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NEMATODES: AN EMERGING ISSUE ASSOCIATED WITH MILLETS, FUTURE FOOD OF INDIA

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• ***Abstract:-***
Millets are a group of eight crops comprising of sorghum, pearl millet, finger millet, kodo millet, little millet, foxtail millet, barnyard millet and proso millet. They are grown in a variety of agro-ecological situations viz., plains, coast and hills as well as in diverse soils and varying rainfall. Millets, a crop that complies with climate change regulations, outperform other grains like wheat and rice in terms of poor growing conditions and high nutritional value. Millets are important warm weather cereal crops. There is not much information available on nematodes of most of the millets crops except sorghum and pearl millet classified as minor millets. These minor millets are cultivated for grain and fodder essentially as dry land crops. In India, millets rank fourth after rice, wheat and maize. Plant parasitic nematodes are one of the limiting factors in crop production throughout the world. ***Heterodera delvi, H. avanae, H. gambiensis, H. zeae, Rotylenchulus reniformis, Meloidogyne incognita, M. javanica, M. arenaria, M. graminicola, Pretylenchus penetrance, P. brachyurus, P. zeae, P. indicus Macroposthonia ornate, Criconemoides ornatus, Criconemella ornate, Hoplolaimus indicus, Caloosia exilis, Hemicriconemoides cocophilus*** 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.

• *Index Terms*:- **Plant Parasitic Nematodes pests, Small millets crops, Cultural chemical, Managements.**

• Introduction:-

Millets are astonishingly low water consuming crops. The rainfall needed for Sorghum, Pearl Millet and Finger Millet is less than 25% of sugarcane and banana, and 30% that of rice. We use 5000 litres of water to grow one kg of rice while all millets grow without irrigation. By any nutritional parameter, millets are miles ahead of rice and wheat. Each one of the millets has more fibre than rice and wheat. Mainly, 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 Ephemerals 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. Plantparasitic nematodes (PPN) are widely spread in millet growing areas of the world. The estimated annual yield loss based on the International survey of crop losses due to nematodes in millet was assessed as 11.8%. When both the organisms (fungus + nematode) interacted synergistically and increase the disease severity by 83 to 96% and reduced the plant growth Pearl millet is also reported to be most favourable host for multiplication of Tylenchorhynchus vulgaris. Incidence of the plant parasitic nematodes associated with millets was reported from different part of the world including southern part of India. Cyst nematode, Reniform nematode, foliar nematode, spiral nematode, root knot nematode, lesion nematode, ring nematode and stunt nematodes are important to millets, but any progress on systematic work on occurrence of these plant parasitic nematodes, interrelationship with other plant pathogens and their management was undertaken.

- **Important Genera of Nematodes attacking Minor Millets:-**

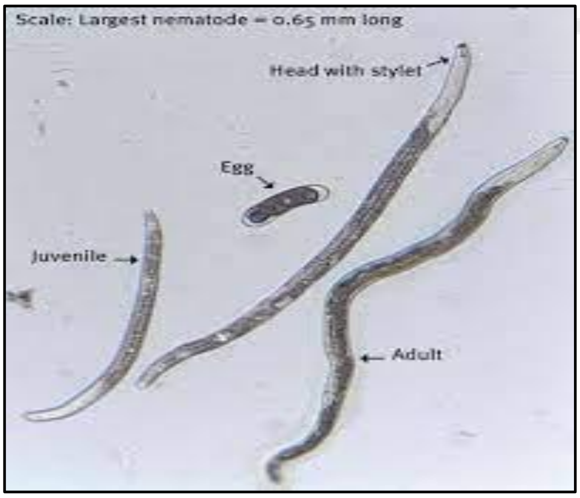
Sorghum (Sorghum bicolor), Finger Millet *(Eleusine coracana*), finger millet (*Eleusine coracana* L. *Gaertn*.), kodo millet (*Paspalum scrobiculatum* L.), foxtail millet (*Setaria italica* L.), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa frumentacea* L.Beauv.) and proso millet (*Panicum miliaceum*) have been reported to attack by a number of plant parasitic nematodes e.g. ***Meloidogyne*** **(root-knot),** ***Pratylenchus*** **(Lesion nematode),** ***Tylenchorhynchus*** **(stunt nematode) and** ***Heterodera sorghi*** **(sorghum cyst nematode)** etc. Among them, ***Tylenchorynchus*** was more frequent and abundant than ***Pratylenchus***, but its region specific obviously.

