Parvatha P. Reddy

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Preface

The destructive plant-parasitic nematodes are one of the major limiting factors in the production of crop plants throughout the world. For centuries, man has been plagued by these microscopic organisms feeding on the roots of crop plants essential to his survival and well-being. Roots damaged by the nematodes are not efficient in the utilization of available moisture and nutrients in the soil resulting in reduced functional metabolism. Visible symptoms of nematode attack often include reduced growth of individual plants, varying degrees of chlorosis, wilting of the foliage, and sometimes death of plants. Furthermore, roots weakened and damaged by nematodes are easy prey to many types of fungi and bacteria which invade the roots and accelerate root decay. These deleterious effects on plant growth result in reduced yields and poor quality of crops. Nematode management is, therefore, important for high yields and quality that are required by the high cost of modern crop production.

The information on various aspects of nematode diseases of crop plants and their management is very much scattered and there is no book at present which comprehensively and exclusively deals with the above aspects. The present book on *Nematode Diseases of Crops and their Management* gives a detailed description of the causal organism, distribution, nature of damage and symptoms, crop losses, host range, biology and life cycle, interaction with other organisms, spread and survival, and management of nematode diseases of cereal, pulse, sugar, fiber, oil seed, vegetable, fruit, plantation, spice, tuber, ornamental, medicinal, and aromatic crops.

The book is divided into nine parts. Part I describes the importance of nematode diseases in agriculture and presents a historical review, economic importance, emerging nematode problems, interaction with other pathogens (fungi, bacteria, and viruses), and nematode management methods (regulatory, physical, cultural, chemical, biological, host resistance, and integrated methods).

The nematode diseases of large grained cereal crops such as rice, wheat, barley, and maize and small grained cereal crop like sorghum are discussed in detail in Part II.

In Part III, the nematode diseases of pulse crops (chickpea, pigeon pea, green gram, and black gram) and oil seed crops (groundnut, castor, soybean, and sunflower) are dealt with in a very systematic manner.

The nematode diseases of fiber crops (cotton and jute) and sugar crops (beetroot and sugarcane) are discussed in detail in Part IV.

In Part V, the nematode diseases of fruit crops such as tropical (banana, citrus, papaya, pineapple, and mulberry), subtropical (guava and grapevine), temperate (peach, strawberry, and apple), and semiarid (pomegranate and fig) are discussed in detail.

Nematode diseases of vegetable crops such as solanaceous (tomato, brinjal, and chili), malvaceous (okra), leguminous (French bean, cowpea, and pea), cucurbitaceous (cucumber, pointed gourd, bottle gourd, and bitter gourd), root (carrot), bulbous (onion and garlic), cruciferous (cabbage and cauliflower), leafy (lettuce and celery) mushrooms, and vegetables grown under protected cultivation (tomato, bell pepper, cucumber, and lettuce) are envisaged in Part VI.

In Part VII, ornamental crops grown under open (tuberose, gladiolus) and protected (carnation, gerbera, chrysanthemum, lilies, orchids, and anthuriums) conditions; medicinal crops (ashwagandha, coleus, brahmi, soda apple, and henbane); and aromatic crops (mints, basil, jasmine, patchouli, davana, scented geranium, and chamomile) are discussed in detail.

Nematode diseases of plantation (coconut, areca nut, coffee, and tea), spice (black pepper, cardamom, ginger, and turmeric), and tuber (taro, sweet potato, yam, Chinese potato, yam bean, winged bean, and elephant foot yam) crops are dealt with in Part VIII.

Part IX deals with future thrusts and conclusion.

This book is mainly intended for postgraduate students specializing in Plant Nematology, Plant Pathology, and Agricultural Entomology. It will be of immense value to the scientific community involved in teaching, research, and extension activities related to crop protection. The book can also serve as a very useful reference to policy makers and practicing farmers. Suggestions to improve the contents of the book are most welcome (E-mail: reddypp42@gmail.com). The publisher, Springer Nature Singapore Pte Ltd., Singapore, deserves commendation for their professional contribution.

