



Integrated management of *Meloidogyne graminicola* under basmati rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

Survey conducted in and around village Bambawad, Gautam Budh Nagar, UP, for nematode population density infested basmati rice and wheat during 2015 indicated low population of rice root-knot nematode, *Meloidogyne graminicola* in IPM adopted fields compared with farmer's practices (FP). With this view, the study was carried out to manage *M. graminicola* under basmati rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system taking advantage of IPM technology developed and validated by ICAR-NCIPM for basmati rice during 2016–19 with some modifications such as soil solarisation, bio-agents etc. Soil solarisation of nursery beds reduced population density of test nematode up to 93.4%, whereas an increase of up to 46% in FP compared to initial population. Analysis of root and soil samples of both rice and wheat crop from IPM fields showed either no visible galling or only 1-3% root galling severity (RGS) and significantly ($P>0.05$) low population density compared to FP. In addition, the population of beneficial soil nematodes (BSN) remained high and significantly ($P>0.05$) higher in IPM as compared to FP with student's t-test. Role of BSN in increasing the nutrient availability through organic matter decomposition has already been established. It is evident from the study that IPM technology might have played important role in antagonising the *M. graminicola* and increased the density of BSN. This technology could be a safe and eco-friendly alternative to manage *M. graminicola* below ETL. Also, it has helped in sustaining IPM by the way of saving on the cost of application of pesticides and enhancing the benefit-cost ratio.

Keywords: Basmati rice, Bio-agents, Cropping system, IPM, *Meloidogyne graminicola*, Wheat

Rice and wheat are world's two most important cereal crops which are grown now in sequence season after season on the same land. It brings pest and diseases of both crops together and adapted the climatic requirement of one another particularly in Indo-Gangetic plains of the Indian subcontinent (Pankaj *et al.* 2010). There has been substantial increase in the area cultivated to rice-wheat cropping system which could be possible by development of short duration and high yielding varieties, i.e. Pusa Basmati 1121 and HD 2967 of rice and wheat respectively. In India, among biological constraints, the rice root-knot nematode *Meloidogyne graminicola* has become an emerging problem since last one decade under rice – wheat cropping system and caused up to 32% yield loss (Jain *et al.* 2007). Besides, *M. graminicola*, rice root nematode, *Hirschmanniella oryzae* was also detected in some fields (Goswami *et al.* 2015). Survey conducted for soil nematode population at Bambawad (Gautam Budh Nagar, UP) during 2015

indicated low population of *M. graminicola* in integrated pest management (IPM) adopted basmati rice fields as compared to non IPM or farmer's practice (FP) fields. It encouraged researchers and felt desirable to widen the scope of present successful and sustainable technology to a largescale to manage rice root-knot nematode, *M. graminicola* in addition to insect pests and disease under basmati rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system during 2016-2019.

The IPM technology comprises: 1) soil solarisation of nursery beds area; 2) 2-3 deep summer ploughing; growing *Sesbania* or mung bean for green manuring; 3) seed treatment with carbendazim at 1 g a.i. /kg; 4) seedling root dipping in plant growth promoting rhizobacteria (PGPR) *Pseudomonas fluorescens* solution (3.0×10^{10} cfu colony forming units) at 5 ml/l of water) and 5) application of *Trichoderma harzianum* (3×10^8 cfu), applied after the harvest of both wheat and rice crops to decompose straw waste in the field with other IPM components (Tanwar *et al.* 2016). In the present article, only important IPM components pertaining to management of *M. graminicola* will be discussed.

MATERIALS AND METHODS

Soil samples were drawn from both IPM and non-IPM fields (farmer's practices) (FP) before sowing, mid-season

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and after harvest of each crop and analysed for nematode population counts, in order to determine population of *M. graminicola* nematodes. Nematode population from soil was assessed by using modified Cobb's sieving and gravity method followed by Baerman's funnel technique (Southey 1986). Four weeks old seedlings from nursery and seven week old rice plants from main fields randomly selected from both IPM and FP fields, which were carefully removed and the adhering soil washed off for assessment of root galls. Root gall severity was rated on a scale of 1 to 9, i.e. 1= indicates no visible galling; 2=1-3%; 3=4-10%; 4=11-25%; 5=26-35%; 6=36-50%; 7=51-65%; 8=66-80% and 9=>80% of the root system galled (Viaene and Abawi 1996).

