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Nematode Problems in Millets and Their Management

Chandramani D. Waghmare, Anju Kamra, Rashid Pervez and Pankaj
Division of Nematology, ICAR-Indian Agricultural Research Institute, New Delhi-110012

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Millets are significant warm-weather grain crops. With the exception of sorghum and pearl millet, which are considered as minor millets, there is little information available on nematodes of most millets crops. These minor millets are grown primarily as dry land crops for grain and feed. After rice, wheat, and maize, millets are the fourth most popular crop in India. Sorghum, pearl millet, finger millet, kodo millet, little millet, foxtail millet, barnyard millet, and proso millet are all part of the group of eight grains known as millets. They are designated as "nutri cereals" because they are 3-5 times more nutritious than rice and wheat in terms of protein, minerals, and vitamins. They are grown in a number of agro-ecological contexts, including plains, the coast, and hills, as well as in a range of soil types and varying rainfall. Plant-parasitic nematodes (PPN) are widespread in areas of the world where millet is produced. According to a global study of agricultural losses caused by nematodes, the annual productivity loss in millet is estimated to be 11.8% (Seshadri, 1970 and Bridge, 1978). There have been reports of *Heterodera delvi, H. avenae, H. gambiensis, H. zeae, Rotylenchulus reniformis, Meloidogyne incognita, M. javanica, M. arenaria, M. graminicola, M. acronea, Aphelenchoides besseyii, Helicotylenchus abunnamai, H. dihystera Tylenchorhynchus vulgaris, T. mashhoodi, Pratylenchus penetrans, P. brachyurus, P. zeae, P. indicus, Macroposthonia ornate, Criconemoides ornatus, Criconemella ornate, Hoplolaimus indicus, Caloosia exilis, Hemicriconemoides cocophilus, Hirschmanniella oryzae, Hemicycliophora* sp. and *Trichodorus* sp. being connected to small millet crops, but there is very little knowledge about their prevalence, distribution/ frequencies, biology, interactions with other plant pathogens, and management considerations.

Despite the fact that small millets have a number of nematode pests, some of which are economically significant, little research has been done on the plant parasitic nematodes that impact these crops. These include cyst nematodes, reniform nematodes, foliar nematodes, spiral nematodes, root knot nematodes, lesion nematodes, ring nematodes, and stunt nematodes are significant. The general symptoms include

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stunting, thin stands, premature wilting under mild heat or water stress, and nutrient deficiency symptoms like yellowing. Areas of stunted growth, yield reduction, and other above-ground signs of nematode damage differ based on distribution of the nematodes in the field and their density.

The current article summarizes on nematode species infecting millet crops and their management.

Nematode pests of Sorghum (*Sorghum bicolor*)

Sorghum (*Sorghum bicolor*) is a valuable forage crop and a commercially significant food in rain fed agriculture. Among the plant parasitic nematodes, the most significant nematode species are *Heterodera sorghi* (Sorghum cyst nematode), *Tylenchorhynchus* (stunt nematode), *Meloidogyne* (root knot), and *Pratylenchus* (lesion nematode). *Meloidogyne incognita, M. javanica, M. arenaria, M. acronea,* and *M. graminicola* are the five root knot species that have been identified in small millets.

Stubby root nematodes (*Paratrichodorus* spp.), lesion nematodes (*Pratylenchus* spp.), and ring nematodes (*Criconemella* spp.) also parasitise Sorghum. Unless the crop has been monocultured for a number of years, damage from these nematodes to sorghum is not serious. Many common nematode pests of sorghum affect both millet and field maize. One or more of the following may indicate that Sorghum has nematode issues now or in the future 1) The previous cropping history i.e. production of sorghum or other grass crops 2) Presence of below-ground symptoms like small knots on roots or stunted and swollen root tips. 3) Above-ground symptoms like off-color and/or stunted sorghum in small patches or large sections of a field.

Sorghum cyst nematode (*Heterodera sorghi*):

This nematode appears to be potentially significant for cereals and millets produced in the Kharif and Rabi seasons, and it presents a significant risk that it will survive and result in yield losses. The only other type of cyst nematode discovered in association with the sorghum crop is *Heterodera gambiensis*. Other nematodes discovered in association with sorghum include *Helicotylenchus dihystera, Hoplolaimus indicus, Longidorus africans, Paratrichodorus* spp., and *Paratrophurus* spp. However, it is unknown whether these nematodes play a part in limiting crop output.

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Fig. 1 Sorghum cyst nematode (*Heterodera* spp.) on the roots of Sorghum crop

Root-knot nematode (*Meloidogyne* spp):

Meloidogyne incognita is the most prevalent species in India, and root-knot is a significant nematode disease that has been linked to the poor development of the sorghum crop. According to field studies, the nematode makes infected plants stunted and chlorotic. Root proliferations and elongated swellings are produced as a consequence of *M. incognita* infestations.

