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Review Paper

Meloidogyne graminicola (Golden and Birchfield): Threat to Rice Production

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Abstract

Meloidogyne graminicola (Golden and Birchfield) causing rice root knot disease has emerged as a major pest recently throughout the world due to its broad host range and ability of causing potential yield loss. The losses caused by M. graminicola may vary from negligible to heavy depending on the severity of disease. Completion of life cycle of M. graminicola is highly temperature dependent and may vary from 15-51 days. The main symptoms of root knot disease of rice are yellowing, dwarfing and gall formation on the roots of rice plants. The degree of symptom manifestation differs with time of infection, age of the plants and load of inoculums. Tillage practices and abiotic factors such as nutrition, temperature, soil type, moisture, etc., may affects population of nematode. Indiscriminate use of chemicals for managing this disease results in the development of pathogen resistance and risk to the environment which has favored the introduction of various eco-friendly approaches of management such as, removal of host weeds, flooding of fields, summer ploughing, organic amendments, and use of effective biocontrol agents. Since each management approach has some advantage, an integrated approach can be a better option to overcome this disease.

Key words: *Meloidogyne graminicola*, root knot disease, ecofriendly approaches, tillage practices.

Introduction

Rice is grown in diverse environments either as a sole crop (rain fed, irrigated or deepwater) or as a major component in various cropping systems. Cropping systems, involving different year specific crop sequences or fallow in a given area, create conditions of varying favourability for microbes, plant parasitic and free living nematodes and weeds, and thus affect the flora and fauna both qualitatively and quantitatively[1]. Since, rice cultivation cover large area in India, even a smallest pest problem would have great impact on yield and farmers' income. Soil borne diseases are becoming increasingly important in the rice-based cropping systems. One of the most important soil borne pests is plant parasitic nematode. About 300 nematode species belonging to 35 genera have been reported infesting rice. Among them, *Meloidogyne graminicola* (Golden and Birchfield) are considered as most important constraints in rice production. This nematode reduced the rice yield by more than 17% in a greenhouse experiment and the yield losses might go as high as 80%[2]. To prevent further yield losses and improve productivity it is necessary to find out the effective sustainable management strategy.

Distribution: Different species of *Meloidogyne* are found in different countries of the world. *M. graminicola* is distributed in countries like S.E. Asia, Burma, Bangladesh, Laos, Thailand, Vietnam, India, China, Philippines, Nepal and USA. *M. oryzae* has been found in Surinam on irrigated rice, *M. incognita* in Costa Rica, Cuba, Egypt, Ivory Coast, Nigeria, South Africa and Japan, *M. javanica* in Brazil, Egypt, Comoro Islands, Nigeria and Ivory Coast, *M. arenaria* in Nigeria, Egypt and South Africa and *M. salasi* in Costa Rica and Panama on upland rice[3]. The root-knot nematode is making its importance felt in almost all the rice growing areas. *M. triticoryzae* infecting both rice and wheat including some monocot weeds is also reported from India[4] and its occurrence is restricted to a few areas. In India, *M. graminicola* is the dominant species infecting rice. *M. graminicola* has been found infecting rice in different parts of India namely, Assam, Andhra Pradesh, Karnataka, West Bengal, Orissa, Kerala, Tripura and Madhya Pradesh[5]. *M. graminicola* is a serious pest of upland rice and nurseries world over in well-drained soils[6]. The nematode was reported on irrigated rice in Andhra Pradesh [7] and Karnataka [8]. The nematode can infect and multiply on semi-deep [9] or deepwater rice also[10].

Yield loss: Depending on the severity of disease, losses caused by *M. graminicola* may vary accordingly. Losses also differ with cropping systems in which the rice is grown. Netscher and Erlan[11] reported that *M. graminicola* caused 28 to 87% yield loss in upland rice in Indonesia. Jairajpuri and Baqri[12] reported grain yield losses from 16 to 32%. Soriano *et al.* [2] recorded 11 to 73% yield losses by this nematode under simulation of intermittently flooded rice, whereas under simulated upland conditions, yield loss varied between 20 and 98%[13]. Padgham *et al.*[14] also reported 16 to 20% yield loss caused by *M. graminicola* in low land rainfed rice in Bangladesh. On upland rice, *M. graminicola* causes 16-32% loss in grain yield due to incomplete filling of kernels [15]. Severe infestations of the root-knot nematod on rice was observed in Mandya district of Karnataka state covering an area of 1500 ha[8].