Bio-agents, *T. harzianum* used during present investigation was commercial preparations and procured from market, whereas *P. fluorescens* liquid preparation was made available by bio-control lab, NCIPM for seedling root dip. The bio-agents were re-isolated from soil of IPM fields using serial dilution and plating technique. The dilutions were prepared up to 10^{-6} and 0.1 ml of each 10^{-5} and 10^{-6} dilutions were spread on Petri plates containing appropriate media followed by incubation at $25\pm 2^{\circ}\text{C}$ for 15 days. The developed colonies were then counted and calibrated to 10^3 cfu/ml. Data on IPM vs FP on root gall severity and soil population were analysed and subjected to student's *t*-test to compare the mean difference at 5% level of significance. Based on calculated *t*-value, $P > 0.05$ or $P < 0.05$ was determined, with interpretation that if *t*-value exceeds the critical value, to be called as significantly

different otherwise non-significant.

RESULTS AND DISCUSSION

Fallowing + summer ploughing and green manuring with *Sesbania* under main fields reduced rice root-knot nematode, *M. graminicola* population up to 68% and 47% respectively, however, only fallowing reduced it by 27% compared to initial population. Both practices are important component of present IPM technology which are used as pre-treatment to reduce initial inoculum level of rice root-knot nematode, *M. graminicola*. Our observations confirmed previous reports that fallowing and summer ploughing when applied as pre-treatment, reduced *M. incognita* population by up to 51% and 53.8% on eggplant (Singh 2013) and on chilli crop (Singh and Singh 2012) respectively.

The soil solarisation in nursery beds (Table 1) effectively reduced *M. graminicola* populations. The seedlings obtained from the solarized nursery beds grew vigorously and were distinctly healthier compared to FP (non-solarized beds). Data on *M. graminicola* population presented in Table 1 showed that initial population ($P < 0.05$) was similar over the years (2016-17 to 2018-19) in both IPM as well as FP nurseries which were then solarised. Results showed that number of *M. graminicola* juveniles in soil after 28 days were significantly ($P > 0.05$) higher in FP compared to solarised nursery beds. A reduction of up to 93.4% over the years was recorded as compared to respective year's initial population and improved seedling growth. Whereas, an increase up to 46% was recorded under FP (Table 1).

Table 1 Root gall severity (RGS) caused by rice root-knot nematode, *Meloidogyne graminicola* on basmati rice and wheat in IPM and FP fields under basmati rice – wheat cropping system from 2016-17 to 2018-19

Year	Root gall severity/swellings per 10 plants/seedlings (Average of 10 nursery beds/fields of 1 ha)											
	Rice						Wheat					
	RGS after 25 DAS (nursery beds)		RGS after 45 DAT		RGS after 90 DAT		RGS after 25 DAS		RGS after 45 DAS		RGS after 90 DAS	
	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP
2016-17	1.9 (24.9±6.5)* {3.1±3.0}** [-87.5]	2.8 (29.7±9.4)* {50.7±10.0}** [+41.4]	2.7	3.4	3.0	6.5	1.0	2.2	1.3	2.8	1.0	3.0
2017-18	1.5 (22.6±9.8)* {8.1±4.5}** [-64.2]	3.1 (31.9±9.7)* {41.6±9.9}** [+23.3]	1.1	4.4	1.3	7.7	1.0	2.8	1.0	2.6	1.0	2.5
2018-19	1.3 (28.9±15.3)* {1.9±1.0}** [-93.4]	3.8 (19.3±9.7)* {36.2±10.0}** [+46.7]	1.5	4.2	1.8	6.1	1.0	2.3	1.7	2.5	1.0	3.2

IPM – IPM module field; FP – Farmer's practice (non-IPM Field); DAS-days after sowing; DAT-days after transplanting; *Figures presented in parentheses () are non-significant initial population of *M. graminicola*, i.e. mean value ± standard deviation; **Figures presented in parentheses { } are significant final population of *M. graminicola*, i.e. mean value ± standard deviation; test of significance (student's *t*-test) significantly different at 5% level of significance; Figures presented in parentheses [] and bold are percent increase (+) or decrease (-) over initial population.

Table 2 Rice root-knot nematode, *Meloidogyne graminicola* and saprophytic nematode population in basmati rice and wheat fields under IPM and FP practices under basmati rice – wheat cropping system from 2016-17 to 2018-19.