Fig. 2 Root-knot nematode (*Meloidogyne* spp.) symptoms on grain Sorghum

Lesion nematode (*Pratylenchus* spp):

Among lesion nematodes, *Pratylenchus zeae* and *P. hexincisus* are the two most significant taxa. In tropical regions of the globe, *P. zeae* is thought to be economically significant to the sorghum crop. In highly infested fields with lesion nematodes, the infected plants exhibit stunting and leaf chlorosis. Brown necrotic lesions are visible on the infected roots.

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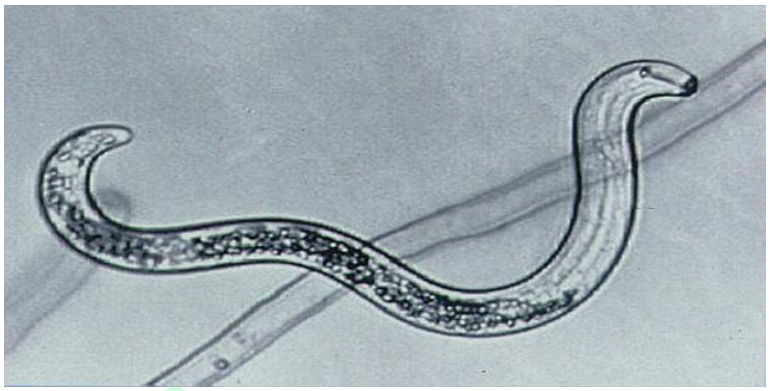

Fig. 3 Lesion nematode (*Pratylenchus* spp) on Sorghum

Stunt nematode (*Tylenchorhynchus* spp)

Sorghum crops have been linked to poor and unthrifty development by several species of stunt nematodes. Although there are several species of this nematode known from different parts of the globe, *Tylenchorhynchus vulgaris* is the one that is most frequently found in sorghum fields in India.

Fig. 4 Stunt nematode (*Tylenchorhynchus* spp) on sorghum

Nematodes of Pearl millet (*Pennisetum glaucum*)

Numerous types of plant parasitic nematodes have been discovered in the rhizosphere of these crops. The root-knot nematode *Meloidogyne incognita*, particularly in the state of Gujarat, creates field problems, especially when it coexists with the fungus *Sclerospora graminicola*. When the fungus and nematode coexist, the disease severity increases by 83 to 96% with decreased plant development. The stunt nematode, *Tylenchorhynchus vulgaris* and the reniform nematode *Rotylenchus reniformis* if prevalent in field soil can reproduce profusely in pearl millet.

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The other nematodes associated with pearl millet in India and other countries include *Belonolaimus longicaudatus*, *Criconemella ornate*, *Helicotylenchus* spp., *Hoplolaimus* spp., *Paratrichodorus minor*, and *Trichodorus* spp.

Fig.5 Ring nematode *Criconemella* spp. in Finger millet

Nematodes of Ragi/ Finger millet (*Eleusine coracana*)

Heterodera delvi, a cyst-forming nematode, was reported in finger millet/African tall millet (*Eleusine coracana*) growing in Karnataka for the first time by Jairajpuri *et al.* (1979). Stunting of plants and patchy leaf yellowing are the primary signs of cyst infection. Even under optimal moisture and nutrient conditions, the affected plants grow slowly. The nematode infected plant roots have cysts embedded in them or affixed to them that are visible with the unaided eye. There are also reports of the reniform nematode *Rotylenchulus reniformis* causing problems in ragi crops in some south Indian regions. The nematode population density is positively correlated with decreased plant height, aerial biomass, root weight, and yield. In addition to *Rotylenchulus* and *Heterodera*.

Fig. 6 Reniform nematode *Rotylenchulus reniformis* in Finger millet

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Besides, finger millet is a good habitat for *Pratylenchus* species (Narayanaswamy and Govindu (1966) from the Indian state of Mysore.

In India, finger millet is also reported to harbor *Helicotylenchus* species in several places in Karnataka (Narayanaswamy and Govindu, 1966), Orissa (Ray and Das, 1989), and all small millet-growing regions of Madhya Pradesh (Shukla *et al*., 1997).

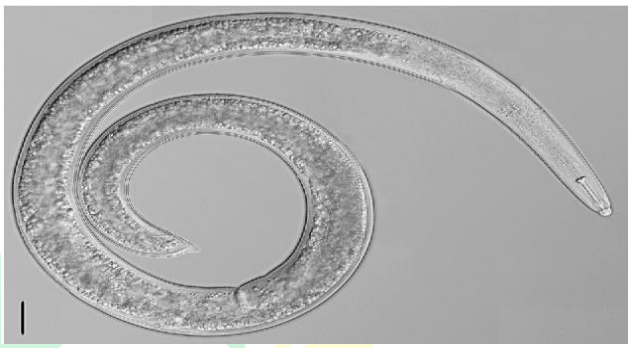

Fig.7 Spiral nematode *Helicotylenchus* spp. in Finger millet

Nematodes of Kodo millets (*Paspalum scrobiculatum*)

Tylenchorhynchus vulgaris and *Meloidogyne incognita* (Kofoid and White) Chitwood have both been identified as novel hosts from Aligarh and Kodo millet, respectively (Alam *et al.*, 1973, Vaishnav and Sethi, 1977).

