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Status, pathogenicity of plant parasitic nematode: A review

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Abstract
Review paper is intended to define the occurrence, distribution and economic damage of Plant-Parasitic Nematodes (PPN) with special reference to India. This paper will help to give an overview of the status of Phytoparasitic Nematodes to the researchers working in related areas.

Keywords: integrated pest management, *Meloidogyne*, Nematicides, pathogens, phytoparasitic nematodes and root knot nematode

Introduction

An Overview of Widespread Species of Phytoparasitic Nematodes

1. Pathogenicity and economic damage

Vegetables, fruits and grains are the major constituents of a healthy diet that provides proper nutrition for the population. But from the beginning of agriculture practices pest infestation has been a major problem for farmers. Among the pests, nematodes are a major threat to Agriculturist. Nematode pests cause approximately 12.3% downfall in global food production annually (Sasser and Freckman, 1987) [52]. According to estimation, approximately 157 billion US dollars global loss occurs due to Phytoparasitic Nematodes (Abad *et al.*, 2008) [1]. Jones *et al.*, 2013 [31] reported *Meloidogyne sp.* as the most damage-causing species among all phytoparasitic nematodes. Several other reports also follow the same for different crops. Kumar *et al.*, 2020 [40] reported 21068.73 million rupees loss due to Plant-Parasitic Nematodes (PPN) in 24 different crops. Plant-parasitic nematodes exhibit great diversity.

Diversity of root-lesion nematode (RLN) and Root Knot Nematode (RKN) in potato were studied by Esteves *et al.*, 2015 [19], *Pratylenchus penetrans* (Cobb) *Pratylenchus neglectus* (Rensch), *Pratylenchus crenatus* Loof and *Pratylenchus thornei* Sher & Allen from Portugal. Hussain *et al.*, 2016 [25] assessed the reproduction of *Meloidogyne incognita* (Kofoid & White) on twelve okra cultivars and the maximum egg mass was found on Sharmeeli (177.8) whereas the minimum was in Sanam (20.2). Kumar *et al.*, 2020 [40] estimated varied percent damage in fruit crops (25.5%), vegetables (19.6%), spices (23.03%), cereal crops (18.8%), pulse crops (23%) and oilseed crops (30%). Kang *et al.*, 2021 [32] collected 943 soil samples from soybean to investigate the distribution and population density of two *Heterodera* (Schmidt) species *i. e. H. sojae* and *H. glycines*. Among the 343 samples, *H. glycines* were seen in 227 samples (66.2%), *H. sojae* in 95 samples (27.7%), and 21 samples (6.1%) were affected with both *H. sojae* and *H. glycines*.

2. Distribution

Sakhuja *et al.*, 1985 [51] surveyed five major groundnut growing districts of Punjab and screened out RKN species, *Tylenchorhynchus vulgaris* Upadhyay *Aphelenchus avenae* Bastian, and *Siddiqia citri* on this crop. Other important nematodes spotted by them were *P. thornei*, *Pratylenchus zeae* Graham, *Hoplolaimus indicus* Sher, *Aphelenchoides aster*. Ocaudatus, *Helicotylenchus elegans* Roman, *Hemicycliophora punensis* (Darekar & Khan), *Macroposthonia xenoplax* (Raski) and *Xiphinema insigne* Loos. The occurrence of *Criconemella*, *Helicotylenchus*, *Meloidogyne*, *Pratylenchus* and *Tylenchorhynchus* were observed by Schmitt *et al.*, in 1988 [53]. Amarantha and Krishnappa 1990 [5] mentioned the presence of *Rotylenchulus reniformis* Linford & Oliveira, *M. incognita*, *A. avenae*, *Helicotylenchus multicinctus* (Cobb) Golden. *Tylenchorhynchus dubius* (Buetschli), and *Aphelenchoides* genera from the root samples. Kashaija *et al.*, 1994 notified *Pratylenchus goodeyi* Sher & Allen *H. multicinctus*, *Radopholus similis* (Cobb) and *Meloidogyne* from banana Euganda. Sharma and Trivedi 1994 [54] notified *Heterodera*, *Helicotylenchus*, *Hoplolaimus*, *pratylenchus*, *Xiphinema*, *Meloidogyne*, *Tylenchorhynchus*, *Rotylenchus* and *Saprozoic* from Jaipur. Parvatha *et al.*, 1996 [44] confirmed the crop loss in Banana due to *R. similis* which cause extensive root necrosis resulting in serious economic consequence. Koenning *et al.*, 1999 Koenning *et al.*, 1999 surveyed on various crops and listed the presence of *Heterodera*, *Haplolaimus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchulus* and *Xiphinema*. Araya *et al.*, 2002 [9] detected *R. similis*, *Helicotylenchus sp.*, *Meloidogyne sp.*, and *Pratylenchus* in banana plantations from Costa Rica, Abidou *et al.*, 2005 found out the occurrence and described the distribution of species of the *Heterodera* avenae Wollenweber in Syria and Turkey. Hallmann *et al.*, 2007 [24] illustrated the data about the economic importance of plant-parasitic nematodes in organic farming in Germany and pointed out the presence of *Pratylenchus* and *Tylenchorchynchus* in vegetables and cereals crops. Mahajan and Chhabra 2009 [41] marked forty-seven plant nematode species associated with 33 crops from Punjab. Out of this *M. incognita*, *Meloidogyne arenaria* (Neal) *P. zeae*, *Tylenchorchynchus brassicae* Siddiqi *Tylenchulus semipenetrans* (Cobb,) *R. reniformis*, *Xiphinema americanum* Cobb, *H. avenae* and *Heterodera* Zeae (Koshy) were reported causative agents of extensive damage. Rajesh