Year	Rice knot-knot nematode, <i>Meloidogyne graminicola</i> and saprophytic nematode population/150 cc soil											
	Rice					Wheat						
	Pre-transplanting	Mid-season (45 DAT)	Final at harvest	Pre-sowing	Mid-season (45DAS)	Final at harvest	Pre-sowing	Mid-season (45DAS)	Final at harvest			
	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP		
2016-17	(184.7 ± 34.0) [598.6 ± 22.9]	(195.8 ± 44.1) [679.6 ± 27.5]	(150.3 ± 59.7) [973.6 ± 100.2]	(204.4 ± 60.3) [933.9 ± 75.5]	(129.9 ± 30.4) [1051.7 ± 69.5]	(172.0 ± 48.6) [817.1 ± 70.1]	(57.8 ± 10.9) [1195.1 ± 90.5]	(114.5 ± 16.5) [982.5 ± 100.2]	(43.1 ± 5.9) [1263.2 ± 80.7]	(129.3 ± 23.6) [1101.1 ± 20.1]	(109.3 ± 26.1) [999.8 ± 16.4]	
t-test	NS	NS	NS	NS	NS	NS	S***	S***	S***	S***		
2017-18	(23.2 ± 6.4) [1127.2 ± 175.7]	(105.9 ± 16.5) [830.3 ± 104.2]	(31.2 ± 3.0) [2096.9 ± 179.8]	(198.6 ± 17.7) [1060.3 ± 62.3]	(12.2 ± 4.6) [2350.3 ± 59.9]	(166.2 ± 40.8) [1117.8 ± 48.2]	(17.4 ± 5.1) [2523.8 ± 61.5]	(194.6 ± 67.1) [1230.7 ± 53.1]	(23.9 ± 5.9) [2846.9 ± 90.7]	(167.3 ± 52.9) [1150.4 ± 65.3]	(137.7 ± 29.4) [1197.1 ± 80.2]	
t-test	S***	S***	S***	S***	S***	S***	S***	S***	S***	S***		
2018-19	(14.4 ± 7.4) [2147.2 ± 66.4]	(122.0 ± 20.2) [920.4 ± 55.6]	(13.3 ± 4.3) [2837.3 ± 352.9]	(154.0 ± 30.8) [1011.1 ± 30.8]	(13.4 ± 3.8) [3385.1 ± 132.4]	(163.9 ± 8.9) [1152.9 ± 60.2]	(28.8 ± 7.6) [3409.2 ± 190.5]	(169.3 ± 9.5) [1120.7 ± 125.7]	(12.7 ± 9.5) [3350.3 ± 65.6]	(99.1 ± 15.9) [200.2]	(25.2 ± 8.9) [3423.9 ± 146.1]	(141.2 ± 25.6) [1164.4 ± 131.9]
t-test	S**	S**	S**	S**	S**	S**	S**	S**	S**	S**		

Figures presented in parenthesis () are mean value ± standard deviation of root-knot nematode, *M. graminicola* population; Figures presented in parenthesis [] are mean value ± standard deviation of saprophytic nematode population; IPM – IPM module field; FP – Farmer’s practice (non IPM Field); DAT-days after transplantation; DAS-days after sowing; **test of significance (student’s-t-test), significantly different at 5%; S- significant; NS – non-significant.

The effect of soil solarisation was studied earlier by Gaur (2013) who reported that the nematode become undetectable in the upper 15 cm soil layer after soil solarisation. Results (Table 1) showed significantly ($P>0.05$) higher nematode population in nursery beds (FP) compared to solarised beds (IPM) where seeds were treated with carbendazim. It has been reported earlier by authors (Singh *et al.* 2019) under *in-vitro* and *in-vivo* studies that carbendazim caused 93% mortality of *M. graminicola* juveniles after 96 h in sterile water. Further, seed treatment with carbendazim effectively reduced number of galls but failed to check nematode population in soil, as the presence of carbendazim on the rootlets at initial stage prevents the entry of *M. graminicola* juveniles into rootlets and with time, effect of carbendazim got reduced and thereby failed to stop the penetration and multiplication of *M. graminicola* at later point.

