Original Research Article

Survey for alternate weed hosts of rice root-knot nematode, *Meloidogyne graminicola*associated with rice crops in Haryana

Abstract

Rice root-knot nematode, *Meloidogyne graminicola* is one of the most serious nematode pest associated with rice throughout the world. With other species of root-knot nematode, *M. graminicola* can also infect wide range of weed flora which is commonly grown in or near the rice field. To study the alternate weed hosts of *M. graminicola* a survey was conducted in the major rice growing blocks of Fatehabad and Sirsa districts of Haryana during Kharif season 2022. A total of 726 samples were collected from rice fields, both from transplanted (TR) and direct seeded rice (DSR) from Phoolan, Bharpur, Ratta Khera, and Jandwala Sotter villages of Fatehabadand Bahauddin and Sikanderpur, Dhottar, Ding andChopta villages of Sirsa. Out of which 353 samples were found free from nematode infestation while 373 samples (209 from DSR and 164 from TR) werefound infested.The juveniles and galls were recorded ranging from 4-190 on the roots of different weed plants. Hence, it is concluded from the present investigation, that nematodes favor more DSR and its weed flora than TR for infection and survival.

Keywords: Alternate weed host, *Meloidogyne graminicola*,Rice, Survey

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop throughout the world, just after wheat and maize, playing a strategic role in solving food security issues. It is a primary crop grown widely over 161 mh in more than 100 countries of the world (Ladha *et al.*, 2009). Approximately 90 percent of the world's rice is grown and consumed in Asia, which is native of 60 percent of the world population (Anonymous 2023). In India, it was cultivated from ancient times and ranked first in area and second in production after China. In India, it grew 46.27 mh with a total production of 129.47 m tonns with an average productivity of 2798 kg/ha (Anonymous 2023).

Rice cultivation is affected by various biotic and abiotic factors which contribute to the lower productivity of rice in India. Among the biotic factors, nematode infestation is considered an important factor responsible for up to 72% of yield loss (Khan *et al.*, 2014; Prasad 2011). Rice root-knot nematode, *M. graminicola* is a serious pest of rice, and is economically most important plant-parasitic nematode infesting rice. This nematode has been recorded in many states of India, such as Jammu and Kashmir (Singh *et al.*, 2007), Kerala (Sheela *et al.*, 2005),Orissa (Rao *et al.*, 1986) Karnataka (Prasad *et al.*, 2010; Narasimhamurthy*et al.*,2015), West Bengal (Mukhopadhyay andKhan 2000; Khan and Murmu 2004) , Haryana, Himachal Pradesh, Panjab (Dabur and Jain 2005; Jain *et al.*, 2012; Singh and Singh, 2009), and Uttar Pradesh (Hassan *et al.*, 2004; Khan *et al.*, 2010)..Previously, *M. graminicola* was only seen in upland rice, but it has rapidly expanded to irrigated and deep-water rice in the last two decades. But recently due to government efforts (intensive-based subsidies) and increasing water shortage during paddy season, farmers are shifting from TR to DSR. Due to a congenital condition, this nematode becomes a channeling task in DSR. *M. graminicola* is an obligate sedentary endoparasite adapted to a wide range of water regimes and soil conditions and in India, this causes 16-32 percent yield loss under irrigated and 11-73 percent under flooded conditions (Tian *et al.*, 2018).

Due to its wide polyphagia, *M. graminicola* survives and reproduces in the off-season on certain weeds which commonly grown in or near the rice field, contributing to the increase of inoculum in the soil and then parasitizing rice cultivation in the next season (Pokharel *et al.*, 2007). In addition to the main host, rice, *M. graminicola* has a wide range of alternative hosts, including cereals and grasses, as well as dicotyledonous plants (Torrini *et al.*, 2020). The broad host range of this nematode is beneficial for maintaining the population in the absence of the main host, many researchers have reported that *M. graminicola* maintain the population multiplies on various weed host and maintain the population on weeds for the next season (Rich *et al.*, 2009, Kumar *et al.*, 2019). Commonly occurring weeds of the family Poaceaelike barnyard grass (*Echinochloa* spp.), *Dactylocteniumaegyptium*, and*Leptochloa chinensis* were reported as good hosts of *M. graminicola* (Kumar *et al.*, 2021). Moreover, *M. graminicola* complete its life cycle within 15 days at 27-37 °C (Jaiswal and Singh, 2010). It indicates that nematodes complete many generations in one crop season. Several reports show that various populations of *M. graminicola* have varying host ranges (Salalia, 2015). The

investigation was designed to gather information on examining the alternate weed host of the rice root-knot nematode, *M. graminicola*, associated with rice crops in Haryana, since *M. graminicola* is a serious nematode pest of rice in many non-traditional rice growing districts of the state where it is primarily used by the farmers.

