

NEMATODE PESTS OF SMALL MILLETS- A REVIEW

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ABSTRACT

Plant parasitic nematodes are one of the limiting factors in crop production throughout the world. *Heterodera delvi*, *H. avanae*, *H. gambiensis*, *H. zae*, *Rotylenchulus reniformis*, *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, *M. graminicola*, *M. acronea*, *Aphelenchoides besseyii*, *Helicotylenchus abunnamai*, *H. dihystra*, *Tylenchorhynchus vulgaris*, *T. mashhoodi*, *Pretylenchus penetrance*, *P. brachyurus*, *P. zae*, *P. indicus*, *Macroposthonia ornate*, *Criconemoides ornatus*, *Criconemella ornate*, *Hoplolaimus indicus*, *Caloosia exilis*, *Hemicriconemoides cocophilus*, *Hirschmanniella oryzae*, *Hemicycliophora sp.* and *Trichodorus sp.* have been reported to be associated with small millet crops, but information is very meager on the occurrence, distribution, biology, interrelationship with other plant pathogens and management aspects. The present paper reviews the work carried out on nematode pests of small millet crops.

Key words: Nematodes pests, Small millets crops.

Small millets comprising finger millet (*Eleusine coracana* L. Gaertn.), kodo millet (*Paspalum scrobiculatum* L.), foxtail millet (*Setaria italica* L.), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa frumentacea* L. Beauv.) and proso millet (*Panicum miliaceum*) are cultivated in almost all the states of India in concentrated pockets. These crops are grown by small and marginal farmers in marginal and degraded soils with little cash input, where crop options are limited. Many of them are of short duration and are able to provide substantial yield in a short period of 60-65 days. Presently these livelihood supporting crops are grown in around 2.6 million hectares of which finger millet alone accounts for about 59 per cent of the area and more than 3/4th production. Utilization of these crops is mainly as food for human consumption, but they also provide good quality fodder for cattle.

Studies on plant parasitic nematodes affecting small millets had received scant attention though a number of nematode pests have been recorded on these crops, some of them are of economic importance. Cyst nematode, reniform nematode, foliar nematode, spiral nematode, root knot nematode, lesion nematode, ring nematode and stunt nematodes are important but no systematic work on occurrence of these plant parasitic nematodes, their frequencies, biology, interrelationship with other plant pathogens and their management was undertaken. Krishanappa *et al.* (1992) reviewed the work on nematode pests of millets. Nematode parasites of finger millet and foxtail millet were studied by Veerbhadra (1992). In the present review, an attempt has been made to review the information gathered in recent past on the nematode pests of small millets.

1. Cyst nematodes, *Heterodera* species

A cyst nematode associated with ragi was reported for the first time during 1972 from Bangalore, India by Setty (1975). However, earlier *Heterodera marioni* was recorded on this host, but it was rather a root gall nematode (Ayyar, 1933 and 1934). Later on Setty *et al.* (1977) studied the various morphological characters viz. lemon shaped cyst, a bullet characters of the vulval cone of the cyst and very strong vulval bridge of cysts. The organism was first reported to be a new species, *Heterodera delvi* by Jairajpuri *et al.* (1979). Subsequently, it was identified as *Heterodera gambiensis*, which was earlier described by Merny and Netscher (1976) who collected it from sorghum and finger millet in Gambia. Krishnaprasad and Krishanappa (1982) and Narayanaswamy *et al.* (1982) recorded this species on finger millet from India. Krishanaprasad *et al.* (1980) studied the reaction of many genotypes of ragi as well as some cereals to ragi cyst nematode, *H. delvi*. Based on the degree of susceptibility finger millet, foxtail millet and *Echinochloa* species were found good host, while *Panicum miliare*, *P. miliaceum* and *Paspalum* species were poor hosts for ragi cyst nematode. Under pot conditions, *Echinochloa frumentacea* has been reported as host, where as *Paspalum scrobiculatum*, *Eleusine coracana* and *Panicum miliare* were reported non-host for *Heterodera avenae* (Gill and Swaroop, 1971). Shukla *et al.* (1997) also reported *Heterodera* species in the vicinity of sawan (barnyard millet) from Madhya Pradesh. Srivastava and Swaroop (1975) studied the reaction of maize cyst nematode, *Heterodera zae* on some graminaceous plants and reported *Setaria italica* as good host, *Panicum* species and *Echinochloa colona* as poor hosts and *Paspalum* species as non-host.

