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RESEARCH ARTICLE

A TAXONOMIC REVIEW OF ROOT-KNOT NEMATODE, *MELOIDOGYNE* SPECIES

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ABSTRACT

Root-knot nematode, *Meloidogyne* is one of the most devastating nematode pests of crops with its more than 5500 host crops. This a polyphagus nematode pest distributed all over the tropical, subtropical as well as temperate regions of the globe. As more the number of species is pouring down under this genus *Meloidogyne,* proper identification is very much essential for its management either through conventional or biotechnological way. The nematode was described under different genus time to time by various authors. This article tries to compile the available literatures on the taxonomic categorization of this important nematode pest in order to reduce the confusion on its nomenclature.

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INTRODUCTION

Plant parasitic nematodes are highly diversified, ubiquitous group of invertebrates that dwell in all possible types and kinds of climatic conditions and habitats. Though the science of nematology is considered to be very young, year 1870 has been fixed as the 'beginning of recent nematology' (Chitwood and Chitwood, 1974; Thorne, 1961), these tiny creatures are realized as great menace in successful cultivation of crops. Plant parasitic nematodes are responsible for 12.3 per cent average annual loss of the worlds' major crops. Their threat being more severe in underdeveloped and developing countries with warm and humid climate than developed countries that lie in the temperate zones. It is evident from the fact that an average loss of 14.6 per cent was estimated due to plant parasitic nematodes in developing countries as compared to 8.8 per cent in developed countries (Sasser and Freckman, 1987). In India, the loss on crops due to plant parasitic nematodes goes up to 10 per cent (Dasgupta, 1998). Root-knot nematodes (genus: *Meloidogyne*; *melon* (gk)- apple/gourd, *oides*: resembling, and *gyne*: female) belonging to the family Meloidogynidae (order : Tylenchida) are polyphagus, sedentary endoparasite of more than 5500 wild and cultivated plants, which includes 226 weed species (Trudgill and Block, 2001; Hussey and Janssen, 2002; Rich *et al.,* 2008). However, vegetable crops are mostly preferred by these nematodes.

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They are widely distributed over tropical, sub tropical and temperate regions of the world. The second stage infective juveniles of these nematodes penetrate into the roots at the zone of elongation, establish feeding sites at the phloem by typical modification of cells (giant cells) and derive nutrients from their hosts. Their infestation lead to hypertrophy and hyperplasia of the cells and produces 'galls' on plant root, which are commonly known as 'root-knot'. The characteristics 'knots' produced by these nematodes give identity to call them as 'root-knot nematode'. Their parasitism on root results in some non specific above ground symptoms on infected plants like, yellowing of leaves, lack of plant vigour, stunted growth and wilting under water stress. The most specific symptom is produced on root, the 'knots', which can easily be seen by gently pulling the plant. Root-knot nematodes (*Meloidogyne* spp.) are ranked as one of the world's top five pathogens affecting world's food production. Presence of one second stage juvenile of these nematodes per gram soil can cause economic damage to the crops.

The economic importance of this nematode genus can be judged from the yield losses caused by this nematode to cereals, vegetables and plantation crops. It has been reported that rice root-knot nematode, *M. graminicola* accounts for yield losses ranging from 17.7 to 33.3 per cent on different rice cultivars in India. In Haryana, India, root-knot nematode, *M. incognita* is responsible for 90.9, 46.2 and 27.3 per cent yield loss of okra, tomato and brinjal, respectively (Bhatti and Jain, 1977).

An compilation of reports of All India Coordinated Research Project on Plant Parasitic Nematodes with Integrated Approaches for their Control revealed that infestation of root-knot nematodes are responsible for 11-35, 10-29, 8-23, 10-42, 21-23, 17, 13-14, 6-18 and 13 per cent yield losses of tomato, okra, chilli, brinjal, bottlegourd, snakegourd, bittergourd, cucumber and pumpkin, respectively in different parts of India (Annon, 2012). Among pulses, chickpea, blackgram and mungbean suffered yield loss of 19-22, 17-23 and 14-29 per cent in India (Anon, 2012) due to root-knot nematodes.

