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ENTOMOLOGY

A Way to Deal with the Root-Knot Nematode (*Meloidogyne graminicola*) in Transplanted Rice of West Bengal

Gautam Chakrabarty[1]*, Shanowly Mondal (Ghosh) [1], Anamika Kar[1], Kusal Roy[2] and Aniruddha Pramanik[2]

[1]All India Coordinated Research Project on Nematodes in Cropping Systems, Kalyani Center, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani-741235, Nadia, West Bengal, India
[2]Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur- 741252, Nadia, West Bengal, India

*Corresponding author: entogautam@gmail.com (ORCID ID: 0000-0003-1850-0487)

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ABSTRACT

A field experiment was conducted to study the management of root-knot nematode (*Meloidogyne graminicola*) in transplanted rice at Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia. The results revealed that all the treatments were significantly superior over check with respect to nematode population, root knot index and yield. Soil solarization of the nursery bed with 25 μm polythene sheet for 15 days during the month of May-June followed by soil application of Carbofuran 3G @ 1kg a.i. ha^{-1} at the 45th day after transplanting were reported to be the best way to manage the root knot nematode in rice with minimum soil and root nematode population (354.34 per 200 cc of soil and 363.91 per 5 gram root), root knot index (1.63) and maximum yield (2.35) with peak incremental cost benefit ratio. Highest percent reduction of soil and root nematode population with 53.59% of yield increase was recorded from the treated plots. However, nursery soil treatment with carbofuran 3G @ 0.3 g a.i. /m^2 and soil application @ 1 kg a.i. ha^{-1} at 45 DAT can also effectively control the nematode in transplanted rice.

Highlights

- Soil solarization of the nursery bed followed by soil application of Carbofuran 3G @ 1kg a.i. ha^{-1} may be used for the root knot nematode management in riceNematode population from soil and root may be minimized through soil solarisation of nursery bed

Keywords: Carbofuran, Management, *Meloidogyne graminicola*, Rice, Soil solarisation

Rice is one of the most important cereal crops in Asia where more than 90 per cent of the world's rice is grown and consumed. It is also a staple food for nearly half of the world population. Rice contributes 43 percent of total food grain production and 46 percent of total cereal production. However, among various pests and diseases that constitute important constraints in the successful crop production, plant parasitic nematodes play an important role and account for yield losses to a great extent. Rice root-knot nematode, *Meloidogyne graminicola*, is an emerging threat to rice cultivation in various rice growing regions of South East Asia where rice is extensively cultivated (Gaur and Pankaj, 2010). The nematode (*M. graminicola*) is found in Assam, Andhra Pradesh, Karnataka, West Bengal, Orissa, Kerala, Tripura and Madhya Pradesh (Jain *et al.* 2007). It is not only serious in the upland conditions but is also wide spread in deepwater and irrigated rice in many states of India (Amaussou *et al.* 2004). This nematode has been reported as a pest of rice causing 17-30% yield losses due to poorly filled kernels (Jain *et al.* 2007). It causes terminal, hook shaped or spiral galls, which are characteristic symptoms of the infection of this nematode species (Sheela *et al.* 2005; Khan *et al.* 2012). It has gained considerable attention during the recent times because of its damage potential to rice, particularly under water stress conditions (Dutta *et al.* 2012). The disease caused by this nematode is characterized by abnormal swelling of roots which is also known as root knots or galls, yellowing, stunting and wilting of plants depending on the initial population density of the nematode in soil. Numbers of *M. graminicola* decline rapidly after 4 months but some egg masses can remain viable for at least 14 months in the waterlogged soil. *M. graminicola* can also survive in flooded soil to a depth of 1 m for at least 5 months.