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Parvatha P. Reddy

About the Book

The destructive plant-parasitic nematodes are one of the major limiting factors in the production of crop plants throughout the world. Annual estimated crop losses due to nematodes in India have been worked out to be about ₹102 billion. For centuries, man has been plagued by these microscopic organisms feeding on the roots of crop plants essential to his survival and well-being. Roots damaged by the nematodes are not efficient in the utilization of available moisture and nutrients in the soil resulting in reduced functional metabolism. Visible symptoms of nematode attack often include reduced growth of individual plants, varying degrees of chlorosis, wilting of the foliage, and sometimes death of plants. Furthermore, roots weakened and damaged by nematodes are easy prey to many types of fungi and bacteria which invade the roots and accelerate root decay. These deleterious effects on plant growth result in reduced yields and poor quality of crops. Nematode management is, therefore, important for high yields and quality that are required by the high cost of modern crop production.

To impart basic knowledge about the nematode diseases of cereal, pulse, oilseed, sugar, fiber, fruit, vegetable, ornamental, medicinal, aromatic, plantation, spice, and tuber crops, a detailed description of the causal organism, distribution, nature of damage and symptoms, crop losses, host range, biology and life cycle, interaction with other organisms, spread and survival, and management is provided.

This book is mainly intended for postgraduate students specializing in Plant Nematology, Plant Pathology, and Agricultural Entomology. It will be of immense value to the scientific community involved in teaching, research, and extension activities related to crop protection. The book can also serve as a very useful reference to policy makers and practicing farmers.

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Part VIII Plantation, Spice and Tuber Crops

About the Author

Parvatha P. Reddy Obtained his M.Sc. (Agri.) degree from Karnatak University, Dharwad, and Ph. D. degree jointly from the University of Florida, Gainesville, USA, and the University of Agricultural Sciences, Bangalore.

Dr. Reddy served as the Director of the prestigious Indian Institute of Horticultural Research (IIHR) at Bangalore from 1999 to 2002 during which period the Institute was honored with "ICAR Best Institution Award." He also served as the Head of the Division of Entomology and Nematology at IIHR and gave tremendous impetus and direction to research, extension, and education in developing bio-intensive integrated pest management strategies in horticultural crops. Dr. Reddy has about 34 years of experience working with horticultural crops and involved in developing an F1 tomato hybrid "Arka Varadan" resistant to root-knot nematodes.

Dr. Reddy has over 250 scientific publications to his credit, which also include about 35 books. He has also guided two Ph.D. students at the University of Agricultural Sciences, Bangalore.

Dr. Reddy is serving as Senior Scientific Advisor to Dr. Prem Nath Agricultural Science Foundation, Bangalore. He had served as Chairman, Research Advisory Committee of Indian Institute of Vegetable Research, Varanasi; Member of the Research Advisory Committees of the National Centre for Integrated Pest Management, New Delhi; National Research Centre for Citrus, Nagpur; and the Project Directorate of Biological Control, Bangalore. Dr. Reddy served as a Member of QRT to review the progress of the Central Tuber Crops Research Institute, Trivandrum; AICRP on Tuber Crops; AICRP on Nematodes, and AINRP on Betel vine. He also served as a Member of the Expert Panel for monitoring the research program of National Initiative on Climate Resilient Agriculture (NICRA) on the theme of Horticulture including Pest Dynamics and Pollinators. He is the *Honorary Fellow* of the Society for Plant Protection Sciences, New Delhi; and *Founder President* of the Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE), Bangalore.

Dr. Reddy has been awarded with the prestigious "Association for Advancement of Pest Management in Horticultural Ecosystems Award," "Dr. G.I. D'souza Memorial Award," "Prof. H.M. Shah Memorial Award," and "Hexamar Agricultural Research and Development Foundation Award" for his unstinted efforts in

developing sustainable, bio-intensive, and eco-friendly integrated pest management strategies in horticultural crops.

Dr. Reddy has organized the "Fourth International Workshop on Biological Control and Management of *Chromolaena odorata*," "National Seminar on Hitech Horticulture," "First National Symposium on Pest Management in Horticultural Crops: Environmental Implications and Thrusts," and "Second National Symposium on Pest Management in Horticultural Crops: New Molecules and Biopesticides."