i. **Root-knot nematode (*Meloidogyne spp*):**

Five species of root knot nematode viz. ***Meloidogyne incognita, M. javanica, M. arenaria, M. acronea and M. graminicola*** were recorded in Small millets. The field observations indicated that the nematode causes chlorosis and stunting of infected plants. The infestations by M. incognita result in production of elongated swellings and root proliferations. Formations of Root Galls or knots are diagnostic symptoms. Yield losses due to ***M. graminicola*** are 21 % in cereals and millets under rainfed and well-drained soils throughout the India: the losses are more pronounced in light-textured soil with low WHC soil. The root-knot nematode, ***Meloidogyne incognita*** has been considered to cause field problem where it occurs in a combined association with a fungus, ***Sclerospora graminicola.***

ii. **Lesion nematode (*Pratylenchus spp*):**

Pratylenchus zeae and ***P. hexincisus*** are the two most important species of lesion nematodes. ***P. zeae*** is



considered economically important to sorghum crop in tropical region of the world. The infested plants show stunting and leaf chlorosis in heavily infested fields with lesion nematodes. The infested roots exhibit brown necrotic lesions. Finger millet was also reported a good host for *Pratylenchus* species by Narayanaswamy and Govindu (1966) from Mysore state of India. 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.***

iii. Cyst nematode (*Heterodera spp.*):

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. Later on, 1977, it was published that 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*, attacking mainly in Sorghum and Finger Millet.

Heterodera sorghi, appears to be potentially important for cereals and millets grown in Kharif and Rabi seasons and presents a great possibility of its ability to survive and cause yield losses ***Heterodera gambiensis*** is the only other species of cyst nematode found associated with sorghum crop. ***Eleusine coracana*** and ***Panicum miliare*** were reported non-host for ***Heterodera avenae*** **(Molya Nematode).**

Patches of stunted planted growth, chlorosis appears, Tillering greatly reduced and clum becomes thinner & weaker. Roots become typically bushy and swelling markings and appearance of white glistening females on the roots from the January to March 1st week. Annual Crop Losses occur due to nematode infestation about 28.8% in monetary terms in rainfed area.


iv. Stunt nematode, (*Tylenchorhynchus* spp.):

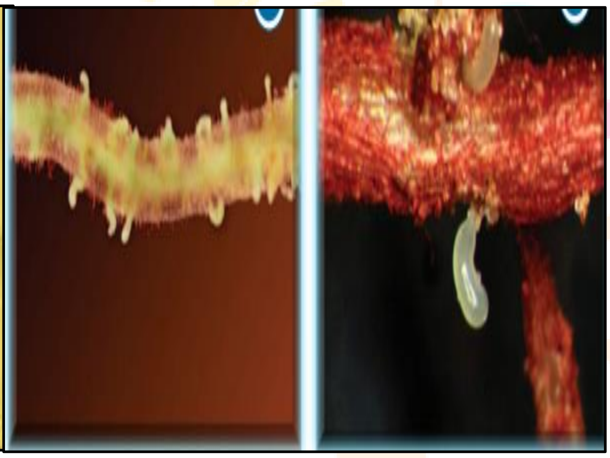
Several species of stunt nematode have been associated with poor and unthrifty growth of Millets. Upadhyay and Swaroop (1972) reported that ***Tylenchorhynchus vulgaris*** had a wide host range and the most suitable hosts for nematode multiplication belong to the family Graminae. A pH range of 5.5 to 7.7 and sandy loam or loam soil favoured nematode multiplication. *Eleusine coracana* was found a very good host for ***T. vulgaris***. Though several species of this nematode have been recorded from various regions of the world, ***T. vulgaris*** occurs most frequently in sorghum fields in India. ***Tylenchorhynchus mashhoodi*** was also found associated with *Eleusine coracana* in Orissa. Though most ***Tylenchorynchus*** species are migratory ecto-parasitic nematodes feeding on epidermal cells of the roots, ***T. brassicae*** has been seen to penetrate throughout the cortex. The worm causes poor germination and stubby root condition.

