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Management of Nematode Disease Complex in Turmeric with Bio Control Agents

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Abstract

Field experiments were conducted at Regional Research Station, Paiyur, India during January 2012 - July 2014 to assess the efficacy of the TNAU talc and liquid commercial formulations of the native bio agents *Pseudomonas fluorescens* (*Pf*) and *Trichoderma viridi*, as turmeric rhizome treatment, soil application, foliar spray and in combination so as to develop nematode centric ipm and to standardize the management practices for nematode disease complex in turmeric. IPM module viz., turmeric rhizome treatment with talc formulations of *Pf* @ 10 g/kg seed rhizome plus soil application of *Pf* @ 2.5 Kg/ha along with 50 kg of well decomposed FYM plus *Pf* foliar spray application @ 2 lit/ha at three months interval recorded higher germination of 94.90 per cent, least injury causing nematode population of 223.0/250 g of soil at two months after sowing, 250.3 numbers/250 g of soil at termination, 32.3 endoparasitic nematodes/10 grams of root sample, 18.47 egg mass/10 g root, 177.40 eggs/egg mass, lower Gall index of 1.87 with 16,638 kg of wet turmeric rhizome/ha and found to be the best treatment followed by standard check viz., Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%. The bioinoculants treatments have higher BC ratio when compared to standard chemical check treatment.

Introduction

India is the largest production of turmeric (*Curcuma longa* L.) (Zingiberaceae) in the world producing about 7,92,980 tones annually from an area of about 1,80,960 hectares (NHB,2011) and it has uses in the social, medicinal and religious lives of the people. The rhizome is an important source natural yellow dye and used as a colouring additive in the drug (Khanna,1999). Nowadays the turmeric extract formulations containing curcuminoid and essential oil of turmeric is blended in such a way to develop a bioactive patented products for the treatment of Alzheimer's disease which gives a safe alternative hope to millions of patients suffering across the globe (Anonymous 2014). The research is also underway for treating oral cancer, depression and diabetics. Hence there is renewed interest in production of turmeric due to various biological and medicinal properties of curcumin, the main constituent of turmeric. However its cultivation is constrained by both biotic and abiotic stress factors. Among the biotic factors, the hidden enemies' viz., plant parasitic nematodes continue to tear the farmers for successful and profitable cultivation of horticultural crops. A number of species of plant parasitic nematodes have been reported to attack turmeric (Bai et al., 1995) of which *Meloidogyne incognita*, *Radopholus similis* and *Pratylenchus coffeae* are of economic importance. The infective second stage juveniles of *M.incognita* invade young roots and initiate hyperplasia and hypertrophy of root tissues surrounding the feeding sites causing the formation of swellings or root galls. Mild infection by the nematodes results in discrete galls along the roots, especially on the laterals that can be mistaken for root nodules but severe infestation produces very large galls on both main and lateral roots, and a greatly reduced root system with subsequent rotting

of roots. The above ground symptoms resulting from damaged roots are yellowing, stunted growth, and marginal tip drying of leaves, reduced tillering, poor yields and early senescence (Ray et al., 1995 and Koshy et al., 2005). These symptoms often appear in clearly defined patches in the field and are more obvious in adverse growing conditions, e.g. drought, and in sandy soils. Infected rhizomes tend to loose their bright yellow colour and levels of protein, carbohydrate, chlorophyll a and b and curcumin content is e lower. (Poornima and Sivagamivadivelu, 1998). In the rhizosphere, nematodes act as a predisposing factor and pave the entry for secondary invaders viz., *Pythium* sp. through the open wounds caused by their feeding mechanism and the presence of *fusarium* chlamydospores in plant debris warrants rhizome and root rot very difficult to control. Chemical management of nematodes and soil borne pathogens is uneconomical and cause environmental and ground water pollution.

Plant growth promoting rhizobia (PGPR) provide different mechanisms for suppressing plant pathogens. They colonize the roots there by giving protection against soil borne pathogens including nematodes. These include competition for nutrients and space (Elad and Chet,1987), antibiosis by producing antibiotics (Pierson and Thomashow, 1992) and production siderophores (Flouresent yellow green pigments) which limits the availability of iron necessary or the growth of pathogens (Lemanceau et.al 1992). Other important mechanism include production of lyctic enzymes such as chitinase which degrade chitin and glucan present in the cell wall of pathogen (Velazhgan et.al 1999).

Biological management offer a scope for eco-friendly approach that can be suitably used in Integrated Nematode and Disease Management (INM &IDM) programmes. Hence the present investigation is proposed to evaluate the TNAU commercial formulations (talc and liquid) efficacy and the effectiveness of the bioagent through proper delivery system and timing of application of the native biocontrol agent *Pf* and Tv as rhizome treatment, soil application and through bionemagation/foliar spray and in combination so as to develop *nematode centric IPM module* and standardize the management practices for nematode disease complex in turmeric of the North Western Zone of Tamil Nadu & Krishnagiri district in particular.