Part I

Introduction

Nematode Diseases of Crop Plants: An Overview

1

Abstract

Plant parasitic nematodes (PPNs) have emerged as a serious biotic stress and significantly impacted the yield potentials of agricultural and horticultural crops. Overall, plant parasitic nematodes cause 21.3% crop losses amounting to ₹102 billion (US$ 1577 million) annually in India. Nematodes induce mechanical injuries and physiological alterations in the plant systems also facilitate the infection of other pathogens. The changing cropping patterns, introduction of new crops, crop diversification, agronomic practices, etc. also change the spectrum of pests and pathogens, including plant parasitic nematodes. In the near future, the management strategies like use of regulatory (seed certification), physical (soil solarization and hot water treatment of planting material), cultural (crop rotation, organic amendments), chemical (naturally occurring nematicides), and biological (natural enemies) methods and host resistance (induced resistance, interruption in recognition of host, and genetically modified crops) will form components of integrated nematode management.

Keywords

Economic importance · Emerging nematodes · Interaction with other pathogens · Nematode management

1.1 Introduction

Nematodes constitute one of the most important groups of organisms which inhabit the soil around the roots of plants and which frequently play a vital role in their growth and production. Rarely any crop is free from their attacks, yet we usually are unaware of their presence because of their microscopic size and protected position within the soil. Plant parasitic nematodes (PPNs) have emerged as a serious biotic

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stress and significantly impacted the yield potentials of agricultural and horticultural crops. Nematode-induced mechanical injuries and physiological alterations in the plant systems also facilitate the infection from other pathogens.

These slender, active, worm-like creatures are so numerous that Cobb (1914) aptly remarked "...if all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable.... We would find its mountains, hills, valleys, rivers, lakes, and oceans represented by a film of nematodes." According to Thorne (1961), "Each year these minute organisms exact an ever increasing toll from almost every cultivated acre in the world: a bag of rice in Burma, a pound of tea in Ceylon, a ton of sugar beets in Germany, a bag of potatoes in England, a bale of cotton in Georgia, a bushel of corn in Iowa, a box of apples in New York, a sack of wheat in Kansas, or a crate of oranges in California."

The destructive plant parasitic nematodes are one of the major limiting factors in the production of agricultural and horticultural crops throughout the world. Some plant parasitic nematodes (PPNs) are capable of causing disease on many economically important crops grown throughout the world and attained the status of pests for substantial reduction of crop yield. For centuries, humans have been plagued by these microscopic organisms feeding on the roots of crop plants essential to their survival and well-being. Roots damaged by the nematodes are not efficient in the utilization of available moisture and nutrients in the soil resulting in reduced functional metabolism. Stunting of individual plants (reduced growth), yellowing of leaves (varying degrees of chlorosis), wilting of the foliage, and sometimes death of plants are some of the visible symptoms of nematode attack. Further, nematodes interact with soil-borne pathogens in inducing disease complexes. Reduced yields and poor quality of crops are some of the deleterious effects on plant growth. In view of the high cost of modern crop production, nematode management is therefore important for high yields and quality of the produce.

1.2 Historical Importance

1.2.1 International Scenario

The first plant parasitic nematode that seems to have been to come to the attention of the early investigators was the seed gall nematode of wheat, *Anguina tritici*, discovered by Needham (1743). It was not until 1855 that Berkeley from England found a root-knot nematode *Meloidogyne* sp. causing galls on the root system of greenhouse grown cucumbers. Kuhn (1857) noticed the stem and bulb nematode *Ditylenchus dipsaci* infesting the heads of teasel. From Germany, the sugar beet cyst nematode *Heterodera schachtii* was reported by Schacht (1859). Other historical highlights on plant parasitic nematodes are listed in Table 1.1.

Table 1.1 A list of historical highlights on plant parasitic nematodes worldwide, in chronological order