2. Reniform nematode, *Rotylenchulus reniformis*

In a field survey, finger millet was found susceptible to *Rotylenchulus reniformis* and increased population of nematode had positive correlations with the reduction in plant height, top weight, root weight and grain yield in finger millet (Chandrasekharan, 1964a and 1964b). High population of *R. reniformis* was found associated with stunted grassy patches of finger millet (Rajagopal, 1965). Association of *R. reniformis* with ragi and *Rotylenchulus* species with *Setaria italica* from Orissa (Ray and Das, 1989) and *R. reniformis* with barnyard millet from Madhya Pradesh (Shukla *et al.*, 1997) were also reported. Interaction of VAM and biofertilizers with nematode population was studied in Tamil Nadu by Sunderbabu *et al.* (1996) and reported that *Glomus fasciculatum* alone and in combination with biofertilizers reduced the multiplication rate of *R. reniformis*, *Pratylenchus zae* and *Meloidogyne* sp. in finger millet. Rajendran and Cannayane (2000) studied the bioefficacy of biomolecules against *R. reniformis* infesting finger millet Cv. CO 7. Symptoms such as general stunting and brown to black discoloration on roots were observed. Growth parameters such as plant height, number of tillers, number of fingers, earhead weight and straw weight significantly increased in plants treated with *Pseudomonas fluorescens* as seedling root dip (2.5 g /lit. water) for 30 minutes + soil application @ 2.5 kg/ha at 30 days after planting. Soil application of *Trichoderma viride* @ 4 g/m² gave 59.7 and 33.5% suppression of *R. reniformis* population in root and soil, respectively. Krishanappa *et al.* (2002) reported that 4.8% of cropped area of ragi is affected by *R. reniformis* in Karnataka and green manuring is highly effective in reducing the nematode population. Effective control of *R. reniformis* in finger millet by soil application of Phorate 10G followed by Carbofuran 3G @ 1 kg a.i./ha was reported by Jothis and

Sunderbabu (1998). Highest grain yield was reported in VAM (100 g/m²) inoculated plots.

3. Foliar nematode, *Aphelenchoides* species

Foliar nematode, *Aphelenchoides besseyi* was reported on *Setaria italica* from Japan (Yoshii and Yamamoto, 1950) and India (Dave *et al.*, 1979 and Lal and Mathur, 1988). The disease was referred as *Light ear* disease of foxtail millet by Shukla *et al.* (1997). Dave *et al.* (1979) observed the concomitant infection of *A. besseyi* and a fungus *Phoma* species in the panicles of foxtail millet under field conditions causing discolouration in irregular patches. Grain development was not observed in such panicles. Lal and Mathur (1988) studied the morpho-metrics of the species highlighting minor variations between the sexes. Females were relatively smaller in body length (540-730 μ m) than males.

Out of 1919 foxtail millet genotypes screened for their reaction to *A. besseyi*, 22 were identified as resistant sources by Cui *et al.* (1989). The seeds of foxtail millet and proso millet received for quarantine clearance prior to export were found to be infested with *A. besseyi*. The best treatment for eradication of nematodes from both crops was presoaking of seeds in 1% H₂O₂ for 3h followed by hot water treatment at 48°C for 15 minute. Without pre-soaking, complete nematode kill was achieved by exposing the seeds to 50°C for 15 minutes (Gotke and Mathur, 1993). In India, 1138 accessions of foxtail millet collected from several locations of Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu were examined for seed borne nematodes by soaking the seeds in water for 24-28 h at 30°C. Ninety one accessions (8%) were found infected with *A. besseyi* with inoculum level varying from 2 to 36 per seed (Lal and Rajan, 1995). In a survey programme, about 10% seed samples of *S. italica* were found infected with *A. besseyi* in Madhya Pradesh (Shukla *et*

al., 1997). Gotke *et al.* (2001) recorded amphimictic mode of reproduction in the populations of *A. besseyi* collected from *S. italica* and *P. miliaceum*. Association of *Aphelenchoides* species with *E. coracana* was reported from Orissa by Ray and Das (1989).