There are various methods available for the management of rice root-knot nematode including fallowing, flooding, deep ploughing, biological control and nematicide application. However, chemical pesticides are still the most effective means of management of nematodes in the rice ecosystem (Prasad *et al.* 2010). Imelda and Georges (2003) reported that crop rotation, fallow and nematicidal treatments in the naturally infested fields could manage *M. graminicola* populations and prevent yield losses. Application of Phosphonothioate 10G at 1 kg a.i./ha at the 7th day prior to uprooting plus the main field application at the 45th day after transplanting at 1 kg a.i./ha exhibited maximum reduction of *M. graminicola* and produced maximum yield (Das and Choudhury 2012). Integrated nematode management study in Assam showed that carbofuran treated nursery bed had minimum galls with 29.6% yield increase. (Sehgal *et al.* 2014). The pesticides are preferred by farmers as they give instant results, while other disease management practices only begin to give visible impact after considerable periods. But, the residue of chemicals used to disinfect the soil has made a great problem of nematode management as it has changed the soil environment by depleting soil biota and by killing all the beneficial bioagents and thus prompted the growth of plant parasitic nematodes. Hence, there is an urgent need to replace these hazardous pesticides with other alternatives, which are less toxic and eco-friendly (Abhishek *et al*. 2013 and Geeta *et al*. 2015). Soil solarization is a very popular way out for disinfecting soil from pathogen. Patidar *et al.* 2016 observed the use of indigenous essential oils in integrated nematode management strategies. Application of antagonistic bioagents like different fungus and bacteria has also become a most popular way to minimize nematode population in the field. With the above view, the present study was conducted with an objective to evaluate the effectiveness of the chemical pesticide like carbofuran, biocontrol agent *Pseudomonas fluorescens*, and neem cake along with soil solarisation process against root-knot of rice caused by *M. graminicola*.

MATERIALS AND METHODS

The present study was planned at the Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, in *Kharif* season of 2014 and 2016. The experiment was laid out in a complete randomised block design with six treatments (T1 - Untreated control, T2 - Soil solarization of the nursery bed with 25 μm polythene sheet for 15 days during May/June, T3 - T2 + Carbofuran (soil application) @ 1kg a.i. ha^{-1} at the 45th day after transplanting (DAT), T4 - Nursery treatment with carbofuran @ 0.3g a.i./ m^2 at sowing, T5 - Soil application of *Pseudomonas fluorescens* @ 20 g/m2 in nursery bed at sowing, T6 - Nursery treatment with carbofuran (soil application) @ 0.3 g a.i./m^2 and carbofuran (soil application) @ 1 kg a.i./ha at 45 DAT) and was replicated four times. Certified seeds of rice (*Oryza sativa* L.) Var – Shatabdi which is found to be the leading variety in this region but very susceptible to *M. graminicola* was selected for the experimental purpose. The seeds were soaked in water for 12 hours and then transferred to a clean muslin bag. The bag was hung in the shade for 24 hours to facilitate seed germination. Thereafter, the seeds were sown in the nursery bed and watered daily. The seed bed was prepared on the previously nematode infested plots where the initial nematode population was recorded @198 and 105 per 200 cc of soil in 2014 and 2016 respectively. The seedlings with four leaves stage and 12-15 cm height in the 28th day were transplanted at a spacing of 20 cm × 10 cm in the main field. The individual plot size was maintained 4 × 4 m^2. For each treatment a separate bed was prepared and the treatments were advocated. The plants were harvested after four months of sowing and subsequently dried for 2 weeks and thrashed separately with a mechanized thrasher to determine the grain yield (with seed husks, without grain milling). The observations were recorded on the following parameters - Initial

Nematode Population (INP) per 200 cc soil (nursery and main-field), Number of galls per 20 seedlings at nursery during uprooting, Final Nematode Population (FNP) per 200 cc soil and 5 g root (main-field), Rice gain yield per plot expressed as t/ha (main-field), Root Knot Index (RKI) at harvest (on 1-5 scale) and Incremental Cost Benefit Ratio (ICBR)

Soil populations of *Meloidogyne graminicola*

The initial population density of *M. graminicola* J2 in the soil of the nursery and main field and final nematode population from the main field were estimated by collecting the soil from the field and by extracting nematode from the soil using Cobb's decanting and sieving method (modified) followed by Baermann's funnel technique (Southey 1986).

Root galls and egg masses

During the experiment, plants were carefully uprooted and the roots were examined at the time of transplanting to count the numbers of galls per 20 seedlings and to determine the root knot index (RKI). The egg masses of *M. graminicola* do not develop on the root surfaces, but rather remain embedded in the root tissues. Hence, they were counted by tearing the galls under stereomicroscope (Khan *et al.* 2012). The final nematode population from 200 cc soil & 5g root in the main field were counted.

Statistical analysis

Analysis of variance (ANOVA) and least significant differences (LSDs) were calculated to identify the significant effect of treatments at the probability levels of $P \leq 0.05$, 0.01 and 0.001. The data transformation with square root transformation was done as and when necessary.