Host range: Wide host range of *M. graminicola* may be the reason for its ability to cause severe losses in different cropping system. It was first reported on barnyard grass, *Echinochloa colonum*[16]. Subsequently it was found that it readily attacks several grasses, bush bean, oats[16], sorghum, pearl millet, wheat and oats, were good hosts of this nematode[17]. Among the entire host, rice being consider as a major economically important host. Anamika *et al*.[18] assess the disease incidence and intensity of root-knot disease on rice and vegetable crops in 21 districts of Uttar Pradesh (India). On the basis of incidence, population density and associated damage on affected crops, *Meloidogyne* species were considered to be the most important parasites of the crops under local condition.

Life cycle: *M. graminicola* is a meiotic parthenogen, with a haploid chromosome number of 18. *M. graminicola* completes its life cycle in 26-51 days in different periods of the year[19]. Bridge and Page [10] however, reported that the life cycle of *M. graminicola* was completed in 19 days at an ambient temperature of 22-29^{0}C. They further noted that the generation time of *M. graminicola* could be as little as 13 days at an ambient temperature of 25-35^{0}C. Khan *et al.*[20] reported that females laid eggs 20 day after inoculation of J_2 of *M. graminicola*. Halbrendt[21] reported that *M. graminicola* can complete its life cycle in as little as 15-19 days due to high reproduction rate. Dabur *et al*. [17] reported that life cycle of this nematode was completed in 24 days. They reported that adult male and females were observed on day 10 and egg laying and release of juveniles were first observed on day 20 and 24, respectively. Singh, K.P *et al*. [22] reported that life cycle of *M. graminicola* required 15-20 days to complete its life cycle in rice during different months in eastern Uttar Pradesh condition where temperature usually ranges between 22-40^0 C.

Symptomology: High initial population of *M. graminicola* causes seedling wilt along with severe reduction in growth parameters whereas low population cause only reduction in growth parameters[23]. The main symptoms caused by *Meloidogyne graminicola* are yellowing, stunting and gall formation on the roots of rice plants. The degree of symptom manifestation varies with inoculums load, time of infection, age of the plants, *etc*. *Meloidogyne spp.* in associated hypertrophied root tissues act as metabolic sinks [24] and receive photosynthates translocated from other parts of the plant through root system for growth and development. During this process, the nematodes deprive the plant of nutrients causing reduced root and shoot growth. *Meloidogyne* also affects nutrient and water absorption and upward translocation by root system [25]. Extent of symptom production thus depends on the degree of alterations caused by nematode infection. Based on the number of penetrating and establishing nematodes within the root system [25] and the ratio between the number of nematodes and food resources supplied by the plants, the magnitude of symptom production varies[26]. Oteifa[27] reported that a high inoculum level of the *M. incognita* reduced shoot growth of Lima bean (*Phaseolus lunatus*) accompanied by a decrease in shoot-root ratio.

Effect of tillage practices and environmental factors on *M. graminicola*

Approximately 123 million hectares of cultivated area is under food grains in India, out of which 55 per cent is under rice and wheat cropping system. In areas where sufficient irrigation and well-distributed rainfall is received, rice-wheat and rice-rice are the two most dominant annual cropping systems. The rice-wheat cropping system is the most important food grain production system.

In Eastern Uttar Pradesh, India, the parasite is wide spread in rice–wheat cropping system [28]. This nematode has also been found damaging the wheat crop too[4]. Effect of tillage practices, in contrast to a no tillage/conservation system, on nematode populations has been inconsistent on different crops, perhaps due to the larger effects of nutrition ,weeds, soil structure, and other factors on crop growth[29]. The nematode population structure varies in time and space, both in zero/minimum tillage and in conventionally tilled soil[30]. Singh *et al*.[31] found that the population density of soil fungi was found to be greater in conventional tillage than in no-till fields in Haryana (India) at the crown root initiation (CRI) and dough stage of wheat, while no such trend was observed in paddy rice. *M. triticoryzae* population declined in puddled soil, as puddling reduced the bulk density and hydraulic conductivity in the upper layers of soil but not in the deeper layers where soil aeration was reduced due to high moisture levels retained in the puddled soil. Higher root-knot nematode population was found in the non-puddled soil especially in unsubmerged condition as compared to puddled and submerged soil [32]. Soil puddling prior to planting paddy rice significantly reduces the population densities of root-knot nematode, *Meloidogyne graminicola* Golden et Birchfield, *M. triticoryza*e Gaur, Saha et Khan, stunt nematode, *Tylenchorhynchus mashoodi* Siddiqi et Basir[33]. Pankaj *et al*.[34] observed that the population densities of the plant parasitic nematodes were significantly greater in zero-tillage fields than those of conventionally tilled fields because of ploughing which decreased nematode population densities by exposing them to adverse environmental conditions. Zero tillage reduces disturbance of the soil, increases organic matter content, improves soil structure and buffers soil temperatures. When the soil is disturbed more frequently in conventional tillage, it may affect the reproduction of the soil flora and fauna and their population densities. House and Parmelee[35] found that cultivation of soil affects its fauna both qualitatively and quantitatively. Cabanillas *et al*.[36] observed decrease in the population of free living nematode in a no-till environment whereas the population of *Rotylenchulus reniformis* Linford et Oliveira were increased. Khan and Singh[37] observed that deep summer ploughing plots recorded reduction in plant parasitic nematodes and saprozoic nematodes in comparison to control fields. The increase in temperature of the soil due to deep summer ploughing and the exposure of the insulating soil layer to the surface caused the decrease of nematode population growth in deep summer ploughed fields. Singh *et al*.[38] found that deep summer ploughing reduced the population by 36.9% and increased the yield by 23.3%. Other than tillage, various environment factors such as nutrition, temperature, moisture, soil type *etc.*, may also determine the nematode populations.

