韓國土壤動物學會誌 10(1-2) : 55~64 (2005)
Korean Journal of Soil Zoology

Predatory Nematodes and Their Potential in Biological Control of Plant Parasitic Nematodes in Soil

Zakaullah Khan and Young Ho Kim*

(Department of Agricultural Biotechnology, Seoul National University, Seoul 151-921, Korea)

포식선충의 토양중 식물기생선충의 생물학적 방제 이용 가능성

Zakaullah Khan · 김 영 호*

(서울대학교 농업생명과학대학 농생명공학부)

ABSTRACT

Predatory nematodes are ubiquitous and feed on soil microorganisms including plant parasitic nematodes. They reduce populations of plant parasitic nematodes in virtually all soils because of their constant association with plant parasitic nematodes in the rhizosphere. Predatory potential of several species of predacious nematodes, belonging to the orders Mononchida, Diplogasterida, Dorylaimida and Aphelenchida, have been studied in detail on plant parasitic nematodes but most of the studies were based on *in vitro* experiments. A review of progress on the use of predatory nematodes as biological control agents of plant parasitic nematodes reveals that advocacy for predatory nematodes dates back to the early 20th century; nevertheless, their potential has begun to be studied in recent years. Information on the efficacy of predatory nematodes under field conditions is lacking; however, some predatory nematodes have given very promising results against plant parasitic nematodes. This article summarizes research progress to date on predatory nematodes and discusses about their possible use in the management of plant parasitic nematodes.

Key words : Biological control, plant parasitic nematodes, predatory nematodes

INTRODUCTION

Soil inhabiting nematodes predominate over all other animals, both in numbers and species (Jairajpuri and Bilgrami 1990). On the basis of their feeding habits, nematodes are known as plant feeder, bacterial feeder, fungal feeder, algal feeder, animal predator, and omnivore (Yeates *et al.* 1993). Several types of organism, including fungi, bacteria, viruses, protists, nematodes and other invertebrates, have been found to parasitize or prey upon plant parasitic nematodes (Stirling 1991). Biological control of plant parasitic nematodes has been oriented almost exclusively to microbial pathogens (Kerry 2000). While pathogens have received significant research emphasis for biological control of plant parasitic nematodes, predatory nematodes have been largely ignored. However, in recent years predatory nematodes have shown biological control potential against plant parasitic nematodes and established themselves as an important entity of the soil food web.

Biological control advocacy of predatory nematodes dates back to the the early 20th century when Cobb (1917) speculated on their possible role in management of plant parasitic nematodes. Nevertheless, their potential has only begun to be studied in recent years. There has been widespread interest in using predatory nematodes to control populations of plant parasitic nematodes (Mankau 1980, Jairajpuri and Bilgrami 1990, Stirling 1991). Yeates and Wardle (1996) introduced the dual function of predation by nematodes: Potential control of plant parasitc nemtodes, and their important role in stimulating cycling of plant nutrients, which may enable plants to better withstand any nematode burden on their roots. Sometimes biological control measures are used alone; more often

* Corresponding author
Phone) +82-2-880-4675, Fax) +82-2-873-2317
E-mail) yhokim@snu.ac.kr

they are combined with cultural methods in systems of integrated pest management (IPM). When used as a part of an IPM program, biopesticides (bacteria, fungi, nematodes, protozoa, viruses) offer viable, safer and ecologically sound alternatives to chemical nematicides (Hom 1996).

This paper reviews the status of progress made up till present time, and discusses future directions that may be followed to enhance the use of predatory nematodes as biological agents in the management of plant parasitic nematodes.

TYPES OF PREDATORY NEMATODES

The majority of predatory nematodes belonging to the orders Mononchida, Dorylaimida, Diplogasterida, Aphelenchida, Enoplida and Rhabditida are classified into three catogeries depending on their feeding apparatus, feeding mechanisms and food preferences. They feed on plant parasitic nematodes when they come in physical contact.

The first type of predators commonly known as mononchs (Mononchida) possess a strongly sclerotized buccal cavity, which is often armed with one or more large puncturing tooth or numerous small grasping teeth or both. Their feeding apparatus is a cutting and engulfing type. Several of commonly occurring mononchids feed extensively, though not exlusively, on plant parasitic and other nematodes. They may swallow their prey whole if it is of smaller size, or at times feed by cutting larger prey into pieces. The second type is referred to as the stylet-bearing predators, e.i. dorylaims, nygolaims and aphelenchs (Dorylaimida and Aphelenchida). They possess piercing and sucking type of feeding apparatus. These predatots puncture the prey with their needle-like feeding apparatus that sucks the prey body contents. Feeding apparatus in dorylaim predators (*Dorylaimus, Labronema*) is axial in position but in nygolaims (*Aquatides*) it is nonaxial. The former has a hollow stylet with a dorsal aperture but later has a slender, protrusible mural tooth with which they pierce or slit their prey. This tooth is not hollow and food is sucked up through the oral aperture. The feeding apparatus of aphelenchs is narrow and pointed with fine lumen and aperture. They penetrate the cuticle of prey nematodes with their fine needle-like stylet and inject digestive enzymes into the prey body, which paralyse the prey almost instantly (Hechler 1963, Wood 1974). Ingestion of the body contents then takes place. The third types are those which feed by cutting the body of prey and then sucking its body contents. These predators belong to the order Diplogasterida (*Mononchoides, Butlerius*), they possess small but well developed buccal cavity armed with a claw-like movable dorsal tooth. Teeth or denticles may also be present to help cut prey cuticle and grind food particles (Jairajpuri and Bilgrami 1990).

BIOLOGICAL CONTROL POTENTIAL

Mononch, dorylaim, nygolaim, diplogaster and aphelench predators show different predatory potential, depend on their rate of predation, prey searching abilities and resistance to adverse conditions.

1. Mononch predators

The possibility of using mononchs to check populations of plant parasitic nematodes in soil was first speculated by Cobb (1917) while making observations on their biology and predatory ability. Steiner and Heinly (1922) observed feeding by *Clarkus papillatus* on *Meloidogyne* sp. and suggested the use of *C. papillatus* for controlling populations of plant parasitic nematodes in sugar-beet fields. However, observations by Thorne (1927) regarding the behavior and habits of various species of mononchs, including *C. papillatus* present in sugar-beet fields were not encouraging. He found that soil population of mononchs tended to be unstable and to change rather abruptly, sometimes disappearing or becoming drastically reduced; some species of mononchs were subjected to infection by an Apicomplexa parasite, which may have been a factor in reducing their numbers.