Materials and Methods

Asurvey was conducted for alternate weed host of rice root-knot nematode,*M. graminicola* associated with rice crops in the major rice growing blocks of Fatehabad and Sirsa districts of Haryana during the kharif season of 2022. During the survey, eight locations/village Panchayats of Fatehabad and Sirsa districts were randomly selected for weed host identification of *M. graminicola*. The weed hosts were identified based on the field symptoms like patchy growth and characteristics hook shaped gall formation on plant roots. Terminated weeds are categorized on the number of galls /plants indexed on a 0-5 scale (Taylor and Sasser 1978). The confirmation of nematode species was done based on a perineal pattern of *M. graminicola* by following Taylor and Sasser's (1978) technique through mature females of stained root for each weed host in the Department of Nematology, CCS HAU, Hisar. The susceptibility/resistant response of the weed host was recorded in terms of galls that developed on each root system as follows

0. 0 galls/egg masses = Immune
1. 1-2 galls/egg masses = H.R. (Highly resistant)
2. 3-10 galls/egg masses = R (Resistant)
3. 11-30 galls/egg masses = MR (Moderately resistant)
4. 31-100 galls/egg masses = S (Susceptible)
5. >100 galls/egg masses = HS (Highly susceptible)

RESULTS AND DISCUSSION

A surveyfor alternate weed host of rice root-knot nematode, *M. graminicola* associated with rice crops in the major rice growing blocks of Fatehabad and Sirsa districts of Haryana during the Kharif season was conducted and data is presented in Table 1 & 2. A total of 726 samples of common weeds from rice fields with five samples for Poaceae and two samples for broad leaf weeds from both TR and DSR were collected. The collected samples were analyzed

for number of infected samples and number of galls. All the plants viz., *Dactyloctenium Egyptian* Beauv., *Echinochloa crus-galli, E. colona, Cynodondactylon, Leptochloa chinensis, Cyperus rotundus,* and *C. difformis,* except *Euphorbia hirta, E. prostrata,* and *Portulaca oleracea,* were found hosts of *M. graminicola,* although variation occurred in respect of number of galls/plant in different plant species.

A maximum number of galls/plant was observed in *Echinochloacolona* followed by *Echinochloacrusgalli* and *Cyperus difformis* having 185.50, 163.75, and 163.75, respectively at village Sikanderpur of Sirsa district in DSR. Whereas in TR maximum number of galls/plants (137.75) was observed in the village Bahauddin. A perusal of data in Table 1&2 indicated that *Euphorbia hirta, E. prostrata,* and *Portulaca oleracea* found nonhosts for *M. graminicola.* Developmental stages of nematode were also recorded in the roots of all the weed hosts, except *Euphorbia hirta, E. prostrata,* and *Portulaca oleracea*. *M. graminicola* is frequently associated with other cereals, as well as dicotyledonous and grass plants, including many weed flora that may constitute a major reservoir of nematodes (Rich *et al.,* 2009).

Results

Table 1: Survey of weed alternate host for rice root-knot nematode, *Meloidogyne graminicola*in Fatehabaddistict

Locations/ village	**Planting System**	**Weed (Scientific name)**	**Number of sample**	**Infected**	**Uninfected**	**Average no. of galls/plant**	**Scale index**
Phoolan	Transplanted Rice	(*Dactylocteniumaegyptium*Beauv.)	5	3	2	7.25	2
		Echinochloa crus-galli	5	4	1	115.50	5
		Echinochloacolona	5	4	1	137.30	5
		Cynodondactylon	5	2	3	9.70	2
		Leptochloa	5	3	2	93.25	4

		chinensis					
		Cyperus rotundus	5	3	2	97.50	4
		Cyperus difformis	5	4	1	87.40	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	4	1	9.00	2
		Echinochloa crus-galli	5	5	0	125.25	5
		Echinochloacolona	5	5	0	167.50	5
		Cynodondactylon	5	3	2	9.40	2
		Leptochloa chinensis	5	4	1	105.35	5
		Cyperus rotundus	5	3	2	99.45	4
		Cyperus difformis	5	5	0	94.25	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
Bharpur	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	2	3	4.30	2
		Echinochloa crus-galli	5	4	1	87.25	4