Pokharel[39] reported that nematode-induced rice yield reduction was low when plots were supplied with nitrogen and phosphorus as compared to control plots (no fertilizer or compost). In contradict, Rao and Israel[40] found that addition of nitrogen up to 40 kg/ha to the soil resulted in increased reproduction of *M. graminicola*. Application of additional phosphorus either alone or in combination with nitrogen also favoured nematode development. Rao and Israel[41] reported maximum hatching of eggs of *M. graminicola* in water at 25 and 30°C. At 15 and 35°C hatching was reduced and at 20°C it was slightly less than that at 25°C. Larval populations of *M. graminicola* in soil were large during December to February when soil temperatures were 20.9°C or less. Populations were small in March, July and August and very small in April, May and June when the soil temperature was 31°C. Maximum galls on rice roots were found during January to March and egg masses during February to March. Soil temperatures of 23.5°C or less were found most favorable for gall formation[40]. Larval invasion was greatest in soils at 32% moisture content; development and egg mass production were greatest at 20 to 30% soil moisture. Greatest larval invasion may occur at pH 3.5 but pH usually does not affect invasion, growth or development of the nematode to any significant extent[41]. In upland soil, which was well-drained and had 74-75% sand, larvae were observed up to a depth of 22-28 cm in nursery soil and 22 cm under transplanted crops[41]. In poorly drained lowland soil, larvae were observed up to a depth of 18 cm in both nursery and transplanted areas. In lowland soils the pore space was less and moisture content high so that the rice roots spread more laterally and nematode populations were greater at a depth of 2-6 cm compared with maximum density observed at a depth of 4-12 cm in upland soils. Coarse and medium soils with particles above 0.053 mm in diameter and sandy soils allowed free movement of infective larvae and invasion into roots of the rice plant. Clayey soils were less suitable tom nematode infection. With an increase in the sand content of the test soils, there was an increase in root growth, root-knot development and egg mass production by the nematode, the relationship between the sand content and the activity of the nematode was linear. Sandy or loamy, laterite soils or recent alluvial soils (in which the available soil nutrients range from moderate to low and water holding capacity is low) favour development of the nematode[42].

Certain factors such as poor drainage, nutritional deficiencies, and soil-borne diseases can conceal the presence of nematodes.

Eco-friendly management approaches

Indiscriminate use of chemicals for the management of the root knot disease results in the development of pathogen resistance and risk to the environment which has favored the introduction of various eco-friendly approaches of management.

Several workers have studied the screening of different varieties/genotypes/germplasm of rice against the *M. graminicola* and almost all the genotypes showed susceptibility and rarely expressed moderate resistance. Several high yielding cultivars of *Oryza sativa* have been screened but not enough genetic variability has been found for resistance to the rice root-knot nematode [13]. Soriano *et al.*[43] worked on the resistance of rice cultivar of *O. sativa, O. longistaminata* and *O. glaberrima* and reported that all the accession of *O. sativa* were susceptible while one and three accession of *O. longistaminata* and *O. glaberrima* were resistant against the *M. graminicola*.