Cassidy (1931) concluded that, under suitable conditions, *Iotonchus brachylaimus* might partially control populations of pest nematodes. Not much work had been done on these aspects until 1970's when several workers recorded observations on the predatory abilities of mononchs but most of these experiments limited to laboratory conditions. Christie (1960) suggested that the use of predatory nematodes should be assessed for determining the practicability of their use in control of plant parasitic nematodes. Further studies in this direction were made by Mulvey (1961), Esser (1963), Esser and Sobers (1964), Ritter and Laumond (1975). According to Webster (1972) and Jones (1974), non-specific predators like mononchs exert only partial control of plant parasitic nematodes. However, studies have shown that they have reduced *Tylenchulus semipenetrans, Globodera rostochiensis* and *Meloidogyne incognita* populations in pots (Cohn and

Table 1. List of predatory mononchs and their prey nematodes (plant parasitic)

Predatory nematodes	Plant parasitic nematodes preyed upon	References
Anatonchus spp.	Aphelenchs, tylenchs, *Paratylenchus vulnus*	Szczygiel (1971) Ritter & Laumond (1975)
A. amiciae	Tylenchs, *Xiphinema*	Coomans & Lima (1965)
A. ginglymodontus	*Meloidogyne hapla*, tylenchs	Szczygiel (1966, 1971)
A. tridentatus	*Aglenchus agricola*, aphelenchs, *Globodera rostochiensis, Paratylenchus macrophallus, Longidorus, Pratylenchus*	Mulvey (1961); Ritter & Laumond (1975) Small & Grootaert (1983)
Clarkus mulveyi	*Helicotylenchus multicinctus, M. incognita, Rotylenchulus reniformis, Tylenchorynchus nudus*	Mohandas & Prabhoo (1980)
C. papillatus	*Aphelenchoides, Hemicriconemoides, Heterodera schachtii, M. hapla, Tylenchus, Tylenchulus semipenetrans, Subanguina radicicola*	Cobb (1917); Menzel (1920) Steiner & Heinly (1922) Thorne (1927); Szczygiel (1966, 1971)
C. sheri	*Tylenchorhynchus*	Bilgrami *et al.* (1986)
C. venezolanus	*Helicotylenchus*	Loof (1964)
Coomansus indicus	*Hemicriconemoides, Pratylenchus, Tylenchorhynchus, Xiphinema*	Bilgrami *et al.* (1986)
Iotonchus acutus	*Rotylenchus robustus, Trichodorus obtusus, X. americanum*	Thorne (1932)
I. amphigonicus	*H. schachtii*	Thorne (1924)
I. antedontus	*Tylenchorhynchus*	Bilgrami *et al.* (1986)
I. basidontus	Tylenchs	Clark (1960)
I. brachylaimus	*Radopholus similis, S. radicicola*	Cassidy (1931)
I. kheri	*H. multicinctus, Hirschmanniella oryzae, M. incognita, R. reniformis, Scutellonema curvata, T. nudus X. elongatum*	Mohandas & Prabhoo (1980)
I. longicaudatus	*Hirschmanniella, Hoplolaimus*	Bilgrami *et al.* (1986)
I. monhystera	*H. multicinctus, H. dihystera, H. oryzae, Hoplolaimus, M. incognita, Pratylenchus, T. nudus, R. reniformis*	Mohandas & Prabhoo (1980) Azmi (1983)
I. nayari	*H. multicinctus, H. oryzae, M. incognita, R. reniformis, X. elongatum*	Mohandas & Prabhoo (1980)
I. parabasidontus	*H. oryzae*	Bilgrami *et al.* (1986)
I. prabhooi	*M. incognita, R. reniformis*	Mohandas & Prabhoo (1980)
I. risoceiae	*Pratylenchus*	Bilgrami *et al.* (1986)
I. shafi	*Hoplolaimus*	Bilgrami *et al.* (1986)
I. tenuicaudatus	*T. semipenetrans, H. dihystera*	Rama & Dasgupta (1998)
I. trichurus	*Hoplolaimus, Pratylenchus, Tylenchorhynchus, Xiphinema*	Bilgrami *et al.* (1986)
I. vulvapapillatus	*Tylenchorhynchus*	Andrássy (1964)
Miconchus aquaticus	*Hoplolaimus, Hemicycliophora, Xiphinema*	Bilgrami *et al.* (1986)
M. citri	*Pratylenchus, Tylenchorhynchus*	Bilgrami *et al.* (1986)
M. dalhousiensis	*Aphelenchoides, Diphtherophora*	Bilgrami *et al.* (1986)
Mononchus spp.	*Aphelenchoides, Heterodera* eggs, *M. marioni*	Linford & Oliviera (1938) Banage (1963); Arpin (1980)
M. aquaticus	*Aglenchus parvus, Anguina tritici, Globodera rostochiensis, H. oryzae, H. indicus, Heterodera mothi, Hoplolaimus indicus, Longidorus, M. incognita, M. naasi, Paralongidorus citri, Paratrichodorus, Rotylenchus fallorobustus, Trichodorus, Tylenchorhynchus mashhoodi, X. americanum*	Grootaert & Maertens (1976) Grootaert *et al.* (1977) Grootaert & Wayss (1979) Small & Grootaert (1983) Bilgrami *et al.* (1984) Bilgrami (1992)
M. truncatus	*Heterodera schachtii*, tylenchs	Thorne (1927); Szczygiel (1971)
M. tunbridgensis	*Hemicriconemoides, Hoplolaimus, Tylenchorhynchus*	Mankau (1980); Bilgrami *et al.* (1986)
Mylonchulus agilis	*Helicotylenchus vulgaris, Longidorus caespiticola, Rotylenchus fallorobustus*	Doucet (1980)
M. brachyuris	*S. radicicola, R. similis*	Cassidy (1931)
M. dentatus	*A. tritici, Basiria, Helicotylenchus indicus, H. oryzae, H. indicus, Longidorus, M. incognita, P. citri, T. mashhoodi, T. semipenetrans, X. basiri*	Jairajpuri & Azmi (1978) Bilgrami & Kulshreshtha (1994)

Table 1. To be continued.