Year	The early records of plant parasitic nematodes
1873	The morphology of free-living nematodes was first described by Butschii
1881	Kuhn—First soil fumigation experiments using CS_2 for the control of the sugar beet cyst nematode *Heterodera schachtii*
1884	In the Netherlands, soil and fresh water nematodes taxonomic monograph was published by DeMan
1888	Strubell—Detailed morphology of *H. schachtii*
1889	Atkinson and Neal—Independently published on root-knot nematodes in the USA
1892	Atkinson—Root-knot nematode and *Fusarium* wilt disease complex in vascular wilt of cotton
1907	Cobb—Joined the USDA, considered to be the father of American nematology
	Titus—Reported *H. schachtii* in the USA
1914	The book "Contributions to a Science of Nematology" was published by Cobb
1918	Cobb—Developed methods and apparatus used in nematology
1933	The book "Plant Parasitic Nematodes and the Diseases they Cause" was published by T. Goodey
1934	S. Stekhoven (1941) translated a book on "Nematodes that are of Importance for Agriculture" published by Filipjev (1934) from Russian to English under the title "A Manual of Agricultural Helminthology"
1943	Carter—Nematicidal value of D-D which initiated the era of soil fumigation
1945	Christie—Nematicidal value of EDB
1948	World's first formal university course in nematology was taught by Allen at the University of California, Berkeley
1950	The book "The Potato Nematode, A Dangerous parasite to Potato Monoculture" was published by Oostenbrink
1951	Christie and Perry—Role of ectoparasitic nematodes as plant pathogens
	The book "Soil and Fresh Water Nematodes" was published by T. Goodey
	FAO—First International Nematology Course and Symposium held at Rothamsted Experiment Station, England
1954	Holdeman and Graham—*Fusarium* wilt of cotton augmented by *Belonolaimus longicaudatus*
1955	European Society of Nematologists was founded
1956	*Nematologica*—First journal devoted entirely to nematology papers published
1958	Hewitt, Raski, and Goheen—Transmission of a soil-borne plant virus (grapevine fan leaf) by a nematode (*Xiphinema index*)
1961	G. Thorne—Book on "*principles of nematology*"
	Society of Nematologists founded in the USA
1967	Organization of tropical American Nematologists was founded
1969	The Society of Nematologists, USA, first published the *Journal of Nematology*
1973	*Nematologia Mediterranea* published from Italy
1978	*Revue de Nematologie* published from France

Table 1.2 A list of historical highlights on plant parasitic nematodes in India, in chronological order

Year	The early records of plant parasitic nematodes
1901	Barber—Root-knot nematode on tea from South India
1913	Butler—'Ufra" disease on rise from Bengal caused by *Ditylenchus angustus*
1919	Milne—Ear cockle disease of wheat from Punjab
1926	Ayyar—Root knot of vegetables and other crops from South India
1936	Dastur—White tip of rice caused by *Aphelenchoides besseyi* from Central India
1956	Thirumala Rao—Root-knot nematodes on citrus from India
1959	Prasad, Mathur, and Sehgal—Cereal cyst nematode from India
1961	Jones (from Rothamsted Experimental Station, UK) recorded potato cyst nematodes from Ootacamund (Nilgiri Hills) in Tamil Nadu which boosted the development of nematology in India
	M.R. Siddiqi—Citrus nematode from India
1966	Nair, Das, and Menon—Reported the burrowing nematode on banana from Kerala, India
1968	First South East Asia Post-graduate Nematology course held in India
1969	The Nematological Society of India founded. First All India Nematology Symposium held at New Delhi
1971	*Indian Journal of Nematology*—first published
1972	New Delhi hosted the First All India Nematology Workshop
1976	Summer Institute in Phytonematology held at Allahabad (India)
1983	Parvatha Reddy—Publication of book on "Plant Nematology" comprehensively covering the subject for the first time from India
1987	Parvatha Reddy—Publication of book entitled "A Treatise on Phytonematology"

1.2.2 Indian Scenario

Although the first plant parasitic nematode from India was reported in 1901, their economic importance to agriculture was realized only during 1960–70s with the interception of "molya" disease of wheat and barley in Rajasthan, golden nematode of potato in Nilgiri Hills (Tamil Nadu), and the burrowing nematode of banana in Kerala. Since then, there has been a spurt in the research efforts on applied aspects of nematode problems in agricultural and horticultural crops. Some of the early records of plant parasitic nematodes are listed below in chronological order (Table 1.2):

1.3 Economic Importance

1.3.1 International Scenario

On a worldwide basis, the 10 most important genera of plant parasitic nematodes were reported, as listed in Table 1.3.

The estimated overall average annual yield loss of the world's major crops due to damage by plant parasitic nematodes is 12.3% (Table 1.4). For the 20 crops (left-hand column) that stand between man and starvation (life-sustaining crops), an

Table 1.3 The 10 most important genera of plant parasitic nematodes on a worldwide basis (Sasser and Freckman 1987)

Sl. no.	Important genera	Sl. no.	Important genera
1	*Meloidogyne*	6	*Tylenchulus*
2	*Pratylenchus*	7	*Xiphinema*
3	*Heterodera*	8	*Radopholus*
4	*Ditylenchus*	9	*Rotylenchulus*
5	*Globodera*	10	*Helicotylenchus*