4. Spiral nematode, *Helicotylenchus* species

In India, natural occurrence of *Helicotylenchus* species was reported in finger millet from several places of Karnataka (Narayanaswamy and Govindu, 1966), Orissa (Ray and Das, 1989) and all small millet growing locations of Madhya Pradesh (Shukla *et al.*, 1997). Maximum multiplication of *Helicotylenchus dihystra* was reported by Rao and Swaroop (1974) on little millet. Padhi and Das (1982) studied the possible hosts of *Helicotylenchus abunaamai* and observed 38 botanical species to be susceptible and favourable hosts. The highest population was recorded in little millet followed by that in rice. Finger millet, proso millet and foxtail millet were also found good hosts for spiral nematode. The feeding habit of *H. abunaamai* was studied on little millet by Padhi and Das (1985). Juveniles and adults were observed feeding ectoparasitically on epidermal cells and also endoparasitically when they had entered inside roots of little millet. Occasionally, adults were observed in a semi-endoparasitic coiled feeding position on little millet roots. Infection sites were swollen with numerous root hairs. Minute brown lesions were also observed at feeding sites and points of entry. Padhi and Das (1986) further reported that *H. abunaamai* took 6-8 days for its embryonic development at the temperature of 25±6.50°C. The life cycle from egg to egg was completed in 32-40 days. Oviposition was observed as a simple and rapid process. The first stage juvenile was formed inside the egg, 4-5 days after egg laying. The first moult took place inside the egg and the second stage juvenile

hatched at 6-8 days after oviposition. Post embryonic development consisted of 3 juvenile stages and the adult with 3 moults. Feeding on host roots by the juveniles was essential for development to subsequent stages.

5. Root Knot nematode, *Meloidogyne* species

Five species of root knot nematode viz. *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, *M. acrona* and *M. graminicola* were recorded in Small millets. Moderate to severe infection of *M. incognita* was recorded in ragi (Krishna Murthy and Elias, 1967), foxtail millet (Krishna Murthy and Elias, 1968), proso millet (Roy, 1972) and good infection in kodo millet (Alam *et al.*, 1973). Later on *Paspalum scrobiculatum*, *Panicum miliare*, *Eleusine coracana* and *Echinochloa frumentacea* were reported good hosts for *M. incognita* as even soil population between 45000 – 81000 larvae per 500 g of soil with good degree of galling on their root system (Vaishnav and Sethi, 1977). Asmus *et al.* (2005) suggested the restricted or no use of finger millet as cover crop in the no tillage system in field infested with *M. incognita*. Finger millet was also reported susceptible to *M. javanica* (Chandwani and Reddy, 1967) and poor host for *M. acrona* (Bridge and Page, 1977). *Setaria italica* and *E. coracana* allowed restricted development and reproduction of *M. graminicola*, but their progeny was less infective to rice (Rao *et al.*, 1970). Later, finger millet was reported host for *M. graminicola* from Orissa (Ray and Das, 1989). The Japanese millet (*E. frumentacea*) was also found susceptible to various populations of *M. arenaria* (McSorley, 1999).

6. Lesion nematode, *Pratylenchus* species

Endo (1959) reported *Setaria italica* as suitable host for *Pratylenchus brachyurus*

and *P. zae*. Population of *P. brachyurus* increased significantly in cropping systems that involved *S. italica* (Good *et al.*, 1973). Finger millet was also reported a good host for *Pratylenchus* species by Narayanaswamy and Govindu (1966) from Mysore state of India. Dunn and Mai (1973) observed that Japanese millet (*Echinochloa crusgalli* var. *frumentacea*) supports the growth of *P. penetrans*. Belair *et al.* (2002) studied the reproduction of *P. penetrans* on various rotations of crops in Quebec and observed that brown mustard is the best host and increased the initial population by 17.2 times. The Japanese millet was also very efficient in multiplying the nematode, while foxtail millet increased the initial population by 5.8 times. At Cuttak ragi plants in direct seeded rice field were found infested with root lesion nematode, *Pratylenchus indicus* (Rao and Prasad, 1977).

7. Ring nematode, *Macroposthonia* species

In a survey of plant parasitic nematode in Orissa, Khuntia and Das (1969) observed *Macroposthonia oranata* in large numbers in the rhizosphere of sorghum, ragi and rice. Acharya and Das (1983) reported rice to be an excellent host, while cabbage, cauliflower, corn, okra, cowpea, sorghum, bajra, mustard and ragi were good hosts for *M. oranata*. Pathogenic relationship of this ring nematode with ragi plant was established by releasing nematodes in logarithmic series (0 to 10000 per plot) around the root zone of one month old ragi plants. After 3 months, the nematode were found to reduce shoot height, root length, shoot and root dry weight from 1.45 to 46.32%, 6.08 to 61.78%, 3.33 to 69.06% and 0.09 to 46.05%, respectively corresponding to different levels of inoculum i.e. 0 to 10000 nematodes per plot in logarithmic series..