Predatory nematodes	Plant parasitic nematodes preyed upon	References
M. hawaiiensis	*H. oryzae, M. incognita, T. nudus, R. reniformis*	Mohandas & Prabhoo (1980)
M. minor	*A. tritici, M. incognita, T. semipenetrans, X. americanum*	Kulshreshtha *et al.* (1993)
M. parabrachyuris	*H. schachtii*	Thorne (1927)
M. sigmaturus	*H. schachtii* (eggs), *M. javanica, R. similis, S. radicicola, T. semipenetrans*	Thorne (1927); Cassidy (1931) Cohn & Mordechai (1973, 1974)
Prionchulus spp.	*Aphelenchoides*	Arpin (1980)
P. muscorum	*Aphelenchs, Hemicriconemoides, Hoplolaimus, Tylenchorhynchus*, tylenchs	Altherr (1950); Szczygiel (1971) Arpin (1976); Bilgrami *et al.* (1986)
P. punctatus	*A. tritici, G. rostochiensis, H. dihystera, M. naasi, R. fallorobustus*	Nelmes (1974); Grootaert *et al.* (1977) Small & Evans (1981) Small & Grootaert (1983)
Sporonchulus ibitensis	*Aphelenchoides*	Carvalho (1951)
S. vagabundus	*Aphelenchoides, Pratylenchus, Hemicycliophora, Trichodorus*	Bilgrami *et al.* (1986)

Mordechai 1974, Small 1979). They also decreased *Trichodorus, Hemicriconemoides, Helicotylenchus* and *Tylenchulus* populations under field conditions (Ahmad and Jairajpuri 1982, Azmi 1983, Rama and Dasgupta 1998).

Mononchs do have efficient predatory capabilities and are able to prey on a wide range of prey. However, mononchs have some flaws from a practical biological control point of view. The main drawback lies in their poor adaptability to environmental fluctuations. They can hardly survive drought or flooded conditions. Besides, their low rate of reproduction and longer life cycle and cannibalistic behavior are other hindering factors. The duration of the life cycle varies from species to species. To complete one generation, *Prionchulus punctatus* takes 45 days while *Mononchus aquaticus* takes only 15 days at 25°C (Maertens 1975, Grootaert and Maertens 1976). The possibility of using mononchs in biological control program can not be ruled out on the basis of above mentioned rather limited studies. This is an explored area and it may be surmised that an extensive research on life cycle, predator-prey interactions in terms to biotic and abiotic factors, population dynamics, etc. may result in more information which could prove very vital in the use of mononchs as promising biological control agents. The species of mononch predators and their prey nematodes are listed in Table 1.

2. Stylet-bearing predators

Substatial information is available on the predatory potential of dorylaim nematodes but mostly based on *in vitro* studies. Feeding by *Eudorylaimus obtusicaudatus* on eggs inside the cysts of *Heterodera schachtii* and an increase in the population of *Thornia* sp. in the presence of citrus nematodes but a decrease in their absence in pot trials suggested more than a casual role of stylet bearing predators in nematode biological control under natural conditions and generated optimism in using these predators as biological control agents (Boosalis and Mankau 1965). Dorylaim and nygolaim predators are the most ubiquitous group of predatory nematodes, occurring in all types of soils, climates and habitats. The presence of two, three or more genera of dorylaims in one place/field is quite common and their abundance has been estimated at 200-500 million/acre (Thorne 1930). These predators may be maintained and established under field conditions by making slight modifications in their environment. In addition to nematodes, they also feed on algae, fungi and protozoa (Ferris 1968). Consequently, these predators can also be cultured on algae and fungi. Genarally dorylaims take 3-6 months to complete one life cycle, while *Labronema vulvapapillatum* completes life cycle in 36 days (Ferris 1968, Wood 1973). The efficient rate of predation and prey preference (Khan *et al.* 1991, 1994, 1995a, b) and wide range of predation on nematode species have established their credentials as efficient biological control agents. The most advantageous and encouraging aspect of dorylaims is that it is easy to maintain their populations simply by adding organic matter to agricultural fields; as they are polyphagous in nature, they will remain abundant in soil without prey nematodes (Webster 1972). *In vitro* studies on dorylaim predators, viz. *Aporcelaimellus nivalis, Allodorylaimus americanus, Discolaimus silvicolus, Neoactinolaimus agilis, Paractinolaimus elongates, Mesodorylaimus bastiani* and *Dorylaimus stagnalis* exhibited preference to prey upon second stage

Table 2. List of stylet-bearing predatory nematodes and their prey nematodes (plant parasitic)

Predatory nematodes	Plant parasitic nematodes preyed upon	References
Dorylaims	*Belonolaimus longicaudatus, Criconemoides, M. marioni*	Linford & Oliviera (1938); Esser (1963)
Actinolaimus	*M. marioni*	Linford & Oliviera (1937)
Allodorylaimus americanus and *Discolaimus silvicolus*	*A. tritici, Aphelenchoides, Basiria, Helicotylenchus indicus, Hemicycliophora dhirenderi, H. mothi, H. oryzae, Longidorus, M. incognita, Trichodorus, T. mashhoodi, T. semipenetrans, X. basiri*	Khan *et al.* (1995a)
Aporcelaimellus nivalis	*A. tritici, Aphelenchoides, Basiria, H. indicus, Hemicriconemoides mangiferae, H. dhirendri, H. mothi, H. oryzae, Hoplolaimus indicus, Longidorus, M. incognita, P. citri, Scutellonema, T. mashhoodi, T. semipenetrans, Trichodorus, X. americanum, X. insigne*	Khan *et al.* (1991); Bilgrami (1993)
A. obscurus	*H. schachtii* (eggs)	Thorne & Swanger (1936)
A. obtusicaudatus	*H. schachtii* (eggs)	Thorne (1928)
Aporcelaimus spp.	*Heterodera trifolii, Meloidogyne*	Doncaster (1962); Esser (1987)
Aquatides thornei	*A. tritici, H. indicus, H. mothi, H. oryzae, Longidorus, M. incognita, P. citri, T. mashhoodi, Paratrichodorus, X. americanum*	Bilgrami *et al.* (1985); Bilgrami (1992)
Carcharolaimus spp.	*Meloidogyne, Rotylenchulus reniformis*	Linford & Oliviera (1937); Esser (1963)
Discolaimus spp.	*Hemicycliophora, M. marioni*	Linford & Oliviera (1937); Esser (1963)
D. arenicolus	*M. incognita*	Esser (1963, 1987)
Dorylaimus spp.	*M. marioni*	Linford & Oliviera (1937)
D. obscurus	*H. schachtii* (eggs)	Thorne & Swanger (1936)
D. stagnalis	*A. tritici, H. indicus, H. mothi, H. oryzae, Longidorus, M. incognita, P. citri, Paratrichodorus, T. mashhoodi, X. americanum*	Shafqat *et al.* (1987) Bilgrami (1992)
Eudorylaimus spp.	*Bursaphelenchus xylophilus, M. incognita*	Boosalis & Mankau (1965); Esser (1987)
E. obtusicaudatus	*H. schachtii* (eggs)	Cobb (1929); Esser (1987)
Labronema vulvapapillatus	*A. tritici, G. rostochiensis, M. naasi, X. index*	Wyss & Grootaert (1977) Grootaert & Small (1982) Small & Grootaert (1983)
Mesodorylaimus spp.	*M. incognita*	Spaull (1973)
M. bastiani	*A. tritici, Aphelenchoides, Basiria, H. indicus, H. dhirenderi, H. mothi, H. oryzae, Longidorus, M. incognita, P. citri, Paratrichodorus, T. mashhoodi, X. americanum, X. basiri*	Bilgrami (1992)
Neoactinolaimus agilis	*A. tritici, Aphelenchoides, Basiria, H. indicus, H. oryzae, H. mothi, M. incognita, R. robustus, P. citri, Paratrichodorus, T. mashhoodi, T. semipenetrans, X. americanum*	Khan *et al.* (1995b)
Paractinolaimus elongatus	*A. tritici, H. indicus, H. oryzae, Longidorus, M. incognita, T. mashhoodi, X. basiri*	Khan & Jairajpuri (1997)
Thornia spp.	*Criconemoides, M. floridensis, P. curvitatus, P. penetrans, P. vulnus, T. semipenetrans*	Boosalis & Mankau (1965) Esser (1987)
Westindicus rapax	*Xiphinema*	Hunt (1978)
Aphelenchoides spp.	*M. marioni*	Linford & Oliveira (1938)
Seinura spp.	*Ditylenchus dipsaci, H. trifolii, G. rostochiensis, Neotylenchus linfordi, M. hapla*	Vinciguerra (1979) Small & Grootaert (1983)
S. demani	*Aphelenchoides bicaudatus, Tylenchus*	Wood (1974)
S. oxyura	*Ditylenchus myceliophagus*	Cayrol (1970)
S. tenuicaudatus	*Aphelenchoides parietinus, D. dipsaci, H. trifolii, M. hapla, M. marioni, N. linfordi, Pratylenchus pratensis*	Linford (1937); Hechler (1963)