The other components of IPM technology, i.e. seedlings root dip with PGPR, *P. fluorescens* (3.0×10^{10} cfu) at 5 ml/l of water at the time of transplanting, and *T. harzianum* applied after harvest of each crop to fasten the decomposition of the straw/remaining stubbles, helped to reduce the nematode multiplication. Second year onwards the impact of *T. harzianum* was visible vis a vis to *P. fluorescens* in both rice and wheat crop. As evident from the data (Table 1 and 2) root invasion and soil population of *M. graminicola* under IPM significantly ($P>0.05$) reduced compared with FP. It seems that seedling root dip with *P. fluorescens* was highly effective in suppression of *M. graminicola* due to its higher root colonisation on rice roots. Several workers recorded significant suppression of number of galls and soil population of *M. graminicola* using *T. harzianum* alone or in combination of other management components (Pankaj *et al.* 2010, Huong *et al.* 2009). Nematode multiplication in terms of root gall severity (RGS), a consequent reduction in RGS was recorded over the years under IPM (Table 1) as compared to farmer's practice, and it further showed RGS between 1 and 2 means below 1-3% galling on seedlings under IPM adopted nurseries. In general, wheat crop showed lower RGS ranges from 1 to 1.3 in IPM and 2.2 to 3.2 under farmer's practice as compared to rice crop ranges from 1.1 to 3 (after 90 days of transplanting first season crop) in IPM and 3.4 to 7.7 in FP for three years (Table 1). Our observations confirmed previous reports with regard to reducing nematode population by *P. fluorescens* and *T. harzianum* (Narsimhamurthy *et al.* 2017).

Nematode population density under rice-wheat cropping system from 2016–2019 is presented in Table 2. It is clear from the data that during 2016–17 the number of *M. graminicola* present in soil did not show any significant difference ($P<0.05$) when compared with IPM and FP fields but in the same year during wheat season it showed significant difference ($P>0.05$). However, lesser number of *M. graminicola* was recorded in the soil of wheat crop as compared to rice crop which was a trend recorded in the subsequent years 2017-18 and 2018-19. It seems that the multiplication of *M. graminicola* hampered due to low winter temperature, activity of introduced bio-agents (*P.*

fluorescens and *T. harzianum*) and increased organic matter due to *Sesbania* green manuring but it sustained on wheat crop during winter season and multiplied well in next rice crop. However, under IPM adopted basmati rice fields *M. graminicola* population remains much lower than the economic injury threshold level (ETL). It is established fact that to ensure higher rice yields, *M. graminicola* populations should be maintained at low density, i.e. below ETL. Previous workers recommended rotation with non-host crop, ideally for two seasons and, application of chemical pesticides before planting rice (Pankaj *et al.* 2010, Dutta *et al.* 2012) to minimize the loss caused by *M. graminicola*. The present IPM technology ensures and maintained not only low density of *M. graminicola* without disturbing agricultural ecosystem and human health, also reduced the cost of cultivation resulted in higher profit.

In spite of significant beneficial roles in the soil environment, researches has given less attention to the free living nematodes-(non-plant feeders), however, these nematodes played an important role in nitrogen mineralization, increased availability of nitrate and ammonium which is important for plant growth and vigour (Hailu and Hailu 2020) and improved agricultural productions (Nahar *et al.* 2006). In present investigation, an attempt has been made to assess the effect of IPM technology on number of these beneficial soil nematodes (BSN). Data presented in Table 2 indicated significantly ($P>0.05$) higher population density of BSN under IPM adopted fields over the years as compared to FP. However, number of BSN at the start of initiation of trials year, i.e. 2016-17, IPM and FP field did not show any statistical difference ($P<0.05$) throughout the rice season. An increase in the number of BSNs were recorded from 598 to 3423 (82%) under IPM fields in comparison to 41% (from 679 to 1164) under FP fields.

The current study provides evidence that IPM technology developed by ICAR-NCIPM to manage insect pests and diseases of basmati rice could manage rice root-knot nematode, *M. graminicola* successfully under rice-wheat cropping system, which may have a future for management of *M. graminicola*. It is also notable that tested IPM components which integrated in the present IPM technology can be considered as a strong candidate for management of rice root-knot disease of rice caused by *M. graminicola* and helpful for increasing the productivity. Accordingly, this package of management practices (IPM technology) could be a safe, sustainable and eco-friendly alternative for controlling rice root-knot pest of rice caused by *M. graminicola*.

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