		Echinochloacolona	5	3	1	117.45	5
		Cynodondactylon	5	2	3	19.70	32
		Leptochloa chinensis	5	3	2	86.50	4
		Cyperus rotundus	5	2	3	91.50	4
		Cyperus difformis	5	4	1	92.25	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	2	3	16.25	3
		Echinochloa crus-galli	5	5	0	109.50	5
		Echinochloacolona	5	5	0	127.20	5
		Cynodondactylon	5	2	3	19.45	32
		Leptochloa chinensis	5	4	1	89.75	4
		Cyperus rotundus	5	2	3	93.25	4
		Cyperus difformis	5	4	1	96.50	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0

Ratta Khera	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	1	4	3.25	2
		Echinochloa crus-galli	5	3	2	90.25	4
		Echinochloacolona	5	4	1	117.30	5
		Cynodondactylon	5	1	4	19.45	32
		Leptochloa chinensis	5	4	1	76.50	4
		Cyperus rotundus	5	2	3	74.75	4
		Cyperus difformis	5	3	2	95.50	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	3	2	8.29	2
		Echinochloa crus-galli	5	4	1	134.50	4
		Echinochloacolona	5	5	0	137.75	5
		Cynodondactylon	5	2	3	21.30	32
		Leptochloa chinensis	5	4	1	76.45	4
		Cyperus rotundus	5	2	3	78.35	4
		Cyperus difformis	5	4	1	99.75	4
		Euphorbia hirta	2	0	2	0	0

		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
Jandwala Sotter	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	3	2	7.45	2
		Echinochloa crus-galli	5	4	1	105.75	5
		Echinochloacolona	5	5	0	127.50	5
		Cynodondactylon	5	2	3	21.75	3
		Leptochloa chinensis	5	4	1	79.50	4
		Cyperus rotundus	5	3	2	67.25	4
		Cyperus difformis	5	4	1	96.50	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	4	1	4.40	3
		Echinochloa crus-galli	5	5	0	105.25	5
		Echinochloacolona	5	5	0	13735	5
		Cynodondactylon	5	3	2	31.50	3
		Leptochloachinen	5	4	1	109.75	5

		sis					
		Cyperus rotundus	5	4	1	67.50	4
		Cyperus difformis	5	4	1	102.25	5
		Euphorbia hirta	2	0	2	0	0
		Euphorbia rostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0

Table 2: Survey of weed alternate host for rice root-knot nematode, *Meloidogyne graminicola*in Sirsa distict

Locations/village	**Planting System**	**Weed (Scientific name)**	**Number of sample**	**Infected**	**Uninfected**	**Average no. of galls/plant**	**Scale index**
Bahauddin	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	1	4	5.00	2
		Echinochloa crus-galli	5	3	2	105.50	5
		Echinochloacolona	5	2	3	137.75	5
		Cynodondactylon	5	2	3	13.25	3
		Leptochloa chinensis	5	3	2	93.50	4
		Cyperus rotundus	5	4	1	87.25	4
		Cyperus difformis	5	4	1	92.50	4
		Euphorbia hirta	2	0	2	0	0

		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	2	3	7.50	2
		Echinochloa crus-galli	5	4	1	115.75	5
		Echinochloacolona	5	3	1	139.25	5
		Cynodondactylon	5	2	3	13.75	3
		Leptochloa chinensis	5	4	1	96.50	4
		Cyperus rotundus	5	4	1	89.75	4
		Cyperus difformis	5	4	1	92.50	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
Sikanderpur	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	4	1	9.75	2
		Echinochloa crus-galli	5	5	0	87.25	4
		Echinochloacolona	5	5	0	127.50	5
		Cynodondactylon	5	2	3	15.75	3
		Leptochloa chinensis	5	4	1	76.20	4