8. Stunt nematode, *Tylenchorhynchus* species

Upadhyay and Swaroop (1972) reported that *Tylenchorhynchus vulgaris* had a wide host range and the most suitable hosts for nematode multiplication belong to the family Graminae. A pH range of 5.5 to 7.7 and sandy loam or loam soil favoured nematode multiplication. *Eleusine coracana* was found a very good host for *T. vulgaris*. Vaishnav and Sethi (1977) reported that *T. vulgaris* reproduced well on *Paspalum scrobiculatum*, *Panicum miliare*, *Eleusine coracana* and *Echinochloa frumentacea* and its population ranged between 15000-52000 nematodes per 500 g of soil as recorded 60 days after inoculation proving that these are also good hosts. *Tylenchorhynchus mashhoodi* was also found associated with *Eleusine coracana* in Orissa (Ray and Das, 1989).

9. Other phytonematodes

Some other plant parasitic nematodes have also been reported by different workers in small millet crops. Finger millet was found good host and supports the population of *Trichodorus* sp. (Narayanaswamy and Govindu, 1966),

Criconemoides ornatus (Mohanti and Das, 1976), *Hoplolaimus indicus*, *Criconemella ornate* and *Caloosia exilis* (Ray and Das, 1989). *Hemicriconemoides cocophilus* was recorded on *Setaria italica* (Ray and Das, 1989), *Hemicycliophora* sp. and *Hirschmanniella oryzae* on barnyard millet (Shukla *et al.*, 1997).

Govindu and Narayanaswamy (1966) and Govindu *et al.* (1966) studied the fungal nematode disease complex and evaluated varieties for resistance to such a complex in finger millet. Mohanti and Das (1976) studied the physiology of parasitism of *Criconemoides ornatus*, the ring nematode in ragi. In the nematode infested roots 9 amino acids were identified as against 8 in healthy. The additional one being L-proline, which they considered as defence mechanism against the invading nematode. Effect of nematicides, nemacur (Fenemiphos), temik (Aldicarb) and disyton (Disulfoton) on enzyme activities in soil under crops of maize and *Paspalum scrobiculatum* was studied by Mohanti and Pradhan (1993) in Orissa. Urease, protease, invertase, amylase and cellulase activity was not affected by the presence of nematicides in the soil or by the type of crop grown.

REFERENCES

- Acharya, A. and Das, S.N. (1983). *Indian J. Nematol.* **13** : 9-15.
 Alam, M.M. *et al.* (1973). *Indian J. Nematol.* **3** : 159-160.
 Asmus, G. L. *et al.* (2005). *Nematologia Brasileira.* **29**: 47-52.
 Ayyar, P.N.K. (1933). *Madras agric. J.* **21** : 97-107.
 Ayyar, P.N.K. (1934). *Indian J. Agric Sci.* **3** : 1064-1071.
 Belair, G. *et al.* (2002). *Phytoprotection.* **83**: 111-114.
 Bridge, J. and Page, S.L.J. (1977). ODM report on the visit to Malawi (21 January to 21 April, 1977.).
 Imp. Coll. of London Univ., Silwood Park, Ascot, Berks., UK. **IV** pp 8.
 Chandrasekharan, N. M. (1964a). M.Sc. (Ag) thesis, University of Madras (T.N.), India.
 Chandrasekharan, N. M. (1964b). *Madras Agric. J.* **51**: 443.
 Chandwani, G. H. and Reddy, T.S.N. (1967). *Indian Phytopath.* **20**: 383-384.
 Cui, G.X. *et al.* (1989). *Acta Agriculture Boreali Sinica.* Supplement : 145-151.
 Dave, G.S. *et al.* (1979). *Sci. & Cult.* **44**: 766.