In natural ecosystem, whenever the pathogen population increases, its natural enemies get activated and cause a decline in their population by parasitism and predation. This is the rule of nature that it maintains a good balance of soil biodiversity and never allows the population builds up of a single dominant species. Fungus *Catenaria anguillulae* Sorokin is a facultative endoparasite of free living and plant parasitic nematodes[44]. Singh and Gupta[44] reported *C. anguillulae* parasitism on *Heterodera sorghi* in epidemic form in a sorghum field severely infested by the cyst nematode that causes steep decline in the population of this nematode. Barooti *et al.*[45] also reported natural parasitism of *C. anguillulae* on plant parasitic nematodes to the extent of 35%. Further, Gupta *et al.*[46] studied *C. anguillulae* parasitism on nematodes in the rhizosphere soils of different fruit plants and reported that it varied between 0.60 to 36%. Likewise, various natural enemies such as nematophagous fungi were found activated and subsequently cause a reduction in the nematode population[47]. Jaffee *et al.*[47] reported that the disease dynamics in soil microcosms exhibited both temporal density-dependent parasitism and a host threshold density for parasitism. Kerry [48] reported that regularity in cereals cropping enhance the attack of cereal cyst nematode causing soil to become suppressive to that pest. Suppression was preceded by an inductive phase in which large densities of pest nematodes helps in increasing their parasites. Similar observations were recorded with the bacterial parasite, *Pasteuria penetrans*, on nematodes[49]. Density dependent parasitism may also be effective in the nematode reduction in organic matter amended soil[50].

Mono-cropping of a highly susceptible host plant greatly increases population of a nematode pest and cause damage to the crop; inversely, growing a poor host will significantly suppress the nematode population. Crop rotation has recently received attention as a pest management tactic for managing plant parasitic nematodes, including *M. graminicola*[51]. Since rice and wheat both are good hosts of *M. graminicola*, there is need to change this crop rotation or grow a non-host/ poor host crop in between this crop rotation.

Some of the dominant weeds serve as reservoir for *M. graminicola*. The presence of such weeds helps in increasing the population of *M. graminicola* in soil. Rice crops growing with such hosts are severely infected due to increased population of this nematode; hence weeding may help in removing the trapped population of *M. graminicola* within the roots of such weeds from the field. This will obviously reduce the build up of inoculum of *M. graminicola* in rice fields.

Soil flooding is one of the options to control *M. graminicola* in rice production[52], although feasibility of this practice is limited by water availability and the potential for damage to the soil structure. It is known that *M. graminicola* can survive in intermittent flooding as endoparasite of rice roots but its population remain inactive in the flooded soil. Kinh *et al.*[53] reported that permanent flooding reduced the damage to rice caused by *M. graminicola*. Crop damage can be avoided from nematodes by growing rice seedlings in flooded soils, nematodes[54].

The root knot disease of rice is adversely influenced by the practice of puddling and submergence[55]. Puddling results poor respiration and movement of nematodes by reducing aeration and providing high moisture levels for long periods resulting in reduction in population densities of *M. graminicola* in puddled field [56]. Shallow flooding decrease the incidence of root damage by the nematode, resulting in an absence of yield-reducing effect by nematode under irrigated conditions[57].

Application of organic amendments is a well established and ancient agricultural practice used by farmers to improve the nutrients and water holding capacity of the soil and thereby improve plant growth, hence increase tolerance to nematodes. Hossain *et al*.[58] reported that organic amendments significantly reduced the root knot severity, population of *M. graminicola* and increased the length and weight of shoot and roots and the growth of rice seedlings. Organic residue decomposition results in the accumulation of specific nematicidal compounds[59]. When green manure crops (leguminous crops) like *Sesbania rostrata* and *Aeschynomere afaraspera*, grown in rotation with rice crop were significantly found to increase yields of irrigated rice in the presence of rice root nematode (*Hirschmanniella oryzae)* by acting as trap crops of the nematode[60]. Amendments of soil with Farm Yard Manure (F.Y.M.) also increase the population of predacious fungi which in turn may reduce the population of *Meloidogyne spp*. [61]. Since each management practice has some advantage, hence, there should be an approach of integrated nematode management.

Conclusion

Meloidogyne graminicola (Golden and Birchfield) causing rice root knot disease has emerged as a major pest in rice crop throughout the world due to its ability to cause potential yield loss. Population of nematode are affected by several factors such as, tillage practices, nutrition, soil type, temperature, moisture, *etc.* which should be taken into consideration while going for management. As indiscriminate use of chemicals for the management of the root knot disease enhances the problem of pathogen resistance and risk to the environment which has favored the introduction of various eco-friendly approaches of management such as, removal of host weeds, flooding of fields, summer ploughing, organic amendments, and use of effective biocontrol agents. Since each management approach has some advantage, an integrated approach can be a better option to overcome this disease.

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