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RESEARCH PAPER

Management of rice root-knot nematode (*Meloidogyne graminicola* Golden and Birchfield)–An integrated approach

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Abstract : An experiment was conducted to know the efficacy of bio agents *viz., Purpureocillium lilacinum, Trichoderma harzianum, Bacillus subtilis,Bacillus megaterium,* Vermicompost and Consortium of bio-agents (*Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillusmegaterium* +Vermicompost) and Carbofuran3G @ 0.3 *i.e.,* alone for management of rice root-knot nematode *Meloidogyne graminicola* for one season at Chikadadakatte village of Honnali taluk, Davanagere district during *Kharif*- 2018. The results revealed that all the treatments were significantly superior over check with respect to growthparameters and nematode population. However, carbofuran 3G significantly reduced the nematode population (275.11 /200 cc soil)which was found to be the best treatment as it recorded highest plant height (114.06 cm), root length (23.13 cm), maximum grain yield (44.60 q/ha) with least RKI (1.20) followed byConsortium of bio-agents (*Purpureocilliumlilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillusmegaterium* +Vermicompost).

Key Words : Bio-management, *Meloidogyne graminicola,* Rice, Rice root-knot nematode

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INTRODUCTION

Rice (*Oryza sativa* L.) is second most important cereal and the staple food for more than half of the world's population. It provides 20 per cent of the worlds dietary energy supply followed by Maize and Wheat. The production of rice to be achieved by 2020 is 128 Mt to feed the growing population in India. To meet the global demand, it is estimated that about 114Mt of additional milled rice needs to be produced by 2035 with an increase of 26 per cent in next 25 years. Worldwide the annual losses due to rice diseases estimated to be 10-15 per cent. Depending upon the age of the plant, time of infection and severity, disease cause yield loss to the extent of 5.9 to 69 per cent (Venkat Rao *et al.,*1990; Naidu, 1992).It is cultivated in five major ecosystems *viz.,* irrigated, deep water,upland, lowland and rainfed rice. About 53% of the world's rice is grown under irrigatedconditions that provide 75% of total global production. Rainfed lowland rice (31% of theworld rice area) is entirely dependent on rainfall, whereas, the deep

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water area (35%) occurs inthe river deltas. Upland rice area (13%) is also rainfed but without surface water accumulation

(Bridge *et al*., 2005). It is affected by several biotic and abiotic stresses, of which, plant parasitic nematodesconstitute an important component (Jain *et al*., 2012). Over 200 species of plant parasitic nematodes (PPN) have beenreported to be associated with rice (Prot, 1994) and are becoming increasingly important in the rapidlychanging production system of rice (Coyne *et al*., 2000). Gaur and Pankaj (2010) studied the common nematode pest of rice and reported that rice is quite susceptible to root-knot nematode and is attacked by species like *M.graminicola, M. triticoryzae, M. incognita, M. javanica, M. oryzae*and *M. arenaria*. Sasser (1989) studied the root knot nematode infestation in agricultural crops and reported that *Meloidogyne* spp. is one of the most devastating and widespread nematode pests of agricultural crops. *M. graminicola*causes terminal, hook shaped or spiral galls which are characteristic symptoms of the infection of this nematode species. In India, about 16-32% yield loss occurred due to the infestation of this nematode in rainfed and upland rice (Prasad *et al*., 2010). Dutta *et al*. (2012) reported that *M. graminicola*is a primary pest of rice and poses a substantial threat to rice cultivation in Southeast Asia. Nematode management is an obligation for successful production of rice. There are few nematicides available for the control of nematodes. However, they are not being used by the farmers because of their high cost, non-availability, phytotoxicity, health hazards to field workers and pollution to the environment (Ravindra, 2007). Integration of chemicals and bio-agents for managing nematode diseases has been considered as a novel approach, as it requires low amounts of chemicals thereby reducing the cost of management as well as soil and groundwater pollution, with minimum interference to biological equilibrium (Papavizas, 1973). Hence, the present investigations were taken up to study the feasibility of using bio-control agents, organic amendment, and chemicals in the management of rice root-knot nematode (*M. graminicola*) under field situation.

Material and Methods

The study was conducted in the month of June, *Kharif*-2018 in a field naturally infested with *M. graminicola*at Chikadadakatte village of Honnali taluk, Davanagere district Karnataka, India). The experiment was laid out in a Randomized Complete Block Design (RCBD) by maintaining eight treatments withthree replication. The susceptible variety Sree Aman was used forthis study and twenty four day old seedlings were transplantedin the field using two seedlings/ hill with a spacing of 20 x 20cm. The crop was transplanted during 3rd week of June.