RESULTS AND DISCUSSION

The experimental result revealed that all the treatments were significantly superior over the control to minimize the number of galls per twenty seedlings. During 2014, minimum 3.00 numbers of galls (Fig. 1) were recorded in T_2 treatment where soil solarization of the nursery bed with 25 µm polythene sheet for 15 days during May/June and T_3 treatment where all the practices of T_2 along with soil application of Carbofuran @ 1kg a.i. ha^{-1} at 45 DAT were practiced. However, in 2016 the same was noticed as minimum in T_6 (2.50 galls) i.e. Nursery treatment with carbofuran (soil application) @ 0.3 g a.i./m^2 and carbofuran (soil application) @ 1 kg a.i. ha^{-1} at 45 DAT followed by T_4 where Nursery treatment with carbofuran @ 0.3g a.i./ m^2 at sowing was followed. These two treatments were found to be statistically on par. When the mean data of two years were taken in consideration, minimum gall was observed in T_6 followed by T_4 but there was no significant difference among the treatments. The parameter of root knot index (RKI) revealed that all the treatments were significantly effective to reduce RKI compared to the check. Minimum mean RKI (1.63) was observed in T_3 treatment and there was significant differences observed with the other treatments (Table 1). The present study was in consonance with the finding of Singh *et al.* 2015, who reported that the combined application of solarization (15 days) either with carbofuran 3G @ 1 kg a.i. ha^{-1} or *P. fluorescens* @1% WP @ 50 g/m^2, increased the seedling growth up to 30 day after sowing and reduced the number of galls and eggs per egg mass at the 24th day after sowing. With respect to the final nematode population in soil, T_3 treatment was seen to be the most effective with least number of populations in soil during 2014 and 2016. Minimum mean of 354.34 numbers of J_2 were recorded from T_3 followed by T_6 (376.29 per 200 cc of soil) and both the treatments were found to be statistically at par for the reduction of soil nematode population (51.80%). However, in case of root, nematode population minimum mean of 363.91 numbers of J_2 were recorded from T_3 followed by T_6 (406.88 per 5 gm. of root) and both the treatments were found to be statistically at par for reduction of root nematode population (55.99%) (Table 2). Ziaul (2013), reported that the soil application and root dip of *P. fluorescens* or *T. harzianum* + carbofuran was found to be the most effective and that it suppressed the gall formation (40-46%), egg mass production (45-57%) and soil population (56-64%) of *M. graminicola,* and increased the plant growth variables by 37-42%. Maximum yield of 2.35 t ha^{-1} that was 53.59 percent increase in yield over control was reported from T_3 followed by T_6 with 2.22 t ha^{-1} and 45.09 percent respectively. The rest of the treatments were also found to be effective to increase the yield. Narasimhamurthy *et al.* 2016 reported that the treatment combination of *Pseudomonas fluorescens*

Table 1: Effect of treatments on Root galls and Root Knot Index of *M. graminicola* at the time of transplanting and harvesting

Treatments	Galls / 20 seedlings			RKI (1-5 Scale)		
	2014	**2016**	**mean**	**2014**	**2016**	**mean**
T_1 - Untreated control	13.67	15.50	14.58	3.50	3.83	3.66
T_2 - Soil solarization of the nursery bed with 25 μm polythene sheet for 15 days during May/June	3.00	6.00	4.50	2.33	2.73	2.53
T_3 - T2 + Carbofuran (soil application) @ 1kg a.i./ha at 45 DAT	3.00	6.50	4.75	1.67	1.60	1.63
T_4 - Nursery treatment with carbofuran @ 0.3g a.i./ m² at sowing	4.67	2.75	3.71	2.50	2.98	2.74
T_5 - Soil application of *Pseudomonas fluorescens* @ 20 g/m² in nursery bed at sowing	3.33	8.00	5.66	2.67	2.53	2.60
T_6 - Nursery treatment with carbofuran (soil application) @ 0.3 g a.i./m² and carbofuran (soil application) @ 1 kg a.i./ha at 45 DAT)	4.67	2.50	3.58	2.33	2.35	2.34
SEm (±)	**0.69**	**1.14**	0.69	0.44	0.18	0.10
C.D. (5%)	2.17	3.47	2.11	1.39	0.55	0.29

Note: *Initial root knot nematode population: 198 juveniles/cm³ of soil, RKI – Root Knot Index.*