- Dunn, R.A. and Mai, W.F. (1973). *Pl. Dis. Repr.* **57** : 728-730.
- Endo, B. Y. (1959). *Phytopathology*. **49**: 417-421.
- Gill, J.S. and Swaroop, G. (1971). *Indian J. Nematol.* **1**: 63-67.
- Good, J. M. *et al.* (1973). *J. Nematol.* **5** : 117-122.
- Gotke, N. N. and Mathur, V.K. (1993). *Nematologica*. **39**: 274-276.
- Gotke, N. N. *et al.* (2001). *Indian J. Nematol.* **31**:115-119.
- Govindu, H. C. and Narayanaswamy, B.C. (1966). In : *Proc. Symp. Dis. Rice ,maize,sorghum and millets*. 1-2 Jan., 1966, Chandigarh, IPS, New Delhi. pp 68-71.
- Govindu, H. C. *et al.* (1966). *Indian Phytopath. Bulletin.* **3** : 79-81.
- Jairajpuri, M.S. *et al.* (1979). *Revue de Nematologia*. **2**: 3-9.
- Jothi, G. and Sunderbabu, R. (1998). *Indian J. Nematol.***28**: 145-149.
- Krishna Murthy, G.V.G. and Elias, N.A. (1967). *Indian Phytopath.* **20** : 374-377.
- Krishna Murthy, G.V.G. and Elias, N.A. (1968). *Indian Phytopath.* **21** : 351-352.
- Krishnaprasad, K.S. *et al.*(1980). *Curr. Res.* **9**: 114-115.
- Krishnaprasad, K.S. and Krishnappa, K. (1982). *Indian J. Nematol.* **12**: 405.
- Krishanappa, K. *et al.* (1992). In: *Nematode Pests of Crops.* (Bhatti, D.S. and Walia, R.K. eds). C.B.S. Publishers and Distributers, Delhi-32. pp 70-76.
- Krishanappa, K. *et al.* (2002). In: *Potentials of Green Manuring in Rainfed Agriculture.* (Shankar, M.A *et al.* eds).pp 45-55.
- Khuntia, N. and Das, S.N. (1969). In : All India Nematology Symposium at OUAT, Bhubaneswar, Orissa (Abstr.). pp 22-23.
- Lal, A. and Mathur,V.K. (1988).*Indian J. Nematol.* **18** : 131.
- Lal, A. and Rajan (1995). *Indian J. Mycol. Pl. Pathol.* **25** : 42-43.
- McSorley, R. (1999). *J. Nematol.* **31** (supplement) : 619-623.
- Merny, G. and Netscher, C. (1976). *Biologic Nematologic.* **11**: 209-218.
- Mohanti, K.C. and Das, S.N. (1976). *Indian Phytopath.* **29** : 434-435.
- Mohanti, R.K. and Pradhan, S. (1993). *Environment and Ecology.* **11**: 7-12.
- Narayanaswamy, B. C. and Govindu, H.C. (1966). *Indian Phytopath.* **19**: 239-240.
- Narayanaswamy, B. C. *et al.* (1982). *Indian J. Soil Biol. Eco.* **2**: 90-91.
- Padhi, N.N. and Das, S.N. (1982). *Indian J. Nematol.* **12** : 53-59.
- Padhi, N.N. and Das, S.N. (1985). *Nematologia Mediterranea.* **13** : 115-116.
- Padhi, N.N. and Das, S.N. (1986). *Indian J. Nematol.* **16** : 141-148.
- Rajgopal, B. K. (1965). M.Sc.(Ag). Thesis, University of Madras. pp 62.
- Rao, Y. S. *et al.* (1970). *Oryza.* **7** : 137-142.
- Rao, V. R. and Swaroop, G. (1974). *Indian J. Nematol.* **4**: 228-230.
- Rao, Y. S. and Prasad, J. S. (1977). *International Rice Research Newsletter.* **2** : 6-7.
- Rajendran, G. and Cannayane, I. (2000). *Current Nematology.***11**: 5-8.
- Ray, S. and Das, S.N. (1989). *Nematode fauna of Orissa.* Dept. of Nematology, OUAT, Bhubaneswar. pp 9-31.
- Roy, A. K. (1972). *Indian J. Nematol.* **2** : 86-89.
- Setty, K. G. H. (1975). In : Report of UNDP / ICAR Research Project, UAS, Hebbal, Bangalore.
- Setty, K. G. H., Gowda, D. N. and Reddy, H. R. (1977).*Curr. Res.* **6** : 156-157.

- Srivastava, A. N. and Swaroop, G. (1975). *Indian J. Nematol.* **5**: 257-259.
- Shukla, B. N. *et al.* (1997). In : *Two decades of nematology in Madhya Pradesh*. Dept. of Plant Pathology, JNKVV, Jabalpur. pp 10-20.
- Sunderbabu, R., Sankaranarayanan and Jothi, G. (1996). *International Journal of Tropical Plant Diseases*. **14** : 85-89.
- Upadhyay, K. D. and Swaroop, G. (1972). *Indian J. Nematol.* **2** : 139-145.
- Vaishnav, M. U. and Sethi, C. L. (1977). *Indian J. Nematol.* **7** : 176-177.
- Veerabhadra, P. K. (1992). M.Sc.(Ag) Thesis, UAS, Bangalore, Karnataka. pp 112.
- Yoshii, H. and Yamamoto, S. (1950). *J. Fac. Agric. Kyushu Univ.* 9(3): 209-222