et al., 2009 [46] reported the presence of *Meloidogyne*, *Pratylenchus*, *Radopholus*, *Trichodorus*, *Rotylenchus*, and *Rotylenchulus* species from sugarcane in Uttar Pradesh. Singh *et al.*, 2009 [57] identified the distribution pattern of PPN infesting Sunflower and they revealed the presence of *R. reniformis* followed by *M. incognita*, *H. indicus*, *Tylenchorhynchus nudus* Allen, *Tylenchorhynchus vulgaris*, *Helicotylenchus elegans* and *Helicotylenchus aquali.* Rathour *et al.*, 2010 [48] also observed the *R. reniformis* and *Helicotylenchus dihystera* (Cobb) while surveying in Madhya Pradesh. Khan *et al.*, 2010 [35] reported *Pratylenchus*, *Meloidogyne*, *Helicotylenchus*, *Tylenchorhynchus*, *Hoplolaimus*, *Rotylenchulus*, *Hirschmanniella*, *Criconemoides* as significant nematode genera infecting the banana. Anes and Gupta 2014 [7] surveyed to study the distribution of PPN in the Soybean growing areas of India and came across the existence of *Helicotylenchus sp*., *Rotylenchulus sp*., *Pratylenchus sp*., *Hoplolaimus sp*., *Tylenchorhynchus sp*., *Heterodera sp*., *R. reniformis*, *Hirschmanniella sp*., *Meloidogyne sp*. and *Trichodorus sp*. Gasti *et al.*, 2016 [21] identified the diversity of PPN in the rhizosphere of the mango and guava at the Indian Agriculture Research Institute farm. The study revealed the presence of *Helicotylenchus indicus* Sher *Hemicriconemoides strictathecatus* Esser, *R. reniformis*, *Hoplolaimus indicus* Sher, *Mesocriconema sphaerocephala* (Taylor) *Tylenchorhynchus mashhoodi* Siddiqi and *T. semipenetrans* (Cobb). Singh *et al.*, 2018 [56] reported the incidence and population density of PPN in vegetable crops and associated yield losses in eastern Uttar Pradesh. The most abundant PPN species detected, in order of decreasing frequency of infestation, were *M. incognita*, *R. reniformis*, *H. indicus*, *T. indicus*, *T. brassicae*, *Pratylenchus sp*., *Helicotylenchus sp*., *Xiphenema sp.* and *Longidorous sp*. whereas yield losses ranged from 4% to 30.2% depending upon the host and nematode. Arun *et al*., 2019 [10] identified the occurrence and distribution of (PPN) in cabbage growing regions of Tamil Nadu and a survey revealed that *M. incognita*, *P. penetrans*, *Hoplolaimus dihystera*, *H. indicus*, *X. americanum* and *Tylenchus filiformis.* Butschli, were encountered in the samples and *M. incognita* was the most dominant species. Ashmit *et al.*, 2021 [11] determined the presence of PPN in sugarbeet fields of North Dakota and Minnesota and found *Paratylenchus* and *Tylenchorhynchus* were widely distributed.

Looking for the present scenario of distribution and damage caused by various PPN species especially by *Meloidogyne sp*. we formulated this review article which focuses on gathering information present about the current status of *Meloidogyne sp*. and their control measures.