Table 1.4 Estimated annual yield losses due to damage by plant parasitic nematodes on a worldwide basis (Sasser and Freckman 1987)

Life-sustaining crops	Loss (%)	Economically important crops	Loss (%)
Banana	19.7	Cocoa	10.5
Barley	6.3	Citrus	14.2
Cassava	8.4	Coffee	15.0
Chickpea	13.7	Cotton	10.7
Coconut	17.1	Cowpea	15.1
Corn	10.2	Eggplant	16.9
Field bean	10.9	Forages	8.2
Millet	11.8	Grapes	12.5
Oat	4.2	Guava	10.8
Peanut	12.0	Melons	13.8
Pigeon pea	13.2	Misc. other	17.3
Potato	12.2	Okra	20.4
Rice	10.0	Ornamentals	11.1
Rye	3.3	Papaya	15.1
Sorghum	6.9	Pepper	12.2
Soybean	10.6	Pineapple	14.9
Sugar beet	10.9	Tea	8.2
Sugarcane	15.3	Tobacco	14.7
Sweet potato	10.2	Tomato	20.6
Wheat	7.0	Yam	17.7
Average	10.7%	Average	14.0%
Overall average—12.3%			

estimated annual yield loss of 10.7% is reported. For the 20 crops (right-hand column) that represent a miscellaneous group important for food or export value, an estimated annual yield loss of 14% is reported (Sasser and Freckman 1987).

Based on 1984 production figures and prices, the nematodes were responsible for monetary crop losses to the extent of US$ 77 billion annually on 21 crops, 15 of which are life sustaining. These figures are staggering, and the real figure, when all crops are considered, probably exceeds US$ 100 billion annually. The losses are 5.8% greater in developing countries than in developed countries (Sasser and Freckman 1987).

Abad et al. (2008) reported that the crop losses caused by phytonematodes in economic terms were estimated to be US$ 157 billion annually to the world agriculture.

1.3.2 Indian Scenario

The avoidable yield losses due to plant parasitic nematodes in horticultural crops are presented in Table 1.5.

In India, the crop losses caused by phytonematodes were estimated at about ₹2100 million annually (Jain et al. 2007).

A critical analysis of crop losses caused by major nematodes to various crop plants in India was made by the different centers (located throughout India) of All India Coordinated Project on Nematodes (Walia and Chakraborty 2018). Overall, plant parasitic nematodes cause 21.3% crop losses amounting to ₹102039.79 million (US$ 1577 million) annually (Table 1.6). The losses in 19 horticultural crops were assessed at ₹50224.98 million, while for 11 field crops, it was estimated at ₹51814.81 million. Rice root-knot nematode *Meloidogyne graminicola* was economically most important causing yield loss of ₹23272.32 million in rice. Citrus (₹9828.22 million) and banana (₹9710.46 million) among fruit crops and tomato (₹6035.2 million), brinjal (₹3499.12 million), and okra (₹2480.86 million) among the vegetable crops suffered comparatively more losses. The details of crop losses incited by major nematodes in different crops are provided in Table 1.6.

1.4 Emerging Nematode Problems

The changing cropping patterns, introduction of new crops, crop diversification, agronomic practices, etc. also change the spectrum of pests and pathogens, including plant parasitic nematodes. For example, the adoption of water-saving techniques like System of Rice Intensification (SRI) in rice and drip irrigation in horticultural crops; diversification toward horticultural crops, particularly protected cultivation systems; and widespread and unchecked movement of planting materials from horticultural nurseries have led to the emergence of new nematode problems in newer areas and intensification of existing nematode problems. Adoption of the intensive cropping systems led to the emergence of a number of new nematode problems.

Some of the emerging nematode problems due to introduction of new nematode pests under globalization of agricultural produce, impact of climate change, threat to lack of management strategy in standing crops, etc. include root-knot nematode problem on rice, pomegranate, guava, and vegetables and flowers grown under protected cultivation, cyst nematodes problem on potato, and many others.