Treatment details:

T_1= Carbofuran 3G at 9.9g/ m²

T_2=*Purpureocilliumlilacinum*@20g/m²+ Vermicompost @ 100gm/m²

T_3=*Trichodermaharzianum*@20g/m²+ Vermicompost @100gm/m²

T_4= *Bacillus subtilis* @ 20g/m² +Vermicompost @ 100gm/m²

T_5=*Bacillusmegaterium*@20g/m² + Vermicompost @ 100gm/m²

T_6= Consortium of *P.lilacinum*@ 20g/m² +*T. harzianum*@ 20g/m²+*Bacillus subtilis* @ 20g/m² +*Bacillusmegaterium* @ 20g/m² +Vermicompost @ 100gm/m²

T_7 = Vermicompost @ 100gm/m²

T_8= Control

The observation on plant growth parameters such as plantheight (cm), root length (cm), root weight (g) and grain yieldper plot, Root Knot Index, nematode populations in 200ccsoil, number of galls/root system were recorded. The soilpopulation of *M. graminicola* was determined using Cobb'sdecanting and sieving method (modified), followed byBaermann's funnel technique (Southey, 1986) and root knot index wasrecorded based on 0-5 rating scale according to the number ofgalls per root system in which 0=No galls (Immune), 1=1-2 galls/root system (Resistant), 2=3-10 galls/rootSystem (Moderately resistant) 3=11-30 galls/ rootsystem (Moderately susceptible) 4=31-100 galls/root system (Susceptible) and 5=>100 galls/root system (Highlysusceptible).

Statistical analysis:

The data obtained in the present investigation regarding parameters such as plant height (cm), root length (cm), rootweight (g) and grain yield per plot, nematode populations in200cc soil, number of galls/root system and number of eggmasses/ root system were subjected to statistical analyses for *in-vivo* studies.

Results and Discussion

The present study results revealed that all the treatments weresignificantly superior over untreated check with respect toplant growth parameters and nematode population. The resultsobtained from the present study are given in Table 1, 2, 3 and 4.

Effect of bioagents on plant growth parameters of rice:

Effect on plant height :

The plant height of rice at 30 DAT is differed significantly in various treatment and also all the treatments were significantly superior over untreated check (34.77cm). The higher plant height was observed in plots treated with carbofuran 3G alone (45.27cm) followed by contortium of bioagents (*Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillus megaterium* +Vermicompost) (44.17 cm), respectively. The plots which was treated with vermicompost alone recorded the minimum plant height of (35.17 cm) and found to be significantly superior compared to check.The similar trends were observed at60, 90 and at the time harvest (Table 1).

Effect on root length:

The root length in various treatments differed significantly.All treatments registered higher length compared to check.The effect of soil application of carbofuran 3G showing highest root length compared to all other treatments which were differed significantly. The maximum root length of 23.13 cm observed plot incorporated with carbofuran 3G followed by consortium of bioagents *viz., Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillus megaterium* +Vermicompost (20.43 cm) which was followed by the treatment *Paceilomyces lilacinus*+ Vermicompost recorded a root length of 20 cm followed by *Trichoderma harzianum*+ Vermicompost (19.53 cm) and the least root length was observed in control plot (12.27 cm). With respect to root weight the incorporation of carbofuran 3G registered highest fresh root weight and dry root weight compare to untreated check where fresh root weight recorded was 7.12 g and dry root weight (3.35 g). The highest fresh root weight of 9.19 was recorded in plots incorporated with carbofuran followed by consortium of bioagents *viz., Purpureocillium lilacinum* + *Trichoderma harzianum* +*Bacillus subtilis*+*Bacillus megaterium*+ Vermicompost where fresh root weight recorded was 8.94 g. *Purpureocillium lilacinum*+Vermicompost recorded a fresh root weight of 8.78 g followed by *Trichoderma harzianum*+Vermicompost (8.71 g) which were on par with each other and the least control plot recorded a lowest fresh weight of 7.12 g. The highest dry root weight (4.79 g) was recorded in incorporation of carbofuran 3G followed by (4.60 g) *Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillus megaterium* +Vermicompost which were on par with each other and treatment *Purpureocillium lilacinum*+Vermicompost had recorded a dry root weight of 4.60g which was followed by treatment *Trichoderma harzianum*+Vermicompost (4.45 g) which were also on par with each other. Lowest dry

Table 1: Effect of bio-agents on plant growth parameters of rice infested by rice root knot nematode