Status of *Meloidogyne* Species

1. Occurrence

Several authors explored the occurrence of various species of *Meloidogyne* from different geographical areas in different crops. Golden and Birchfield 1968 [23] reported rice RKN *Meloidogyne graminicola* as a new pest of rice from Laos. This was followed by several other reports for its association with rice in many countries. In 1975 [13] Brathwaite *et al.*, revealed a survey of (PPN) and observed the presence of *Reniform* nematodes, *Rotylenchulus sp.* on vegetable crops, *R. similis* on banana, *Pratylenchus brachyurus* (Godfrey) and *H. dihystera* on sugarcane, and cabbage and root-knot *Meloidogyne sp.* on all crops. Ali and Koshy 1982 reported the presence of RKN in cardamom plantations of Kerala and yield loss (39.7%), delayed fruit ripening and low fruit in tomato by *M. incognita* had been reported by Reddy 1985 [50]. Singh *et al.*, 2015 [55] determined the PPN population densities from vegetables and revealed the maximum loss was 43% in eggplant, 40% in tomato, 38% in okra, 35% in bottle gourd and 32% in potato. Ramana *et al.*, 1987 [47] reported the fourteen genera of PPN in which *M. incognita*, was reported in the highest frequency. Davide 1988 [15] has described the nematodes as a major pest of banana, pineapple, citrus, tomato, ramie and sugarcane and found *Meloidogyne sp.* were the major destructive nematode for tomato, okra, celery and fiber crops. They also observed the occurrence of ramie and *Radhopholus similis* (Cobb) in banana. Khan *et al.*, 1990 [34] during observation in vegetable crops also noticed the presence of *M. incognita*. Fourie *et al.*, 2001 [20] observed the abundance of RKN *M. incognita*, *Meloidogyne javanica* (Treub), *Meloidogyne hapla* Chitwood, *Meloidogyne ethiopica* Whitehead, Lesion nematode, *P. zeae* and *P. Brachyurus*. Agu 2004 [2] found *M. incognita* for reducing shoot growth, shoot-to-tuber ratio, days to maturity and tuber yields of sweet potato. The first report of *M. graminicola* infecting rice crop in Jammu was identified by Singh *et al.*, 2007 [59]. Prasad *et al.*, 2008 [45] calculated 18-40% yield loss in the same crop. In 2008 Kumar *et al.*, identified the *M. incognita*, *M. javanica* & *M. arenaria* from Haryana Similarly Hallman *et al.*, 2007 [24] reported the *M. incognita* as a predominant plant-parasitic nematode from Kenya. Devran *et al.*, 2009 [18] identified the *M. incognita*, *M. javanica* and *M. arenaria*, as the prominent RKN species from Turkey. Moens *et al.*, 2009 [42] reported *M. arenaria*, *M. incognita* and *M. javanica* from USA. Ali 2009 [4] observed *M. incognita* and *M. javanica* in chickpea fields from Rajasthan. Rathour *et al.*, 2010 [48] conducted their study in vegetable, cereal, oil-seed and fruit crops and found the presence of *M. incognita*, *M. javanica* and few other species of phytoparasitic nematodes. Singh *et al.*, 2010 [58] noticed infestation of *M. graminicola* in Wheat whereas Wesemael *et al.*, 2011 [60] found *Meloidogyne hapla*, *Meloidogyne naasi* Franklin, *Meloidogyne chitwoodi* Golden, *Meloidogyne fallax* Karssen, *M. arenaria*, *M. javanica* and *M. incognita* prevalency from Europe. Anamika *et al.*,2011 [6] reported the highest frequency of *M. incognita* on vegetable crops from Uttar Pradesh and Madhya Pradesh. Anwar *et al.*, 2012 [8] run a survey in Punjab and found okra as the most susceptible crop for *M. incognita*. Anwar and Mckenry 2012 [8] conducted a survey in 16 major vegetable production areas of Punjab and found *M. incognita* & *M. javanica* predominantly in carrot, cucumber, eggplant, lettuce, okra, pea, pumpkin, etc. Toumi *et al.*, 2014 observed the infestation of *M. javanica* and *M. incognita* in tomatoes from Syria. Karuri *et al.*, 2017 reported *M. incognita* is the most prevalent species in the Kenyan sweet potato field. Ravindra *et al.*, 2017 [49] examined the interactions between *M. graminnicola* and weeds of rice agroecosystem in Karnataka. The weeds of Poaceae are classified as good hosts whereas other weeds are poor hosts. Janati *et al.*, 2018 [29] determined the occurrence of *M. javanica* and *M. incognita* in vegetable crops from Morocco. Ahamed *et al.*, 2018 also recorded yield loss in rice crops in different districts of Uttar Pradesh. Montasser *et al.*, 2019 reported the susceptibility of tomato to *M. incognita*. Jagdev *et al.*, 2019 [28] observed *M.*

incognita incidence on fig from Aurangabad and Pune. Chandrakala 2020 [14] identified the presence of *Meloidogyne* species from Telangana. Similarly, Kumar *et al.,* 2020 [40] found *M. incognita* from Haryana and declared it the most infecting parasite in cotton. These all observations revealed the prominence of *Meloidogyne* species in various crops.