Table. 3. List of predatory diplogasters and their prey nematodes (plant parasitic)

Predatory nematodes	Plant parasitic nematodes preyed upon	References
Butlerius degrissei	*Aphelenchoides fragariae, Pratylenchus, G. rostochiensis, M. naasi, R. robustus*	Grootaert *et al.* (1977) Small & Grootaert (1983)
Diplogaster spp.	*M. marioni*	Linford (1937)
Mononchoides fortidens and *M. longicaudatus*	*A. tritici, H. indicus, H. oryzae, Longidorus, M. incognita, Trichodorus, T. mashhoodi, X. americanum*	Bilgrami & Jairajpuri (1988, 1989b)
M. gaugleri	*A. tritici, H. indicus, H. mangiferae, H. oryzae, Hoplolaimus indicus, Longidorus attenuatus, M. incognita, Paratrichodorus christiei, T. mashhoodi, X. americanum*	Bilgrami *et al.* (2005)
Odontopharynx longicaudata	*A. amsinckiae, A. pacificae, Aphelenchoides fragariae, Criconemella xenoplax, M. hapla, M. incognita, M. javanica, P. vulnus, Trichodorus, T. semipenetrans, X. index*	Chitambar & Noffsinger (1989)

juveniles of endoparasitic nematodes viz. *Anguina tritici, M. incognita, Heterodera mothi* and *T. semipenetrans* over other prey nematodes used in the experiments (Khan *et al.* 1991, 1994, 1995a, b, Bilgrami 1992, 1993, 1995, Khan and Jairajpuri 1997). The aggregation of some of these dorylaimid predators around injured prey at the feeding site and their subsequent feeding together on that prey is an indication of the positive response of predators towards prey secretions. Widespread and abundant presence of these predators in fields, and their omnivorous feeding habits, chemotaxis sense and inverse relationship with prey nematode are certainly encouraging phenomenon, to explore their biocontrol potentials.

Aphelenchs in spite of their smaller body size and slender stylet, these predators are able to cope successfully with prey many times larger than their own size by injecting enzymes into prey body (Linford and Oliveira 1937). Some of the members of the order Aphelenchida have been observed feeding on plant parasitic nematodes. *Seinura* spp. complete their life cycles in 3-6 days (Hechler 1963, Hechler and Taylor 1966), have a high reproductive potential and can be easily and rapidly cultured on fungivorous nematodes under laboratory conditions. The species of stylet-bearing predators and their prey nematodes are listed in Table 2.

3. Diplogaster predators

The diplogasters feed on nematodes, bacteria and other soil microorganisms. They complete their life cycles in 8~15 days and are the most readily cultured nematodes, being easily maintained on simple nutrient media containing bacteria (Yeates 1969). This group of predators was largely neglected until Yeates (1969) evaluated the predatory abilities of *Diplenteron colobocerus* (=*Mononchoides potohikus*), which feed on bacteria in the absence of prey nematodes, whereas Grootaert *et al.* (1977) examined feeding habits of *Butlerius degrissei*. Both studies suggested that future use of diplogasters in biological control of plant parasitic nematodes. Diplogasterid predators appear to be more prey-selective than other groups. *Odontopharynx longicaudata* attacked and killed six out of 17 prey species presented in the laboratory study and 100% of individuals of *Anguina pacificae* were killed (Chitambar and Noffsinger 1989). They also reported that its ability to eliminate a population of *Anguina pacificae* is of particular interest because it suggests that a target prey-predator relationship exists in the field habitat from where the two species were collected. A strong degree of prey preference was reported for *Mononchoides fortidens, M. longicaudatus* and *M. gaugleri*: they preferred juveniles of endoparasitic over ectoparasitic nemaodes (Bilgrami and Jairajpuri 1989a, Bilgrami *et al.* 2005). The main advantages of using diplogasterid predators lie in their chemotaxis sense and high rates of predation, short life cycles, high fecundity and easy culture. In addition, they form dauer larvae under adverse conditions (Bilgrami and Jairajpuri 1990). Because of these characteristics, diplogasterid predators certainly deserve the attention to explore their potential. A list of diplogasterid predators and their prey nematodes is given in Table 3.

EFFICACY OF PREDATORY NEMATODES

Interests in predatory nematodes for biological control of plant parasitic nematodes is long standing, yet remarkably few efficacy experiments have been reported while these have been restricted to petridish or pot studies. Cohn and Mordechai (1974) found *Mylonchulus* suppressed the population of the reniform nemtodes in pot experiments. Small (1979) subsequently reported a significant reduction in the population of potato cyst nematode, *Globodera rostochiensis* and root-knot nematode, *Meloidogyne incognita* in the presence of *Prionchulus punctatus*, also in pots. Root-knot development caused by *M. incognita* on chilli (*Capsicum annuum*) significantly declined in the presence of *Mononchus aquaticus*. The severity of root-knot infection was reduced when chipped leaves of neem (*Azadirachta indica*) and castor (*Ricinus communis*) were incorporated into the soil and improvement in plant growth was positively correlated with the level of nematode control (Akhtar and Mahmood 1993).