Treatments	Plant height(cm)				Root length (cm)	Root weight (g)	
	30DAT	60DAT	90DAT	At harvesting stage		Fresh root weight	Dry root weight
T_1	45.27 (6.80)	92.57 (9.67)	114.06 (10.72)	124.36 (11.19)	23.13 (4.91)	9.19 (3.19)	4.79 (2.40)
T_2	43.43 (6.66)	90.87 (9.58)	108.83 (10.48)	121.60 (11.07)	20 (4.58)	8.78 (3.13)	4.60 (2.37)
T_3	42.63 (6.60)	89.97 (9.53)	107.63 (10.42)	120.03 (11.00)	19.53 (4.53)	8.71 (3.12)	4.45 (2.33)
T_4	37.27 (6.18)	88.50 (9.46)	105.43 (10.31)	119.16 (10.96)	19 (4.46)	8.41 (3.07)	4.31 (2.30)
T_5	36.33 (6.10)	88.87 (9.47)	105.10 (10.30)	118.66 (10.93)	17.97 (4.35)	8.2 (3.03)	4.25 (2.29)
T_6	44.17 (6.72)	91.63 (9.62)	111.00 (10.58)	122.36 (11.10)	20.43 (4.63)	8.94 (3.15)	4.71 (2.39)
T_7	35.17 (6.01)	86.67 (9.36)	104.43 (10.26)	117.36 (10.87)	16.63 (4.20)	8.1 (3.02)	4.14 (2.27)
T_8	34.77 (5.98)	85.93 (9.32)	100.86 (10.09)	115.83 (10.80)	12.27 (3.64)	7.12 (2.85)	3.35 (2.09)
S. E.±	0.12	0.16	0.08	0.03	0.08	0.02	0.05
C.D. (P=0.05)	0.38	0.51	0.26	0.09	0.26	0.07	0.16

DAT= Days after transplanting

* Figures in the parenthesis are square root transformed value

root weight was recorded in control *i.e.,* 3.35g.

Effect on grain yield and RKI :

Data on the efficacy of bio-agents on grain yield and RKI ofrice was recorded at the time harvests are presented in the Table 2. All the treatments recorded significantly higher yield and least RKI compared to untreated control.The yield of rice per plot was significantly higher in all the treatments compared to untreated check (33.53 q^{-1}ha). Maximum yield was recorded in plants treated with carbofuran (44.60q^{-1}ha) and RKI (1.3) which is followed by consortium of bioagents *viz*., *Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillus megaterium* +Vermicompost (43.13q^{-1}ha) and RKI (1.5). While least yield and maximum RKI was observed in untreated control.

Table 2: Effect of bioagents on yield and RKI of rice infested with rice root knot nematode

Treatments	Yield (q^{-1}/ha)	RKI (0-5)
T_1	44.6 (6.75)	1.3
T_2	42.8 (6.62)	2.0
T_3	42.23 (6.57)	2.3
T_4	41.57 (6.52)	2.6
T_5	40.4 (6.43)	2.7
T_6	43.13 (6.64)	1.5
T_7	38.4 (6.28)	3.7
T_8	35.33 (6.03)	4.8
S.E.±	0.06	
C.D. (P=0.05)	0.20	

* Figures in the parenthesis are square root transformed value

Effect on nematode population in soil:

The initial nematode population before treatment imposition were recorded and the average nematode population of experimental plot was 650.00 second stage juvenile (J2) per 200cc of soil.The observation was recorded after the harvest of crop with respect to nematode population in soil revealed that carbofuran 3G significantly reduced the nematode population (275.11 / 200 cc soil) when compared to control (778.22 /200 cc soil) and the plot treated with *Purpureocillium lilacinum* + *Trichoderma harzianum* + *Bacillus subtilis* +*Bacillus megaterium* +Vermicompost (275.22/ 200 cc soil) where, treatment carbofuran 3G and *Purpureocillium lilacinum*+*Trichoderma harzianum*+ *Bacillus subtilis*+*Bacillus megaterium* +Vermicompost were on par with each other and the plots treated with *Purpureocillium lilacinum*+ Vermicompost recorded a nematode population of 296.77/ 200 cc soil (Table 3).