		Cyperus rotundus	5	3	2	91.45	4
		Cyperus difformis	5	4	1	106.66	5
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	4	1	13.50	3
		Echinochloa crus-galli	5	5	0	163.75	5
		Echinochloacolona	5	5	0	185.50	5
		Cynodondactylon	5	3	2	15.35	3
		Leptochloa chinensis	5	5	0	112.25	5
		Cyperus rotundus	5	4	1	103.20	5
		Cyperus difformis	5	5	0	126.75	5
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
Dhottar	Transplanted Rice	(*Dactyloctenium aegyptium*Beauv.)	5	0	5	0	0
		Echinochloa crus-galli	5	3	2	76.50	4
		Echinochloacolo	5	4	1	97.00	4

		na					
		Cynodondactylon	5	1	4	16.75	3
		Leptochloa chinensis	5	3	2	79.25	4
		Cyperus rotundus	5	2	3	82.50	4
		Cyperus difformis	5	3	2	95.75	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
	Direct Seeded Rice	(*Dactyloctenium aegyptium*Beauv.)	5	4	1	6.20	2
		Echinochloa crus-galli	5	3	2	79.35	4
		Echinochloacolona	5	4	1	108.75	5
		Cynodondactylon	5	2	3	12.50	3
		Leptochloa chinensis	5	4	1	73.25	4
		Cyperus rotundus	5	3	2	85.50	4
		Cyperus difformis	5	4	1	99.75	4
		Euphorbia hirta	2	0	2	0	0
		Euphorbia prostrate	2	0	2	0	0
		Portulaca oleracea	2	0	2	0	0
Ding Chopta	Transpla	(*Dactyloctenium*	5	1	4	6.60	2

	nted Rice	*egyptium*Beauv.)					
		Echinochloa crus-galli	5	4	1	114.75	5
		Echinochloacolona	5	3	2	107.50	5
		Cynodondactylon	5	2	3	26.75	3
		Leptochloa chinensis	5	4	1	73.20	4
		Cyperus rotundus	5	1	4	61.25	4
		Cyperus difformis	5	3	2	89.75	4
		Euphorbia hirta	1	0	1	0	0
		Euphorbia prostrate	1	0	1	0	0
		Portulaca oleracea	1	0	1	0	0
	Direct Seeded Rice	(*Dactyloctenium egyptium*Beauv.)	5	2	3	7.2	2
		Echinochloa crus-galli	5	4	1	124.50	5
		Echinochloacolona	5	5	0	117.40	5
		Cynodondactylon	5	3	2	13.75	3
		Leptochloa chinensis	5	5	0	67.76	4
		Cyperus rotundus	5	2	3	59.26	4
			5	3	2	95.67	4
		Euphorbia hirta	1	0	1	0	0
		Euphorbia	1	0	1	0	0

		rostrate					
		Portulaca oleracea	1	0	1	0	0

Photo 1.

Galls on *Cyperus difformis*and rice plant

Photo 2.

Galls in close association of *Cyperus difformis*and rice

Photo 3.

Photo 4.

Our results are in conformity with those of Devi *et al.,* (2016) who observed that barnyard grass, chottisavank and badisavankwere good hosts of *M. graminicola.*Kumar *et al.,* (2021) reported that *Dactylocteniumaegyptium*and *Leptochola chinensis*were host of *M. graminicola.* Roy (1977) evaluated 46 weeds commonly grown in or around rice fields of Assam and many weeds were found as moderate to good hosts of*M. graminicola.M. graminicola* also has several alternative/collateral hosts such as *E. colonum, C. compressus, C. rotundus, Brachiaria ramose, Ranunculus pusillus* etc. These weeds were commonly encountered in rice fields of the Southern US and South-East Asian countries (Jain *et al.,* 2012).

Khan *et al.* (2004) observed 17 weeds associated with kharif and boro rice grown in Nadia district of West Bengal (India) and all these were supporting *M. graminicola* for their survival and multiplication in field situations. Some of the weeds like *Bothriochloa intermedia, Physalis minima, Alternanthera sessilis, Agropyron repens, D.aegyptiacum,* and *Sporobolus diander* were reported as new hosts of *M. graminicola*.Bajaj and Dabur (2000) reported that *C. difformis* (motha) a common weed of rice in Haryana as a host of *M. graminicola* and

demonstrated that it could multiply on the weed under rice-wheat crop sequence. Mac Gowan and Langdon (1989) also assessed 100 host plants of *M. graminicola*, which includes food, fodder, fruits, ornamentals and also certain weeds.Among 14 weeds observedin rice, 5 (*Echinochloacolona, Echinochloacrusgalli, Dinebraretroflexa, Eleusine indica,* and*Eclipta alba*) as alternate hostsof root*M. graminicola*(Raj*et al.*,2022).