The efficacy of diplogaster predators has been suggested from a handful of pot experiments. Osman (1988) showed *Diplogaster* reduced population of *Meloidogyne javanica* and *Tylenchulus semipenetrans* in pots. Fauzia *et al.* (1998) demonstrated the ability of *Mononchoides longicaudatus* to reduce root galling caused by root-knot nematodes, resulting in improved vegetative growth and increased root masses. Further Khan and Kim (2005) reported that a pre-plant application of *M. fortidens* in potted field soil infested with root-knot nematode, *M. arenaria* reduced the root galling on tomato plants and suppressed the *M. arenaria* population, and the final population density of *M. fortidens* increased by about 2-folds compared to initially added density. Thus, the diplogasterid predators may prove promising as biological control agents, but only further studies will confirm their utility at commercial level.

CULTURE AND CONSERVATION OF PREDATORY NEMATODES

A huge population of predators is required to execute biological control programs successfully against a plant parasitic nematode species population in the field. The better understanding and advanced knowledge to elevate population of predators both under *in vitro* and *in vivo* conditions is therefore required. With a few exceptions, predators are reared using *in vivo* methods, which require maintaining concurrent prey cultures, thereby reducing efficacy. Esser (1963) cultured predatory mononchs, Pillai and Tailor (1968) cultured diplogasters on a dixenic culture of bacteria and *Aphelenchus avenae*, Yeates (1969) cultivated *D. colobocerus* on agar plates using a bacterium, *Bacillus cereus* var *mycoides*. Nelmes (1974) reared *P. puntatus* on *Aphelenchus avenae* and *Panagrellus redivivus* in soil extract agar medium and reported that *A. avenae* appear to be more suitable prey for many mononchs. Grootaert and Maertens (1976) and Small (1977) used the same technique to raise the populations of *Mononchus aquaticus* and *P. punctatus* using *P. redivivus* as prey. Small and Evans (1981) cultured sufficient *P. punctatus* on *A. avenae* and *P. redivivus* in soil extract agar at pH 7 to use as a biological control agent in pot trials. Allen-Morley and Coleman (1989) reported that larger populations of *Mononchus tunbridgensis* were supported by *A. avenae* but also that mononchs could be cultivated on 'thick lawns' of bacteria. Shafqat *et al.* (1987) and Bilgrami and Jairajpuri (1988) cultivated predators, *D. stagnalis* and *M. fortidens* and *M. longicaudatus*, respectively using *Rhabditis* sp. in agar plates supplemented with infant milk powder (Lactogen) under *in vitro* conditions. Addition of milk powder boosted bacterial growth in maintaining their culture for long duration. Khan *et al.* (1991, 1994, 1995a, b) and Khan and Jairajpuri (1997) have also used the same technique to elevate population of dorylaim predators.

The conservation of predatory nematodes appears to be simple and cost effective. With relatively little efforts their activity may be stimulated and density elevated to counter populations of target pest nematode. Lal *et al.* (1983) recorded a two-fold increase in the population of predatory nematodes, such as species of *Dorylaimus, Discolaimus* and *Mononchus*, when green manure was added to the soil. Few studies on soil nematodes with neem (*A. indica*) products such as leaf powder, sawdust and oil seed cake showed encouraging results in maintaining and conserving predatory nematode populations in the field (Akhtar 1995). Winter mulching could be another option to imrove predatory nematodes preservation in the field. This technique has been found to be effective in stabilizing the population of *Iotonchus tenuicaudatus* that feeds on *T. semipenetrans* and *Helicotylenchus dihystera* in ornge orchards (Rama and Dasgupta 1988). Further studies are warranted on the role of organic matter in predatory nematode conservation. Prey nematodes and bacteria have supported growth and development of diplogasters predators.

CONCLUSION AND PROSPECTS

Many studies have shown predatory nematodes to be effective at killing plant parasitic nematodes. Much of the information on predatory nematodes is based on agar plate experiments; limited data are available on predation in soil. Small and Grootaert (1983) emphasized that studies on predatory nematodes as biocontrol agents should concentrate on the migratory stages of endoparasitic nematodes as these are more susceptible to predation. This view was also supported by the findings of Khan *et al.* (1991, 1994, 1995a, b), Bilgrami (1992, 1993), and Bilgrami *et al.* (2005). Predation rate often depends on chance encounter and thus density dependent (Yeates 1969, Osman 1989, Bilgrami 1993). It may be assumed that impact of predatory nematodes as biocontrol agent may increase during the peak season of hatching/ emergence of plant parasitic nematodes, especially of endoparasitic nematodes under field conditions.

Biological control potential and efficacy of predatory nematodes vary with their groups. Mononchs because of their long life cycle, low fecundity, susceptibility to changing environmental conditions and cannibalistic behavior do not fulfill the requirements of an efficient biological control agent. On the other hand, the advantage of dorylaim, nygolaim and other stylet-bearing predators lied in their wide spread natural occurrence and easy mass culturing due to their polyphagous feeding habits. Also, their population may be elevated in the field by adding organic materials. However, more fields studies are needed to confirm this hypothesis. Their long life cycle and low rate of fecundity are also causes of concern.

The real possibility of using predatory nematodes in biological control of nematodes lies in diplogasterid predators, due to their chemotaxis sense and high rates of predation, short life cycles, high fecundity and easy culture. In addition, they are polyphagous and form dauer larvae under adverse conditions (Bilgrami and Jairajpuri 1990). These groups of predators are likely to offer the most promising as augmentative agents in colonization efforts in combination with cultural practices, such as cover crop, green manuring or organic amendment and plant resistance. The immediate need is to assess the diversity of predacious species present in different agro-climatic regions. The efforts should include identification of the predatory nematode species that are well adapted to local climates and develop sustainable techniques for their mass culturing, formulation, and time and mode of application. The effectiveness of predatory nematodes can be tested on migratory stages of endoparasitic nematodes. After testing predation potential in pot experiments, field experiments need to be conducted and, if results are encouraging, properly designed multi-location trials should be initiated. Greater research and development and extension efforts are required to identify and popularize this environmentally friendly nematode pest management approach.

REFERENCES

Ahmad, N. and M.S. Jairajpuri. 1982. Population fluctuations of predatory nematode *Parahadronchus shakili* (Jairajpuri 1969) Mulvey 1978 (Mononchida). Proc. Symp. Ecol. Anim. Popul. India. Pt. **3** : 1-12.

Akhtar, M. 1995. Biological control of root-knot nematode *Meloidogyne incognita* in tomato by the predatory nematode *Mononchus aquaticus*. *Int. Pest cont.* **37** : 18-19.