Besides their direct effect on production and productivity of crops, these nematodes involves in interaction with other soil borne pathogens to cause serious damage to the crops, particularly to the vegetables. In majority of cases, they act as a predisposing factor for other soil borne pathogens. Many fungi mainly, *Fusarium, Rhizoctonia, Sclerotium, Pythium, Phytophthora, Macrophomina* etc. commonly interact with root-knot nematode in the rhizospheric zone of vegetable crops, pulses, ginger, cardamom, beetlevine, banana, jute, cotton etc. These nematodes also associate with wilt causing bacteria, *Ralstonia solaraciarum* and increase the intensity of disease in tomato, brinjal and potato. Many viruses like tobacco ring spot virus, tobacco mosaic virus, tomato leaf curl virus produces early symptoms in presence of root-knot nematodes. Another important effect of root-knot nematode is the breakdown of resistance. A variety resistant to other fungal or bacterial pathogen breaks its resistance if they are infected with root-knot nematode. They are also reported to show synergistic interaction with *Stomopteryx nertaria* in mungbean (Prasad *et al.,* 1971), *Tyrophagus putrescentiae* in tuberose (Ganguly *et al.,* 1993) to do severe damage to these crops.

The first account of the root-knot nematode was made by Miles Joseph Berkeley, an eminent Victorian scientist, in 1855, when he noticed galls along with eggs and nematodes in roots of cucumber grown under green houses of Nuneham, England. He observed that there was enormous development of the vascular tissues of the root and in the gall structures several *Vibrios* lived freely and inside the eggs. In 1875, Licopoli recoded small nematodes within the tubercles on the roots of *Sempervivum tectorum* and in some Crassulaceae in Italy. After three years, Jobert (1878) reported root-knot (galls along with eggs) on coffee roots from Rio de Janeiro, Brazil. A Frenchman, Maxime Cornu (1879) first described root-knot nematode as *Anguillula marioni* from the roots of *Onobrychis sativa*. He described the females of this nematode as cyst and speculated a close relationship with *Heterodera schachtii*. In contrary to his speculation, he established its relationship with *Anguillula radicicola* (later on *Subanguina radicicola*). Carl Müllar (1984) transferred *A. radicicola* to *Heterodera radicicola* and synonemized *A. marioni* as *H. radicicola.* Müllar (1884) made a detailed study on the morphology of root-knot nematodes and, for the first time observed and illustrated the perineal pattern of these nematodes. He also worked out the differences between root-knot and cyst nematodes. However, the name proposed by him for root-knot nematode, *Heterodera radicicola* was used for root-knot nematode until 1932. Melchior Treub (1885), a botanist from Denmark reported a new species of root-knot nematode, *H. javanica* from sugarcane in Indonesia. However, Beizerinck (1887) and van Breda de Haan (1900) considered this species as synonym to *H. radicicola*. Emil August Göldi (1887, published in 1892) described and illustrated root-knot nematodes from Coffee in Rio de Geneiro, Brazil as *Meloidogyne exigua*. Göldi was the first to propose the generic name *Meloidogyne* for root-knot nematodes. He published the description with figures of eggs at different stages, different juvenile stages and of matured female of root-knot nematode. In another publication made during 1889, Göldi published some morphological data of different life stages of *M. exigua* and differentiated his genus from *Heterodera.* Unfortunately, his publication was not seriously considered by the nematologists until 1949. Neal (1889) described root-knot nematodes of USA as *Anguillula arenaria*. He comprehensively described and illustrated root-knot nematodes from radish, peach, fig and oranges. In his publication, he critically observed on the presence of spike tail in 3rd and 4th stage juvenile, which got lost during the final moult. He also stated that this disease was known to occur in Florida, USA since 1805. In the same year, Atkinson observed 'giant cells' in root-knot infested roots. He thought that the giant cells were formed due to presence of dead female of *Heterodera radicicola*. He described the life history of this nematode.