2. Infestation intensity

The various reports also support the fact that various species of *Meloidogyne* exhibit varied intensities. Anwar *et al.,* 2012 [8] estimated the percentage of *Meloidogyne* infestation i.e. *M. incognita* (90%), *P. penetrans* (30.2%), *Tylenchorhynchus clarus* Allen (29%), *Hoplolaimus columbus* Sher, (15%), *Paratrichodorus minor* (Colbran,) (7.5%), *X. americanum* (7.1%), *M. javanica* (7%), *Belonolaimus longicaudatus* Rau, 1958 (5.6%), *Longidorus africanus* Merny (5%), and *H. dihystera* (3.2%). In Chattisgarh Gautam *et al.,* 2014 [22] reported the frequency of *M. incognita* (63.33%), *M. arenaria* (20%) & *M. Javanica* (16.67%). Mahalik *et al.,* 2017 found *M. incognita* (359.7 /200cc) from Odisha. Singh *et al.,* 2015 determined the most abundancy of *M. incognita* (82.16%), *M. javanica* (68.42), *R. reniformis* (43.98%), *Xiphinema basiri* Siddiqi (23.45%), *H. indicus* (21.99%), *Tylenchorhynchus. nudus* Allen (16.60%), *P. zeae* (15.77%), *H. avenae* (7.88%), *Aglenchus costatus* (7.47%), *T. mashoodi* (6.64%), *A. avenae* (5.39%), *Discolaimus* Cobb, (4.15%), *Boleodorus similis* (3.32%), and *Tylenchus* (2.07%) from western Uttar Pradesh.

3. Estimated Loss

Several authors also quantified the loss that occurs due to *Meloidogyne* in various Agri produces. They cause severe loss in cereals, fruits and vegetable crops worldwide. In 1977 [12] Bhatti *et al.,* estimated the yield loss in 91% under okra, 46% in tomato and 27% in brinjal by *M. incognita* and it is also estimated by krishnaappa 1981 in brinjal and reported 44.87 percent yield loss alone in a heavily infested field. Paruthi and Gupta 1985 observed a significant reduction in growth characters and no. of galls and egg masses over control was observed in Bottle gourd by *M. javanica*. Jain *et al.,* 1994 [26] in tomato (71.9%) by *M. incognita* and 47.3% in Tomato, 41.8% in Brinjal and 29.9% in Okra due to *M. javanica*. Devappa *et al.,* 1998 [7] did the estimation of avoidable losses in yield due to root-knot nematode *M. incognita* in (16.44%). Jonathan *et al.,* 2000 assessed the yield loss in banana due to *M. incognita* (30.9%) and also observed the significant reduction in plant height, Pseudostem girth, no. of leaves, leaf area, carbohydrates, non-reducing sugars, total soluble solids & ascorbic acid. Khan *et al.,* 2000 [40] reported maximum yield loss in eggplant, cucumber, okra, tomato, pepper and lowest with cabbage and cauliflower while surveying four species *M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla.* There are more than 4100 species of plant-parasitic nematode (Decraemer and Hunt, 2006) which are major constraints to global food security. Main Phytoparasitic Nematodes affected crops are tomato (27.21%), brinjal (16.67%), chickpea (18.30%), chilli (12.85%), okra (14.10), cowpea (27.30%), cucurbits (18.20%), groundnut (21.60%), jute (21.35%), pomegranate (17.30%) etc. (Jain *et al.,* 2007) [27]. He reported *Meloidogyne sp.* is responsible for great loss in crop production. Ali 2009 [4] estimated the unavoidable yield losses to the tune of 25.6% in chickpea and 15% each in pea and lentils due to *M. javanica*. Singh *et al.,* 2015 [55] determined the plant-parasitic nematode population densities from vegetables and revealed the maximum loss of 43% in eggplant, 40% in tomato, 38% in okra, 35% in bottle gourd and 32% in potato.

In all of the above studies, we can say that *Meloidogyne* causes a major loss in agriculture production. Hence *M. incognita* was voted at the top of the list among all the nematodes. This study was also cited by several reports from time to time.

Conclusion

These all observations revealed that the Plant Parasitic Nematodes pathogenicity is correlated with plant species. The various reports also support the fact that various species of *Meloidogyne* exhibits varied intensity. The status of (PPN) with special reference to India was intensively reviewed in the present document. *Meloidogyne sp*. seems to be the most destructive species.

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