Akhtar, M. and I. Mahmood. 1993. Effect of *Mononchus aquaticus* and organic amendments on *Meloidogyne incognita* development on chilli. *Nematol. Medit.* **21** : 251-252.

Allen-Morley, C.R. and D.C. Coleman. 1989. Resilience of soil biota in various food webs to freezing perturbations. *Ecology* **70** : 1127-1141.

Altherr, E. 1950. Les nématodes du Parc National suisse. (Nématodes libres du sol). Ergebn. Wiss. Unters. Schweiz. Nat. Parks. N.S. **3** : 1-46.

Andrássy, I. 1964. Süßwassernematoden aus den Großen Gebrigsgegenden Ostafrikas. *Acta. Zool. Acad. Scient. Hung.* **10** : 1-59.

Arpin, P. 1976. Étude et discussion sur un milieu de culture pour Mononchidae (nematoda). *Rev. Écol. Biol. Sol.* **13** : 629-634.

Arpin, P. 1980. Les éléments prédateurs de la microfaune du sol. In: P. Pesson (Eds.), Actualités d'Écologie forestiére. Paris. Gauthier Villars, pp. 507-517.

Azmi, M.I. 1983. Predatory behaviour of nematodes. Biological control of *Helicotylenchus dihystera* through the predaceous nematodes, *Iotonchus monhystera*. *Indian J. Nematol.* **13** : 1-8.

Banage, W.B. 1963. The ecological importance of free-living soil nematodes with special reference to those of moorland soil. *J. Anim. Ecol.* **32** : 133-140.

Bilgrami, A.L. 1992. Resistance and susceptibility of prey nematodes to predation and strike rate of the predators, *Mononchus aquaticus, Dorylaimus stagnalis*, and *Aquatides thornei*. *Fund. Appl. Nematol.* **15** : 265-270.

Bilgrami, A.L. 1993. Analysis of relationships between predation by *Aporcelaimellus nivalis* and different trophic categories. *Nematologica* **39** : 356-365.

Bilgrami, A.L. 1995. Numerical analysis of the relation between *Mesodorylaimus bastiani* (Nematoda: Dorylaimida) and different prey trophic categories. *Nematol. Medit.* **23** : 81-88.

Bilgrami, A.L. and M.S. Jairajpuri. 1988. Attraction of *Mononchoides longicaudatus* and *M. fortidens* (Nematoda: Diplogasterida) towards prey and factors influencing attraction. *Revue Nématol.* **11** : 195-202.

Bilgrami, A.L. and M.S. Jairajpuri. 1989a. Resistance of prey to predation and strike rate of the predators *Mononchoides longicaudatus* and *M. fortidens* (Nematoda: Diplogasterida). *Revue Nématol.* **12** : 45-49.

Bilgrami, A.L. and M.S. Jairajpuri. 1989b. Predatory abilities of *Mononchoides longicaudatus* and *M. fortidens* (Nematoda: Diplogasterida) and factors influencing predation. *Nematologica* **35** : 475-488.

Bilgrami, A.L. and M.S. Jairajpuri. 1990. Diplogasterid predators. In: Jairajpuri, M.S., Alam, M.M., Ahmad, I. (Eds.). Nematode bio-control (Aspects and prospects). CBS Publishers & Distributors Pvt. Ltd., Delhi, India, 135-142 pp.

Bilgrami, A.L. and R. Kulshreshtha. 1994. Evaluation of predation abilities of *Mylonchulus dentatus*. *Indian J. Nematol.* **23** : 191-198.

Bilgrami, A.L., I. Ahmad and M.S. Jairajpuri. 1983. Some factors influencing predation by *Mononchus aquaticus*. *Revue Nématol.* **6** : 325-326.

Bilgrami, A.L., I. Ahmad and M.S. Jairajpuri. 1984. Observations on the predatory behaviour of Mononchus aqaticus. *Nematol. Medit.* **12** : 41-45.

Bilgrami, A.L., I. Ahmad and M.S. Jairajpuri. 1985. Predatory behaviour of *Aquatides thornei* (Nygolaimina: Nematoda) *Nematologica* **30** : 457-462.

Bilgrami, A.L., I. Ahmad and M.S. Jairajpuri. 1986. A study on the intestinal contents of some mononchs. *Revue Nématol.* **17** : 339-340.

Bilgrami, A.L., R. Gaugler and C. Brey. 2005. Prey preference and feeding behaviour of diplogastrid predator *Mononchoides gaugleri* (Nematoda: Diplogasterida). *Nematology* **7** : 333-342.

Boosalis, M.G. and R. Mankau. 1965. Parasitism and predation of soil microorganisms. In: Baker, K.F., Snyder, W.C., (Eds.), Ecology of soil-borne plant pathogens. Berkeley University of California Press, pp. 374-391.

Carvalho, J.C. 1951. Una nova espècie de *Mononchus (M. ibitiensis* n. sp.). *Bragantia* **11** : 51-54.

Cassidy, G.H. 1931. Some mononchs of Hawaii. *Hawaiian Planters' Rec.* **35** : 305-339.

Cayrol, J.C. 1970. Action des autres composants de la biocénose du champignon de couche sur le nématode mycophagae, *Ditylenchus myceliophagus*. J.B. Goodey, 1958 et étude son anabiose: Forme de survie en conditions défavorables. *Rév. Écol. Biol. Sol* **7** : 409-440.

Chitambar, J.J. and E.M. Noffsinger. 1989. Predaceous behaviour and life history of *Odontopharynx longicaudata* (Diplogasterida). *J. Nematol.* **21** : 284-291.

Christie, J.R. 1960. Biological control-predaceous nematodes. In: Sasser, J.M., Jenkins, W.R. (Eds.), Nematology: Fundamentals and recent advances with emphasis on plant parasitic and soil forms. University of North Carolina Press, Chapel Hill, pp. 466-468.

Clark, W.C. 1960. The Mononchidae (Enoplida: Nematoda) of New Zealand II. The genus *Iotonchus* (Cobb, 1916) Altherr, 1950. *Nematologica* **5** : 260-274.

Cobb, N.A. 1917. The mononchs (*Mononchus* Bastian 1865): A genus of free-living predatory nematodes. *Soil Science* **3** : 431-486.

Cobb, N.A. 1929. Nemas of genus *Dorylaimus* attacking the eggs of mites. *J. Parasitol.* **15** : 284 (Abstr).

Cohn, E. and E. Mordechai. 1974. Experiments in suppressing citrus nematode populations by use of marigold and a predacious nematode. *Nematol. Medit.* **2** : 43-53.

Coomans, A. and B. Lima. 1965. Description of *Anatonchus amiciae* n. sp. (Nematoda: Mononchidae) with observations on its juvenile stages and anatomy. *Nematologica* **11** : 413-431.

