphinema index* and *X. diversicaudatum.* Proc. Helminth. Soc. Wash. 34:68-72.
19. Gilbert, R.G. and J. Altman. 1966. Ethanol extraction of free amino acid from soil. Plant and Soil 24:229.
20. Golden, M.A. and O.J. Dickerson. 1973. *Heterodera longicolla* n. sp. (Nematoda: Heteroderidae) from buffalo-grass (Buchloe dactyloides) in Kansas. J. Nematology 5:150-154.
21. Griffin, G.D. 1969. Effects of temperature on *Meloidogyne hapla* in alfalfa. Phytopathology 59:599-602.
22. Griffin, G.D. 1971. Susceptibility of common sainfoin to *Meloidogyne hapla.* Plant Dis. Reporter 55:1069-1072.
23. Griffin, G.D. and O.J. Hunt. 1972. Effect of plant age on resistance of alfalfa to *Meloidogyne hapla.* J. Nematology. 4:87-90.
24. Griffin, G.D. and E.C. Jorgenson. 1969. Pathogenicity of the northern root-knot nematode [*Meloidogyne hapla*] to potato. Helminthol. Soc. Wash. 36:88-92.
25. Griffin, G.D. and E.C. Jorgenson. 1969. Life cycle and reproduction of *Meloidogyne hapla* on potato. Plant Dis. Reporter 53:259-261.
26. Griffin, G.D. and W.W. Waite. 1971. Attraction of *Ditylenchus dipsaci* and *Meloidogyne hapla* by resistant and susceptible alfalfa seedlings. J. Nematology 3:215-219.
27. Griffin, G.D., W.W. Waite, and A.A. Kitchen. 1971. Pathogenicity of *Ditylenchus dipsaci* to several plant species. (Abstr.) Proc. Western Soc. Crop Science. U. of Wyoming. 11 pp.
28. Holtzmann, O.V. 1964. Soil temperature affects the resistance of tomato to the root-knot nematode [*Meloidogyne incognita*]. Hawaii Farm Sci. 13:13-14.
29. Holtzmann, O.V. 1965. Effect of soil temperature on the resistance of tomato to the root-

knot nematode [*Meloidogyne incognita*]. Phytopathology 55:990-992.

30. Holtzmann, O.V. 1967. Reproductive cycles of three nematode species on sugar cane. (Abstr.) Phytopathology 57:1005-1006.
31. Holtzmann, O.V. 1968. Control of root-knot nematodes in tropical and sub-tropical crops. Proceedings: Symposium on root-knot nematode in the Western United States. Riverside, California.
32. Hunt, O.J., et al. 1968. Plant resistance for root-knot control. Proceedings: Symposium on root-knot nematode in western states. Riverside, California.
33. Hunt, O.J., L.R. Faulkner and R.N. Peaden. 1972. Breeding for nematode resistance. Chapter XVI in Alfalfa Science and Technology. ASA Monograph Series No. 15. American Society of Agronomy. Madison, Wisconsin.
34. Jatala, P. and H.J. Jensen. 1972. Bibliography of nematode interacting with other organisms in plant disease complexes. Department of Botany and Plant Pathology, Oregon State Univ., Corvallis, Oregon.
35. Jensen, H.J. 1967. Do saprozoic nematodes have a significant role in epidemiology of plant diseases? Plant Dis. Reptr. 51:98-102.
36. Jensen, H.J. 1968. The role of saprozoic nematodes in dissemination of plant diseases. (Abstr.) Soil Fungus Conference, Phoenix, AZ.
37. Jensen, H.J. and S.R. Siemer, 1971. Protection of *Fusarium* and *Verticillium* propagules from selected biocides following ingestion by *Pristionshus lheritieri.* J. Nematology 3:23-27.
38. Jorgenson, E.C. 1964. Nematode control in Utah. Proceedings Utah State Horticulture Society (Manuscript).
39. McCallum, D.K. and O.J. Dickerson. 1972. Nematicide tests on pinto beans and soybeans in 1970. Fungicide and Nematicide Test 27:159.
40. McCallum, D.K. and O.J. Dickerson. 1972. Nematicide tests on soybeans in 1970. Fungicide and Nematicide Test 27:172.
41. McClure, M.A. 1972. Comparative biochemistry of cotton resistant and susceptible to the root-knot nematode. Phytochemistry 11:2209-2212.
42. McClure, M.A., K.C. Ellis, and E.L. Nigh, Jr. 1974. Resistance of cotton to the root-knot nematode, *Meloidogyne incognita.* J. Nematology 6:17-20.
43. McClure, M.A., K.C. Ellis, and E.L. Nigh, Jr. 1974. Post-infection development and histopathology of *Meloidogyne incognita* in resistant cotton. J. Nematology 6:21-26.
44. Mulvey, R.H. and O.J. Dickerson. 1970. *Miconchus kansasensis* n. sp. (Mononchidae: Nematoda) from Kansas, United States. Can. J. Zool. 48:231-234.
45. Nigh, E.L., Jr. 1964. Parasitic nematodes, a hazard to many Arizona crops. Progressive Agriculture in Arizona, Jan.-Feb. 16:8-9.
46. Nigh, E.L., Jr. 1972. Resistance of selected alfalfa clones to root-knot nematode, *Meloidogyne incognita*. Phytopathology 62(8):780.
47. Nigh, E.L., Jr. 1972. Susceptibility of Arizona-grown ornamentals to attack by several nematode species. Plant Dis. Reporter, (10), 56:914-916.
48. Nigh, E.L., K.C. Ellis and R.B. Hine. 1969. Alfalfa stem nematode. Prog. Agr. in Ariz. XXI (3):10-12.
49. Nigh, E.L. and A.D. Jenkins, 1970. Influence of *Meloidogyne incognita* on mineral composition of cotton roots resistant and susceptible to the nematode. Proc. Annual Cotton Disease Council (30th).
50. Polychonopoulas, A.G. and B.F. Lownsberry, 1968. Effect of *Heterodera schactii* Schmidt on sugarbeet seedlings under monoxenic conditions. Nematologica 4(526-534).
51. Robbins, R.T., O.J. Dickerson and J.H. Kyle. 1972. Pinto bean yield increased by chemical control of *Pratylenchus* spp. J. Nematology 4:28-32.
52. Roggen, D.R., D.J. Raski and N.O. Jones. Cilia in nematode sensory organs. Science 152:515-516.
53. Smerda, S.M., H.J. Jensen and A.W. Anderson. 1971. Escape of *Salmonellae* from chlorination during ingestion by *Pristionchus lheritieri* (Nematoda: Diplogasterinae). J. Nematology 3:201-204.
54. Willis, W.G. and O.J. Dickerson. 1969. Soil fumigation guide for nematode control. Plant Dis. Leaflet 171-Revised. Extension Service, K.S.U.
55. Wright, K.A. 1965. The histology of the esophageal region of *Xiphinema index* Thorn and Allen, 1950, as seen with the electron microscope. Can. J. Zool. 43(689-700). 16 plates.
56. Wright, K.A. and N.O. Jones. 1965. Some techniques for the orientation and embedding of nematodes for electron microscopy. Nematologica 11:125-130.