Conclusion:

This study revealed thatamong 10 weeds observed in rice, 7 (*Echinochloacolona, Echinochloacrusgalli,Dactylocteniumaegyptium, Cynodondactylon, Leptochloa chinensis, Cyperus rotundus,* and *C. difformis*) were alternate hostsof rice root-knot nematodes. Among all villeges/location of Fatehabad and Sirsa *M. graminicola*problem is more in DSR than TR.

REFERENCES

Anonymous 2023. https://www.indiastat.com/Home/Login.

Bajaj, H. K and Dabur, K. P. (2000). *Cyperus deformis*, a new recorded of rice root knot nematode,*Meloidogynegraminicola. Indian Journal Nematology*,**30**(2):256.

Dabur, K. R., and Jain, R. K. (2005). Rice root nematode (*Meloidogyne graminicola*)—A threat to rice wheat cropping system. *Indian Journal Nematology*,**34:**237-238.

Devi, P., R. S. Kanwar, and A. Kumar(2016). Studies on population variation of *Meloidogynegraminicola* using some weeds, forage and vegetable crops, Forage Res., **42**: 135-139.

Hassan, M. G., Pant, V. R., and Devi, L. S. (2004). Infestation of rice root-knot nematode (*Meloidogyne graminicola*) associated with different varieties of rice in Allahabad District of Uttar Pradesh, India. *Indian Journal Nematology*,**34:**227.

Jain, R. K., Khan, M. R., and Kumar, V. (2012). Rice root-knot nematode (*Meloidogyne graminicola*) infestation in rice. *Arch. Phytopath. Plant Prot.***45:**635-645.

Jain, R. K., M. R. Khan, and Kumar, V. (2012). Rice rootknot nematode (*Meloidogyne graminicola*) infestation in rice, Archives of Phytopathology and Plant Protection, 45 : 635-645.

Jaiswal RK, Singh KP. A technique for studying the life cycle of *Meloidogyne graminicola* in rice roots; Int. Rice Res. Notes. 2010; 35:0117-4185.

Khan, M. R. and Murmu, B. (2004). Occurrence of *Meloidogyne* species and prevalence of races in West Bengal. *Annals of Plant Protection Sciences*, **12:**162-165.

Khan, M. R., Haque, Z., and Kausar, N. (2014). Management of the root-knot nematode *Meloidogyne graminicola* infesting rice in the nursery and crop field by integrating seed priming and soil application treatments of pesticides. *Crop Prot.*,**63:**15-25.

Khan, M. R., Mehboob, A., and Khan, U. (20100. Interaction of entomopathogenic nematode, *Steinernema masoodi* and root-knot nematode, *Meloidogyne incognita* on tomato. *Nematol. Mediterr*.**38:**177-183.

Khan, M. R., S. Ghosh, and S. P. Bhattacharya, (2004). Weed hosts of rice root-knot nematode, *Meloidogyne graminicola* from West Bengal. *Environmental Ecology*, 22 : 583-584.

Kumar, M., Chand, R., Kumar, V., Gautam, S. B. and Verma, H. (2019). Survey on alternate weed host of rice root-knot nematode, *Meloidogyne graminicola* in kharif Session. *Journal of Entomology and Zoology Studies*, **7(2):** 1287-1290.

Kumar, V., Kumar, A. and Mann, S. S. (2021). Host suitability of forage, vegetable, cereals and weeds to *Meloidogyne graminicola. Forage Research.,* **47** (3) : 359-362.

Ladha, J.K., Kumar, V., Alam, M.M.; Sharma, S.; Gathala, M.; Chandna, P.; Saharawat, Y.S.; Balasubramanian, V. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice-wheat system in South Asia. In Integrated Crop and Resource Management in the Rice–Wheat System of South Asia; Ladha, J.K., Singh, Y., Erenstein, O., Hardy, B., Eds.; IRRI: Los Baňos, Philippines, 2009; pp. 69–108.

Mac Gowan, J. B., and K. R. Langdon, (1989). Hosts of the rice root-knot nematode, *Meloidogyne graminicola.Nematology*,**172** : 1-4.