Doncaster, C.C. 1962. Predators of soil nematodes (film). *Parasitology* **52** : 19p.

Doucet, M.E. 1980. Description d'une nouvelle espèce de genre *Mylonchulus* (Nematoda: Mononchida). *Nematol. Medit.* **8** : 37-42.

Esser, R.P. 1963. Nematode interactions in plates of nonsterile water agar. *Proc. Soil Crop Sci. Soc. Florida* **23** : 121-128.

Esser, R.P. 1987. Biological control of nematodes by nematodes I. Dorylaims (Nematoda: Dorylaimida). Nematology circular No. 144, Fla Dep. Agric. & Consumer Serv., 4 pp.

Esser, R.P. and E.K. Sobers. 1964. Natural enemies of nematodes. *Proc. Soil Crop Sci. Soc. Florida* **24** : 326-353.

Fauzia, M., S. Jairajpuri and Z. Khan. 1998. Biocontrol potential of *Mononchoides longicaudatus* on *Meloidogyne incognita* on tomato plants. *Inter. J. Nematol.* **8** : 89-91.

Ferris, R.V. 1968. Biometric analysis in the genus *Labronema* (Nematoda: Dorylaimida) with a description of *L. thornei* n. sp. *Nematologica* **14** : 276-284.

Grootaert, P. and D. Maertens. 1976. Cultivation and life cycle of *Mononchus aquaticus*. *Nematologica* **22** : 173-181.

Grootaert, P. and R.W. Small. 1982. Aspects of biology of *Labronema vulvapapillatum* (Meyl) (Nematoda: Dorylaimida) in laboratory culture. *Biol. Jb. Dodonaea* **50** : 135-148.

Grootaert, P. and Wyss, U. 1979. Ultrastructure and function of anterior region feeding apparatus in *Mononchus aquaticus*. *Nematologica* **25** : 163-173.

Grootaert, P., A. Jaques and R.W. Small. 1977. Prey selection in *Butlerius* sp. (Rhabditida: Diplogasteridae). *Med. Fac. Landbouww. Rijksuniv. Gent.* **42** : 1559-1563.

Hechler, H.C. 1963. Description, developmental biology, and feeding habits of *Seinura tenuicaudata* (De Man), J.B. Goodey, 1960 (Nematoda: Aphelenchoididae), a nematode predator. *Proc. Helminth. Soc. Wash.* **30** : 183-195.

Hechler, H.C. and D.P. Taylor. 1966. The life histories of *Seinura celeris, S. olivierae, S. oxura* and *S. steineri* (Nematoda: Aphelenchoididae). *Proc. Helminth. Soc. Wash.* **33** : 71-83.

Hom, A. 1996. Microbial pesticides, IPM and the consumer. *IMP Practioner* **18** : 1-10.

Hunt, D.J. 1978. *Stomachoglossa bryophilum* n sp., (Brittonematidae), *Westindicus rapax* n.sp. (Paractinolaimidae), *Caribinema siddiqi* n. sp. and *C. longidens* Thorne, 1967 (Charcharolaimidae) from St. Lucia. *Nematologica* **24** : 175-183.

Jairajpuri, M.S. and M.I. Azmi. 1978. Some studies on the predatory bahaviour of *Mylonchulus dentatus*. *Nematol. Medit.* **6** : 205-212.

Jairajpuri, M.S. and A.L. Bilgrami. 1990. Predatory nematodes. In: Jairajpuri, M.S., Alam, M.M., Ahmad, I. (Eds.), Nematode biocontrol: Aspects and prospects. CBS Publishers & Distributors Pvt. Ltd., New Delhi, pp. 95-125.

Jones, F.G.W. 1974. Control of nematode pest, back background and outlook for biological control. In: Jones, P.D., Solomon, M.E. (Eds.), Biology in pest and disease control. 13rd Symposium British Ecology Society Oxford.

Kerry, B. (2000). Rhizosphere interactions and the exploitation of microbial agents for biological control of plant parasitic nematodes. *Ann. Rev. Phytopathol.* **38** : 423-441.

Khan, Z. and M.S. Jairajpuri. 1997. Predatory behavior of *Paractinolaimus elongatus* on plant parasitic nematodes. *Int. J. Nematol.* **8** : 178-181.

Khan, Z. and Y.H. Kim. 2005. The predatory nematode, *Mononchoides fortidense* (Nematoda: Diplogasterida), suppresses the root-knot nematode, *Meloidogyne arenaria*, in potted field soil. *Biol. Control.* **35** : 78-82.

Khan, Z., A.L. Bilgrami and M.S. Jairajpuri. 1991. Some observations on the predation ability of *Aporcelaimellus nivalis* (Altherr, 1952) Heyns, 1966 (Nematoda: Dorylaimida). *Nematologica* **37** : 333-342.

Khan, Z., A.L. Bilgrami and M.S. Jairajpuri. 1994. Attraction and food preference behaviour of predatory nematodes, *Allodorylaimus americanus* and *Discolaimus silvicolus* (Nematoda: Dorylaimida). *Indian J. Nematol.* **24** : 168-175.

Khan, Z., A.L. Bilgrami and M.S. Jairajpuri. 1995a. A comparative study on predation by *Allodorylaimus americanus* and *Discolaimus silvicolus* (Nematoda: Dorylaimida) on different species of plant parasitic nematodes. *Indian J. Nematol.* **25** : 94-103.

Khan, Z., A.L. Bilgrami and M.S. Jairajpuri. 1995b. Observations on the predation abilities of *Neoactinolaimus agilis* (Dorylaimida: Actinolaimoidea). *Indian J. Nematol.* **25** : 129-135.

Kulshreshtha, R., A.L. Bilgrami and Z. Khan. 1993. Predation abilities of *Mylonchulus minor* and factors influencing predation. *Ann. Plant*

Prot. Sci. **1** : 79-84.

Lal, A., K.C. Sanwal and V.K. Mathur. 1983. Changes in the nematode populations of undisturbed land with the introduction of land development practices and cropping sequences. *Indian J. Nematol.* **13** : 133-140.

Linford, M.B. 1937. The feeding of some hollow-stylet nematodes. *Proc. Helminth. Soc. Wash.* **4** : 41-46.

Linford, M.B. and J.M. Oliviera. 1937. The feeding of hollow-spear nematodes on other nematodes. *Science* **85** : 295-297.

Linford, M.B. and J.M. Oliviera. 1938. Potential agents of biological control of plant parasitic nematodes. *Phytopathology* **28** : 14.

Loof, P.A.A. 1964. Free-living and plant-parasitic nematodes from Venezuela. *Nematologica* **10** : 2001-300.

Maertens, D. 1975. Observations on life cycle of *Prionchulus punctatus* (Cobb, 1917) and culture conditions. *Biol. Jb. Dodonaea* **43** : 197-218.