Nematodes of little millets (*Panicum sumatrense*):

On small millets, nematodes do not pose a significant threat. However, various researchers have reported the presence *Helicotylenchus abunaamai*, *Tylenchorhynchus vulgaris*, *Heterodera delvi*, and root-knot nematode *Meloidogyne incognita* (Narayanaswamy and Govindu, 1966, Vaishnav and Sethi, 1977, Shukla *et al.*, 1997, Padhi and Das, 1982).

Nematodes of Proso millet (*Panicum miliaceum*):

Aphelenchoides besseyi was the nematode that was identified by Gokte *et al.* (1992) from New Delhi.

Fig.8 Foliar nematode *Aphelenchoides* spp. in Proso millet

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Nematodes of Foxtail millet (*Setaria italica*):

According to Endo (1959), *Setaria italica* is a suitable host for *Pratylenchus brachyurus* and *P. zeae*. *P. brachyurus* population substantially increased in cropping systems involving *S. italica* (Good *et al.,* 1973). There were only few species found in the foxtail millet crop: *Pratylenchus, Aphelenchoides, Hoplolaimus*, *Helicotylenchus*, and *Tylenchorynchus*, according to various reports.

Nematodes of Barnyard Millet (*Echinochloa frumentacea*)

Hoplolaimus, the sole nematode genus, was discovered in soil samples collected from a crop of barnyard millet (Shukla *et al.*, 1997). The infectivity, development and reproduction of nematode species are significantly influenced by temperature, soil type, moisture, and tillage practices.

Management Strategies

Cultural practices

Crop rotation

Instead of being the target of a nematode management initiative, sorghum is more likely to be used as a nematode management tool in rotation with other crops to lower numbers of various plant parasitic nematode species. However, if infested with the stubby root and/or lesion root nematodes to which it is susceptible, sorghum should not be used for rotation. For root knot nematodes (*Meloidogyne* spp.) the majority of sorghum varieties are moderate to poor hosts. The nematode *Rotylenchulus reniformis* does not multiply on sorghum. As a result, sorghum is a useful management aid when growing many vegetable crops as well as cotton, peanut and soybean.

Crop rotation is a useful management strategy against various nematodes. Monoculture of the same crop is to be avoided when *Heterodera zeae*, a host-specific nematode, is present. It may be beneficial to rotate non-host crops for two years because this would reduce the nematode population below economic threshold levels. Ploughing in the summer and maintaining weed-free areas can also help to reduce nematode survival and reproduction during the off-season. Additionally, two to three deep ploughings during the hot summer months of April and May significantly lower nematode numbers.

Resistance/Tolerance:

The most efficient and cost-effective control strategy is the use of nematode resistant and tolerant cultivars.

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Soil amendments:

The population of the majority of nematodes can be effectively managed through the use of oil-cakes and other organic soil additives. Field tests using different soil organic amendments have demonstrated that the combination of mustard-cake and tobacco dust is a good farming practice widely used in the country, at a rate of 2.5 q/ha. It is reported to be as effective as carbofuran soil treatment @ 2.0 kg ai/ha in increasing crop yield and controlling nematode populations (Srivastava *et al.*, 1995).

Biocontrol agents

It has some degree of effectiveness. The true possibilities for managing nematodes are yet to be discovered and explored.

Chemical approaches:

In the past, pre-sowing soil application of phenamiphos led to a decrease in cyst (*Heterodera zeae*) production than other chemicals. The potential of carbosulfan seed treatment has proven to be a highly successful method for lowering the overall requirement as well as the expense of chemicals to combat *Heterodera zeae* on maize (Srivastava *et al.*, 1995).

Integrated Approach: -

For controlling Root-Knot Nematode, application of carbofuran (Furadan) (3G) @ 1 kg a.i./ha + *Pseudomonas fluorescens* (Biofor Pf) or *Bacillus* sp./*Trichoderma* sp. @ 20 g/m2 with vermicompost @ 1:10 ratio is effective.

Soil solarization or clear plastic mulching during summer for 5 weeks coupled with carbofuran (Furadan) @ 3kg a.i./hectare or solarization with neem cake/neem oil leads in a considerable improvement of crop and decrease the nematode densities.

Conclusion:

Addressing nematode problems in millets demands a multifaceted strategy for sustainable agriculture in India. The pervasive threat these microscopic pests pose to millet crops necessitates urgent action. Integrated nematode management, incorporating biological controls like fungi and bacteria, cultural practices such as crop rotation, and, when necessary, targeted chemical interventions, offers a comprehensive solution. This approach not only mitigates current nematode challenges but also ensures long-term resilience for millet cultivation. Collaborative efforts among farmers, researchers, and policymakers are vital for disseminating knowledge and promoting the widespread adoption of these strategies. By

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embracing integrated management, we not only safeguard millet yields but also fortify the foundation of India's food security and sustainable agricultural practices. The battle against nematode issues in millets is an integral part of the broader narrative of securing a resilient and bountiful agricultural future

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