Mukhopadhyay, A. K. and Khan, M. R. (2000). Nematode pests in rice-wheat-legume cropping systems. Proceedings of Review and Planning Meeting and Training Workshop; 1999 April 5–10; New Delhi: Division of Nematology, Indian Agricultural Research Institute. Rice-wheat-

consortium Paper Series 7, New Delhi, India: Rice-Wheat Consortium for Indo-Gangetic Plains and Patancheru, Andrapradesh, India: ICRISAT. Distribution of *Meloidogyne graminicola* and other nematodes in rice-based cropping system in West Bengal. pp. 20–21.

Narasimhamurthy, H.B., Ravindra, H, Jayalakshmi, K, Lydia, T.M. and Saritha, A. G., (2015). Survey and mapping of rice rooknot nematode in Shivamogga and Davanagere districts of Karnataka State., International Rice Symposium- IRS., Hyderabad., p515.

Pokharel, R. R., G. S. Abawi, N. Zhang, J. M. Duxbury, and C. D. Smart (2007). Characterization of isolates of *Meloidogyne* from rice-wheat production fields in Nepal.*Journal of Nematology*, 39 : 221-230.

Prasad, J. S., Somasekhar, N., and Varaprasad, K. S. (2010). Nematode infestation in paddy. Pages 17-71 in: Nematode Infestations, Part I: Food Crop. M. R. Khan and M. S. Jairajpuri, eds. Indian Academy of Sciences, Bengaluru, India.

Prasad, R. (2011). Aerobic rice systems. *Adv. Agron.***111:** 207-247.

Raj R, Das TK, Pankaj, Banerjee T, Ghosh A, Bhattacharyya R, Chakraborty D, Prasad S, Babu S, Kumar V, Sen S and Ghosh S (2022). Co-implementation of conservation tillage and herbicides reduces weed and nematode infestation and enhances the productivity of direct-seeded rice in North-western Indo-Gangetic Plains. *Front. Sustain. Food Syst.*, **6:** 1017013. doi: 10.3389/fsufs.2022.1017013

Rao, Y.S., Prasad, J.S. and Panwar, M.S. (1986). Nematode pests of rice in India. In: NonInsect

Rich, J. R., J. A. Brito, R. Kaur and J. A. Ferrell, 2009 : Weed specie s as hosts of Meloidogyne: a review. *Nematropica*, **39** : 157-185.

Roy, A. K. (1977).Weed hosts of *Meloidogyne graminicola*. *Indian Journal of Nematology*, **7 :** 160-163.

Salalia, R.(2015). Study on the diversity, ecology and biomanagement of rice root-knot nematode, *Meloidogyne graminicola* Golden and Birchfield, 1965. Ph. D. thesis submitted to CCS Haryana Agricultural University Hisar. pp 80+x.

Sheela, M. S., Jiji, T., Nisha, M. S., and Rajkumar, J. (2005). A new record of *Meloidogyne graminicola* on rice, Oryza sativa in Kerala. *Indian Journal of Nematology*,**35:** 218.

Singh, S.K., & Singh, K.P. (2009). A first record of root-knot nematode (*Meloidogyne graminicola*) on wheat in Uttar Pradesh, India. *Journal of Mycology and Plant Pathology*,**39:** 340-342.

Singh, V. K., Kalia, C. S., and Kaul, V. (2007). New record of root-knot nematode, *Meloidogyne graminicola* infecting rice in Jammu. *Indian Journal of Nematology*,**37:** 94.

Taylor A. L, Sasser J. N. Biology, identification and control of root-knot nematode, Meloidogyne spp. Int. Deve., Raleigh. NC. USA, 1978, 111.

Tian, Z. L., Maria, M., Barsalote, E. M., Castillo, P. and Zheng, J. W. (2018). Morphological and molecular characterization of the rice root-knot nematode, *Meloidogyne graminicola*, Golden and Birchfeild, 1965 occurring in Zhejiang, China. *Journal of Integrative Agriculture*, **17:** 2724-2733.

Torrini, G., P. F. Roversi, C. F. Cesaroni, and L. Marianelli (2020). Pest risk analysis of rice root-knot nematode (*Meloidogyne graminicola*) for the Italian territory. EPPO Bull, 50 : 330-339.