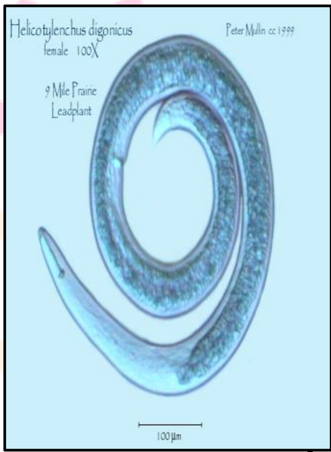
- **Some other Phyto-Nematodes attacking Minor Millets:-**

- Some other plant parasitic nematodes have also been reported by different workers in small millet crops. In a survey of plant parasitic nematode in Orissa, Khuntia and Das (1969) observed ***Macroposthonia oranata*** **(Ring Nematode)** in large numbers in the rhizosphere of sorghum and ragi.
- Finger millet was found good host and supports the population of ***Trichodorus*** **sp. (Stuby root Nematode).**
- In India, natural occurrence of ***Helicotylenchus*** **(Spiral Nematode)** 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. Finger millet, proso millet and foxtail millet were also found good

hosts for spiral nematode. . Infection sites of such Spiral Nematode were swollen with numerous root hairs. Minute brown lesions were also observed at feeding sites and points of entry.

- In a field survey, finger millet was found susceptible to ***Rotylenchulus reniformis*** **(Reniform Nematode)** 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. Symptoms such as general stunting and brown to black discolouration 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.
- Foliar nematode, ***Aphelenchoides besseyi*** was reported from India (Dave et al., 1979 and Lal and Mathur, 1988).The disease was referred as Light ear disease of foxtail millet. 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.





- **Management Strategies effective for PPNs in Millets:-**

Reniform Ne

al practices: There is a good scope for adopting crop rotation as control measure for different ne... case of host specific nematode, *Heterodera zeae*, monoculturing of the same crop should be avoided. Two years rotation with non-host crops can be fruitful as it would bring down the nematode population below economic threshold limits.

✓ Summer ploughing and keeping the fields free from weeds can also help in checking the survival and perpetuation of nematodes in off-season .Two to three deep ploughing during April/ May month in hot summer would also reduce the nematode populations to a considerable extent.

✓ Using clean planting material is the most effective strategy to manage cyst nematodes and limit new land infestations.

✓ Deep ploughing and drying of the soil throughout the summer months desiccates the infective juveniles, lowering the initial inoculum in the soil.

✓ Planting trap crops such as ***Tagetes patula*** and ***T. erecta*** between two or three rows increases crop performance and decreases root knot development.

- **Resistance and Tolerance:** The best way to manage them is to use of nematode resistant and tolerant cultivars, which can minimize most effectively and economical management approach. A total of 36 enteries (9 hybrids and 18 parental lines and 9 restorer lines) of Pearl Millet were subjected to screening for resistance against root-knot nematode, ***Meloidogyne graminicola***. ICMB 843- 22, ICMB 94555, HMS 47 B, HMS 53 B of Pearl Millet were found to be moderately resistant against root-knot nematode, *Meloidogyne graminicola* infection. RD-2052, RD-2035, RD-387 all are the Molya/Cyst Nematode resistant cultivars.

- **Soil Amendments & Physical Control:-** The use of oil-cakes and other organic soil amendments have also been proved effective in managing the population of most of the nematodes. Field trials using various soil organic amendments have clearly indicated that combination of mustard-cake and tobacco dust @2.5q/ha a good practice adopted by farming of the country is as efficient as Carbofuran soil treatment @2.0kg ai/ha in terms of increased crop yield and containment of the nematode populations.