Mankau, R. 1980. Biological control of nematode pests by natural enemies. *Ann. Rev. Phytopathol.* **18** : 415-440.

Menzel, R. 1920. Über die Nahrung der freilebenden Nematoden und die Art ihrer Aufnahme. Ein Beitrag zur Kenntnis der Ernährung der Würmer. *Verhandl. Naturf. Ges. Basel* **31** : 153-188.

Mohandas, C. and N.R. Prabhoo. 1980. The feeding behaviour and food preference of predatory nematodes (Mononchids) from soil of Kerala (India). *Rev. Écol. Biol. Sol.* **17** : 53-60.

Mulvey, R.H. 1961. The Mononchidae: A family of predaceous nematodes. I. Genus *Mylonchulus* (Enoplida: Mononchidae). *Can. J. Zool.* **39** : 665-696.

Nelmes, A.J. 1974. Evaluation of feeding behaviour of *Prionchulus punctatus* (Cobb) a nematode predator. *J. Anim. Ecol.* **43** : 553-565.

Osman, G.Y. 1988. Studies on the potential use of the predator, *Diplogaster* sp. (Nematoda: Diplogasteridae) on certain root parasitic nematodes. *Anz. Schadl. Pflanzen. Umwelt.* **61** : 70-73.

Osman, G.Y. 1989. Studies on *Diplogaster* sp. (nematodes) as a predator of some plant parasitic nematodes. *Anz. Schadl. Pflanzen. Umwelt.* **62** : 11-14.

Pillai, J. and D. Talor. 1968. Biology of *Paroigolaimella bermensis* and *Fictor anchicoprophaga* (Diplogasteridae) in laboratory culture. *Nematologica* **14** : 159-170.

Rama, K. and M.K. Dasgupta. 1998. Biocontrol of nematodes associated with mandarin orange decline by the promotion of predatory nematode *Iotonchus tenuicaudatus* (Kreis, 1924). *Indian J. Nematol.* **28** : 118-124.

Ritter, M. and C. Laumond. 1975. Review of the use of nematodes in biological control programs against parasites and pests of cultivated plants. Bull. Des. Resch. Agrono. Des. Gem. San. D'Elude Agric Hijej. Des plants. pp. 331-334.

Shafqat, S., A.L. Bilgrami and M.S. Jairajpuri. 1987. Evaluation of the predatory behaviour of *Dorylaimus stagnalis* Dujardin, 1845 (Nematoda: Dorylaimida). *Revue Nématol.* **10** : 455-461.

Small, R.W. 1977. The culture and ecology of predatory nematode populations, especially of *Prionchulus punctatus*. Ph.D. thesis, University of London, 451pp.

Small, R.W. 1979. The effects of predatory nematodes on populations of plant parasitic nematodes in pots. *Nematologica* **25** : 94-103.

Small, R.W. and A.A.F. Evans. 1981. Experiments on the population growth of the predatory nematode *Prionchulus punctatus* in laboratory culture with observations on life history. *Revue Nématol.* **4** : 261-270.

Small, R.W. and P. Grootaert. 1983. Observations on the predation abilities of some soil-dwelling predatory nematodes. *Nematologica* **29** : 109-118.

Spaull, V.W. 1973. Distribution of nematode feeding groups at Signy Island, South Orkney Islands with an estimate of their biomass and oxygen consuption. *Brit. Antarc. Sur. Bull.* **37** : 21-32.

Steiner, G. and H. Heinly. 1922. The possibility of control of *Heterodera radicicola* and other plant injurious nematodes by means of predatory nemas, especially *Mononchus aquaticus*. *J. Wash. Acad. Sci.* **12** : 367-385.

Stirling, G.R. 1991. Biological control of plant parasitic nematodes. Progress, problems and prospects. Wallingford, UK: CAB International, 282 pp.

Szczygiel, A. 1966. Studies on the fauna and population dynamics of nematodes occurring on strawberry plantation. *Ekol. Pol.* **14** : 651-709.

Szczygiel, A. 1971. Wystepowanie drapieznych nicieni z rodziny Mononchidae w glebach uprawnych w Polsce. Zesze. Probl. Postep. *Nauk. Roln.* **121** : 145-158.

Thorne, G. 1924. Utah nematodes of the genus *Mononchus*. *Trans. Am. Microscop. Soc.* **43** : 157-171.

Thorne, G. 1927. The life history, habits and economic importance of some mononchs. *J. Agric. Res.* **34** : 265-286.

Thorne, G. 1928. Nematodes inhabiting the cysts of the sugar beet nematode (*Heterodera schachtii*) (Schmidt). *J. Agric. Res.* **37** : 571-575.

Thorne, G. 1930. Predaceous nemas of the genus *Nygolaimus* and a new genus, *Sectonema*. *J. Agric. Res.* **41** : 445-466.

Thorne, G. 1932. Specimens of *Mononchus acutus* (=*Iotonchus acutus*) found to contain *Trichodorus obtusus*, *Rotylenchus robustus* and *Xiphinema americanum*. *J. Parasitol.* **19** : 90.

Thorne, G. and H.H. Swanger. 1936. A monograph of the nematode genera *Dorylaimus*, *Aporcelaimus*, *Dorylaimoides* and *Pungentus*. *Capita Zool.* **6** : 1-223.

Vinciguerra, M.T. 1979. Role of nematodes in the biological process of the soil. *Boll. Zool.* **46** : 363-374.

Webster, J.M. 1972. Nematodes and biocontrol. In: Webster, J.M. (Eds.), Economic Nematology. Academic Press, London pp. 469-496.

Wood, F.H. 1973. Nematode feeding relationships. Relationships of soil dwelling nematodes. *Soil Biol. Biochem.* **5** : 593-601.

Wood, F.H. 1974. Biology of *Seinura demani* (Nematoda: Aphelenchoididae). *Nematologica* **20** : 347-353.

Wyss, U. and Grootaert, P. 1977. Feeding mechanisms in *Labronema* sp. Med. Fac. Landbouww. Rijskuniv. *Gent* **42** : 1521-1527.

Yeates, G.W. 1969. Predation by *Mononchoides potohikus* (Nematoda: Diplogasteridae) in laboratory culture. *Nematologica* **15** : 1-9.

Yeates, G.W. and D.A. Wardle. 1996. Nematodes as predators and prey: relationships to biological control and soil processes. *Pedobiologia* **40** : 43-50.

Yeates, G.W., T. Bongers, De R.G.M. Goede, D.W. Freckman and S.S. Georgieva. 1993. Feeding habits in soil nematode families and genera -An outline for soil ecologists. *J. Nematol.* **25** : 101-113.