Table 1.5 Avoidable yield losses in horticultural crops due to plant parasitic nematodes in India

Crop	Nematode(s)	Yield loss (%)	Reference(s)
Banana	*Radopholus similis*	38.00	Rajagopalan and Naganathan (1977b)
		32.00	Parvatha Reddy et al. (1996)
		41.00	Nair (1979)
	Meloidogyne incognita	30.90	Jonathan and Rajendran (2000)
Sweet orange	*Tylenchulus semipenetrens*	69.00	Baghel and Bhatti (1983a)
Lemon	*T. semipenetrans*	29.00	Mukhopadhyaya and Suryanarayana (1969)
Sweet lime	*T. semipenetrans*	19.00	Mukhopadhyaya and Dalal (1971)
Grapevine	*M. incognita*	55.00	Rajagopalan and Naganathan (1977a)
	M. javanica	53.00	Baghel and Bhatti (1983b)
Papaya	*Rotylenchulus reniformis*	28.00	Rajendran and Naganathan (1981)
Pomegranate	*Meloidogyne* sp.	24.64–27.45	Singh et al. (2003)
Peach	*Mesocriconema xenoplax*	33.00	Anon (1990a)
Plum	*M. xenoplax*	10.00	Anon (1990a)
Potato	*M. incognita*	42.50	Prasad (1989)
	Globodera rostochiensis	99.50	Prasad (1989)
Tomato	*M. incognita*	30.57–46.92	Bhatti and Jain (1977) Reddy (1981) Darekar and Mahse (1988)
	M. javanica	77.50	Anon (1993a, b)
	R. reniformis	42.25–49.02	Subramanyam et al. (1990)
Brinjal	*M. incognita*	27.30–48.55	Bhatti and Jain (1977) Parvatha Reddy and Singh (1981) Darekar and Mahse (1988)
Chili	*Meloidogyne* sp.	24.54–28.00	Singh et al. (2003)
Okra	*M. incognita*	90.90 28.08	Bhatti and Jain (1977) Parvatha Reddy and Singh (1981)
	M. javanica	20.20–41.20	Jain et al. (1986)
French bean	*M. incognita*	19.38–43.48	Das (1994) Parvatha Reddy and Singh (1981)

(continued)

Table 1.5 (continued)

Crop	Nematode(s)	Yield loss (%)	Reference(s)
	M. javanica	30–40	Sharma et al. (2002)
Cowpea	*M. incognita*	28.60	Parvatha Reddy and Singh (1981)
	R. reniformis	13.20–32.00	Palanisamy and Sivakumar (1981) Hasan and Jain (1998)
Peas	*M. incognita*	20.0–50.61	Parvatha Reddy (1985) Upadhyay and Dwivedi (1987) Sharma (1989)
	R. reniformis	15.8	Dalal and Vats (1998)
Carrot	*M. incognita*	56.64	Devi (1993)
Bitter gourd	*M. incognita*	36.72	Darekar and Mahse (1988)
Pointed gourd	*M. incognita*	30–40	Verma (2001)
Water melon	*M. incognita*	18–33	Hasan and Jain (1998)
Mushroom	*Ahelenchoides sacchari*	40.6–100.0	Singh et al. (2003)
	A. composticola	35–60	Laqman Khan (2001)
	A. avenae	25.8–53.5	Bajaj and Jain (2001)
Crossandra	*M. incognita*	21.64	Khan and Parvatha Reddy (1994)
Tuberose	*M. incognita*	13.78	Khan and Parvatha Reddy (1994)
Patchouli	*M. incognita*	47.00	Prasad and Reddy (1984)
Davana	*M. incognita*	50	Haseeb and Pandey (1989)
Lemon grass	*M. incognita*	20	Pandey (1994)
Carnation	*M. incognita*	27	Nagesh and Parvatha Reddy (2000)
Gerbera	*M. incognita*	31	Nagesh and Parvatha Reddy (2000)
Coleus forskohlii	*M. incognita*	70.2	Senthamarai et al. (2006)
Chethikoduveli (*Plumbago rosea*)	*M. incognita*	29.00–43.96	Santhosh Kumar and Sheela (2004)
Kacholam (*Kaempferia galanga*)	*M. incognita*	18–64	Sheela and Rajani (1998)
Colocasia	*M. incognita*	24	Anon (1990b)
Menthol mint	*M. incognita*	30	Pandey (2003)
Cardamom	*M. incognita*	32–47	Ali (1986)
Betel vine	*M. incognita*	21.1–38	Saikia (1992) Jonathan et al. (1990)
Ginger	*M. incognita*	29.60–33.35 74.10 46.40	Ramana et al. (1998) Koshy (2002) Charles and Kurian (1979)
	R. similis	39–73	Sundararaju et al. (1979)

(continued)