- ***Meloidogyne*** may be removed from root propagative material with a 65-minute hot water treatment at 47° C and a 4-8-hour hot air treatment at 50° C.
- Treatment of infected tubers in hot water at 50° C for 45-60 minutes decreases spread of Root Lesion Nematode.
- Nematode populations in the field are reduced by short periods of flooding. The nematode can also be eliminated from contaminated soil after 5 minutes of treatment with 50° C hot water.

Biological Control:- ***Paecilomyces lilacinus*** has been shown to lower nematode levels in the field. ***Glomus fasciculatum***, an endomycorrhizal fungus, inhibits *R. reniformis* penetration and reproduction on tomato and cucumber. Crop rotation to boost Mycorrhizae might help regulate population numbers (Kumar et al., 1993). Highest grain yield was reported in VAM (100 g / m^2) inoculated plots. Apply ***Purpureocillium lilacinum*** at 2.5 kg/ha at the time of sowing along with farm yard manure (FYM) for getting rid off Reniform Nematode. Seed dressing with ***Gluconoacetobacter diazotrophicus*** (strain 35-47) @ 100 g (powder formulation) or 50 ml (liquid formulation)/5 kg seed for preventing from Root-knot Nematodes. Nursery bed treatment with either ***Trichoderma viride*** formulation (FYM incubated) @ 2.5 g/m^2 or ***Pseudomonas fluorescens*** formulation @ 20 g/m^2 .

Chemical Control:- In field studies, the combination of nematicides with neem cake boosted the yield of crops. Pre-sowing soil application of Phenamiphos resulted in higher reduction of cyst production than other chemicals .The carbosulfan seed treatment accompanied with carbosulfan foliar spray resulted in additional control of the nematode. The potential of carbosulfan seed treatment proved to be very effective approach in reducing the total requirement as also the cost of the chemicals against ***Heterodera zeae*** on maize. ***R. reniformis*** can be controlled with a variety of fumigant and non-fumigant nematicides. The nematode penetration was minimised by a single foliar treatment of oxamyl. Effective nematode control was obtained by using carbofuran at 3 kg a.i./ha or ethoprop at 10 kg a.i./ha. These insecticides were more effective when sprayed in two equal split doses, once at planting and once during earthing. Seed dressing with carbosulfan (25DS) @ 3% w/w followed by soil application of carbofuran (3G) @ 1 kg a.i./ha is effective for Root-Knot Nematode.

Integrated Approach:-

- **For controlling Root-Knot Nematode,** Application of carbofuran (3G) @ 1 kg a.i./ha + Pseudomonas luorescens (Biofor Pf) @ 20 g/m2 with vermicompost @ 1:10 ratio is effective.
- Soil solarization or clear plastic mulching for 5 weeks coupled with carbofuran @ 3kg a.i./hectare or solarization with neem cake leads in a considerable improvement of crop and decrease the nematode densities.

Conclusion:-

The most important challenge to local Nematologists remains to find suitable, effective and sustainable measures for producers to manage Millet crops in ways that would keep plant-parasitic nematode populations below damage threshold levels. Millets are a very resilient and tolerant crop that are widely cultivated throughout the world and provide farmers with a sizable income. Environmental conditions are another important variable to investigate and involve all possible crops and rotation-system variations. Nematode population dynamics and several other aspects of plant nematology relating to conservation and precision agriculture would not only contribute to support the development and adoption of these approaches but also would provide invaluable basic information about plant nematology that would previously have been very difficult to justify investigating. With the support of 72 other nations, India suggested to the UN that 2023 be designated as the International Year of Millet in order to eliminate these uncertainties. The Indian government's primary objective is to promote various millet products and their innovative farming techniques. 2023 has been designated as the International Year of Millets in order to promote completely sustainable agricultural methods for millets and their value-added products.

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