Kati Marcinowski (1909), the first women to work on root-knot nematodes, published detail morphological differences between males, females and juveniles of this nematode. In her same publication, she shifted *M. exigua, Heterodera javanica, Anguillula arenaria, A. marioni* and *A. vialae* to *Heterodera radicicola.* In 1919, Kofoid and White described some eggs of Oxyurid nematode from the faeces of man. They reported these eggs as eggs of a new species of nematode *Oxyuris incognita*. But, the dimensions of eggs provided by them did not matched with the dimensions of any nematodes infecting human beings. Observing similar type of eggs in a hookworm campaigns in USA and adjoining areas, Sandground (1923) stated that the eggs reported by Kofoid and White (1919) were of soil nematodes, not of animal parasites. He explained that when beat roots infested by root-knot nematode (*Heterodera radicicola*) were eaten by men, and then these eggs might come out with their faeces. Those eggs might have described by Kofoid and White (1919) as eggs of helminths.

Goodey (1932 a, b) stated that *A. radicicola* belongs to *Subanguina radicicola* and proposed *Heterodera marioni for A. marioni.* This nomenclature (*H. marioni*) was extensively used up to 1949. Chitwood (1949) gave a new dimension in the taxonomic study of root-knot nematodes. On the basis of extensive study on morphology of diverse group of described nematodes, he published 'revision of genus *Meloidogyne* Göldi, 1887'; where he re-erected the genus *Meloidogyne* and distinctly separated it from *Heterodera.* He described *M. hapla* and *M. incognita* var. *acrita*; and redescribed *M. arenaria, M. exigua, M. incognita* and *M. javanica*. He differentiated these species of *Meloidogyne* on the basis of perineal pattern, stylet, shape of stylet knob and distance of dorsal oesophageal gland opening from the stylet base. The publication of Chitwood was regarded as the starting point for the taxonomy of root-knot nematode and considered as benchmark for all subsequent works on this nematode group.

The early described species of root-knot nematodes were morphologically distinct from each other, particularly on perineal pattern. In general, identification and description of *Meloidogyne* species were made primarily on pattern on the perineum and supported by morphological characters of female, male and juvenile. In 1930, Nagakura suggested for using information on biology, host range and morphology of each stages for better describing a species of root-knot nematode. However, Chitwood (1949) emphasised on using morphology of perineal pattern, size and shape of stylet, shape of stylet knobs and dorsal oesophageal gland opening distance from stylet base for describing a species of root-knot nematode. Sesser (1952) proposed a new method for identifying the species described by Chitwood in 1949. The new method was termed as 'host reaction'; which was became popular as 'North Carolina differential host test' in later date. Root-knot nematodes were placed under subfamily Meloidogyninae for the first time by Skarbilovich (1959) under Heteroderidae. He made an effort to distinguish between root-knot nematodes from cyst forming nematodes.

Sasser (1954), Taylor *et al.* (1955), Triantaphyllou and Sasser (1960) strongly emphasised on the importance of perineal pattern for identification of species of root-knot nematode. Eisenback and Hirschmann (1980) and Eisenback *et al.* (1981) gave more weightage on morphological characters of male head for this purpose. Sledge and Golden (1964) proposed a new genus, *Hypsoperine* on the basis of thicker and elevated perineal pattern. He transferred *M. arenaria* to *H. arenaria.* Whitehead (1968) did not consider Hypsoperine and synonemised *Hypsoperine* with *Meloidogyne* and transferred all six species described under this genus to *Meloidogyne.* In the later date, Franklin (1971), Esser *et al.*(1976), Siddiqi (1986, 2000) also considered *Hypsoperine* as Junior synonum of *Meloidogyne*. In 1987, Jepson synonemized *Hypsoperine* and *Sprtonema* with *Meloidogyne*. However, Gaur *et al.* (1996) tried to consider *Hypsoperine* and *Meloidogyne* as two separate genus based on PCR-RFLP study.

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