Effect on number of galls and egg masses:

With respect to number of galls per root system and eggmasses per galls Carbofuran 3G was very effective in reducing galls per root system where it was significantly superior over all other treatment and recorded least number of galls 9.11 per root system and 6.16 egg masses/gall (Table 4). The treatment combination of Consortium of *P.lilacinum*+ *T. harzianum*+ *Bacillus subtilis* + *Bacillus megaterium* + Vermicompost was found to be the next best treatment with 13.33 galls per root system along with 8.00 egg masses per gall which was followed by *Paceilomyces lilacinus*+Vermicompost (14.00 galls per root system and 10.00 egg masses per gall) where these two treatments

Table 3: Effect of bioagents on nematode population of soil

Treatments	Nematode population /200cc of soil			
	30DAT	60DAT	90DAT	At harvesting stage
T_1	490.89 (22.10)	447.55 (21.08)	382.66 (19.49)	275.11 (16.23)
T_2	580.00 (24.08)	507.11 (22.39)	398.00 (19.78)	296.77 (17.11)
T_3	619.67 (24.89)	509.55 (22.57)	457.11 (21.40)	327.55 (18.02)
T_4	622.66 (24.88)	530.66 (23.03)	469.55 (21.62)	358.44 (18.94)
T_5	633.78 (25.17)	568.44 (23.84)	470.11 (21.67)	366.33 (19.04)
T_6	561.55 (23.56)	503.44 (22.29)	394.77 (19.67)	275.22 (16.24)
T_7	673.89 (25.82)	632.77 (25.13)	470.22 (21.70)	376.11 (19.34)
T_8	747.66 (27.33)	754.11 (26.42)	767.77 (27.08)	778.22 (27.84)
S. E. ±	1.42	1.47	1.48	1.79
C.D. (P=0.05)	4.32	4.47	4.51	5.45

* Figures in the parenthesis are square root transformed value DAT= Days after transplanting

Table 4: Effect of bioagents on gall formation and reproduction of rice root knot nematode

Treatments	Galls	Egg mass
T_1	9.11 (3.17)	6.16 (2.67)
T_2	14.00 (3.86)	10.00 (3.29)
T_3	19.78 (4.55)	13.11 (3.75)
T_4	28.66 (5.43)	15.11 (3.99)
T_5	40.00 (6.39)	16.11 (4.12)
T_6	13.33 (3.77)	8.00 (2.99)
T_7	42.66 (6.60)	17.11 (4.25)
T_8	56.44 (7.57)	30.11 (5.57)
S. E.±	0.16	0.19
C.D. (P=0.05)	0.50	0.59

* Figures in the parenthesis are square root transformed value

were on par with each other.

Somasekhara *et al.* (2012) showed that the adoption of INMT (Integrated Nematode Management Technology) resulted in reducing the nematode population from 320 J2/200 cc soil as initial nematode population to 135 (cabrofuran (0.3 g a.i/m^2). The present findings are in tune with the findings of Ziaul Haque (2013) who reported that the soil application and root dip of *P. fluorescens* or *T. harzianum*+ Carbofuran was found most effective and suppressed the gall formation, egg mass production and soil population of *M. graminicola.* Further, Krishnaprasad and Rao (1980) reported that carbofuran below 250 ppm had persistent toxicity and inhibits the egg mass production. Similar results were also given by Rahman and Taylor (1983); Mukesh Sehgal *et al*. (2014) who reported that use of Carbofuran, *P. fluorescens* and *T. viride* were effective in suppressing the soil population of nematode, galls and egg masses. *T. harzianum* and *P. lilacinum* would more closely mimic the natural situation and might broaden the spectrum of biocontrol activity with enhanced efficacy and reliability of control. They also acts asgrowth promoting organism as they enhance the growth of plants height, root length and yield by reducing nematode population and serves as nematophagus fungus by producing some special structure, which kills the eggs and juvenile by producing toxins and alkaloids which hinders the growth and activity of nematodes (Siddiqui and Shaukat, 2004). Nematicides are not easily available, costlier, phytotoxic, health hazardous and causemuch damage to the environment. They form a small proportion of total pesticides and herbicide usage. However, some compounds have been with drawn from the market because of health hazards to labour community because oftheir detection at unacceptable levels in ground water. Unless, more acceptable nematicides are produced, the strategies for nematode management will be forced to change. The other methods of nematode management *viz*., crop rotation, field sanitation, fallowing, flooding and resistant crop varieties are having their own limitations and majority of the times not practicable. Nowaday, there is dearth of nematicides in Indian market as an alternative to nematicides of chemicalorigin many natural enemies attack plant parasitic nematodesin soil and reduced their population.

Conclusion:

The study was conducted to know the efficacy of bio agents, vermicompost and nematicides for the management of rice root-knot nematode *Meloidogyne graminicola* at Chikadadakatte village of Honnali taluk, Davanagere district during *Kharif* 2018. The results revealed that all the treatments were significantly superior over check with respect to growth parameters and nematode population. However, carbofuran 3G significantly reduced the nematode population (275.11 / 200 cc soil) which was found to be the best treatment as it recorded highest plant height (114.06 cm), root length (23.13 cm), maximum grain yield (44.60 q/ha) with least RKI (1.20) compared to other treatments and check.

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