Table 2: Effect of different treatments on population of *M. graminicola* in main field condition

Treatments	*M. graminicola* (J_2/200 cc soil)			% reduction over control	*M. graminicola* (J_2 /5g root)			% reduction over control
	2014	**2016**	**mean**		**2014**	**2016**	**mean**	
T1	292.33 (17.10)	1178.00 (34.31)	735.17 (27.12)	—	522.33 (22.87)	1117.75 (33.36)	820.04 (28.62)	—
T2	174.67 (12.23)	845.50 (29.06)	510.08 (22.59)	30.61	361.67 (19.00)	789.50 (28.05)	575.58 (23.98)	29.81
T3	159.67 (12.67)	549.00 (23.35)	354.34 (18.80)	51.80	325.33 (18.02)	402.50 (19.96)	363.91 (19.07)	55.99
T4	236.00 (15.37)	901.00 (30.02)	568.43 (23.85)	22.68	382.67 (19.54)	766.25 (27.67)	574.46 (23.98)	29.94
T5	222.00 (14.93)	879.50 (29.66)	550.83 (23.48)	25.07	418.00 (20.42)	719.50 (26.72)	568.75 (23.80)	30.64
T6	160.33 (12.68)	592.25 (24.28)	376.29 (19.38)	48.81	344.00 (18.55)	469.75 (21.57)	406.88 (20.17)	50.38
SEm (±)	0.44	0.95	0.61	—	0.61	1.36	0.77	—
C.D. (5%)	1.34	2.88	1.84	—	1.87	4.14	2.35	—

Fig. 1&2: Hook shaped gall in rice root due to *M. graminicola*

Table 3: Effect of different treatments against *M. graminicola* on yield of rice at the time of harvest

Treatments	Yield (t/ha)			% increase over control	ICBR		
	2014	2016	mean		2014	2016	mean
T1 - Untreated control	1.16	1.90	1.53	—	—	—	—
T2 - Soil solarization of the nursery bed with 25 µm polythene sheet for 15 days during May/June	1.26	2.15	1.71	11.76	0.36	2.51	1.44
T3 - T2 + Carbofuran (soil application) @ 1kg a.i./ha at 45 DAT	1.95	2.75	2.35	53.59	1.75	2.35	2.05
T4 - Nursery treatment with carbofuran @ 0.3g a.i./ m² at sowing	1.28	2.37	1.82	18.95	0.68	7.28	3.98
T5 - Soil application of *Pseudomonas fluorescens* @ 20 g/m² in nursery bed at sowing	1.33	2.14	1.73	13.07	0.70	1.87	1.29
T6 - Nursery treatment with carbofuran (soil application) @ 0.3 g a.i./m² and carbofuran (soil application) @ 1 kg a.i./ ha at 45 DAT)	1.84	2.60	2.22	45.09	1.92	2.38	2.15
SEm (±)	0.13	0.07	0.18	—	—	—	—
C.D. (5%)	0.41	0.22	0.56	—	—	—	—

Note: *ICBR – Incremental Cost Benefit Ratio.*

at 20g/m² + carbofuran (0.3 g a.i/m²) showed the highest plant height, root length, maximum grain yield and least nematode population with the reduction of 79.34% nematode population. On the other hand, When the incremental cost benefit ratio was calculated it was reported that the treatment T_3 yielded the highest value of 3.98 followed by T_6 (Table 3). Soil solarisation of nursery beds for 15 days and the application of carbofuran 3G at 15g/m² to the nursery for the effective management of root knot nematode (Ravindra 2006) were used. Senthilkumar *et al.* 2008, reported that Carbofuran 3G resulted in the lowest root gall index (3.00), and highest shoot weight (8.19 g) and root length (24.71 cm). Other researchers have also reported the effectiveness of carbofuran against rice root-knot nematode (Mohanty *et al.* 2000; Soriano and Reversat, 2003; Khan *et al.* 2012).

CONCLUSION

The present study implies that soil solarization of the nursery bed with 25 µm polythene sheet for 15 days during the month of May-June followed by soil application of Carbofuran 3G @ 1kg a.i. ha^{-1} at 45 DAT is the best way to control the root knot nematode in rice. Again nursery soil treatment with carbofuran 3G @ 0.3 g a.i. /m² and soil application @ 1 kg a.i. ha^{-1} at 45 DAT can also effectively control the nematode in transplanted rice.

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