Materials and Methods

Field experiments were conducted at regional research station, TNAU, Paiyur (12°21'N, 78°18'E & 490 M/1889 above MSL FT) in two crops year seasons viz., 2012-13 & 2013-14 under normal flow irrigated conditions. The soil was sandy loam in texture with pH 8.1. The available NPK were 175, 25 and 27.5 Kg/ha with organic Carbon of 0.5%.

The details of the experiments conducted are given below.

Particulars	***First Experiment***	***Second Experiment***
Crop Year	2012-2013	2013-2014
Season	Kharif 2012	Kharif 2013
Month	July 2012	July 2013
Date of Sowing/Planting rhizomes	12.07.2012	04.07.2013
Design	RBD	RBD
Replication	Three	Three
Variety	*BSR 2*	*BSR 2*
Plot size	6.0 × 2.0 m 2	6.0 × 1.6 m 2
Spacing	45 × 25 cm	45 × 20 cm
Treatments	10	11
Field number	G 7	G 7

In the confirmatory trial (2013-2014), an additional treatment viz., IPM module with best of the seed treatments plus best of the soil application treatments plus best of the liquid formulations of the first year of the trial viz.,:-Rhizome treatment with talc formulations of *Pseudomonas flouresens* (*Pf*) @ 10 g/kg seed rhizome plus soil application of *Pf* @ 2.5 Kg/ha along with 50 kg of FYM plus foliar liquid formulation of *Pf* application @ 2 lit/ha at three months interval was included as per technical programme for experimentation & test verified.

The experiment was conducted for two crop years till July 2014 in turmeric BSR-2 variety with the following treatmental details:

T1.	Rhizome treatment with talc formulation of *Pseudomonas fluorescens* (*Pf)* @10 g/kg seed rhizome.
T2.	Rhizome treatment with talc formulation of *Trichoderma viride* (*Tv*) @ 4 g/kg seed rhizome.
T3.	Soil application of *Pf* @ 2.5 kg/ha mixed with 50 kg of FYM at the time of planting.
T4.	Soil application of *Tv* @ 2.5 kg/ha mixed with 50kg of FYM at the time of planting.
T5.	Rhizome treatment with talc formulation of *Pf* @10 g/kg seed rhizome + Soil application of *Pf* @ 2.5 kg/ha mixed with 50 kg of FYM at the time of planting.
T6.	Rhizome treatment with talc formulation of *Trichoderma viride* (T v) @ 4 g/kg seed rhizome + Soil application of *Tv* @ 2.5kg/ha mixed with 50kg of FYM at the time of planting.
T7.	Application of liquid formulation of *Pf* @ 2 litres/ha at planting.
T8.	Application of liquid formulation** of Tv @ 2litres/ha at planting.
T9.	IPM module (Best of the seed treatments + Best of the soil application treatments + Best of the liquid formulations).
T10.	Application of Carbofuran @ 3G @ 1 kg a.i/ha in 2 rounds at 3 rd and 5 th month after planting and drenching with Copper oxy chloride 0.25% (standard check).
T11.	Untreated control.

The recommended dose of fertilizers was applied during the course of investigation. The data on the biometrics/growth characters like germination, plant height at 60, 120 DAS (cm), population of nematodes/nematode load in 250 ccs/g of soil at 60, 120 DAS and at termination of crop, population of endo parasitic nematodes in 10 g roots at termination of the crop, root knot index (gall index), number of egg mass per 10 g root, number of eggs per egg mass, per cent disease incidence (root rot), injury causing insects (thrips & chewing insects), crop stand, fresh rhizome yield were recorded and benefit cost ratio was worked out.

Treatments	***Particulars***	***Plant height at 60 DAS (cm)***	***Plant height at 120 DAS (cm)***	***Nematode population at 60 DAS (in 250 g soil)***	***Nematode population at 120 DAS (in 250 g soil)***	***Nematode population at termination of crop(in 250 g soil)***	***Nematode population at termination of crop(in 10 g root)***	***No. of egg mass/10 g root***	***No. of eggs/egg mass***	***Gall index***
T1	Rhizome Treatment with Talc Formulation of Pf@ 10 g/Kg of Seed Rhizome	45.3	64.94	282.7 d (2.450)	426.8 c (2.6301)	546.3 d (2.7373)	28.6 c d (1.4572)	34.33	353.60	3.08
T2	Rhizome Treatment With Talc Formulation of TV @ 4 g/Kg Seed Rhizome	44.4	64.22	314.0 c (2.496)	459.7 b (2.6624)	625.3 b (2.7960)	30.0 c (1.4770)	36	337.00	2.87
T3	Soil application of Pf@2.5 kg/ha mixed with 50kg of FYM at planting	45.8	64.95	295.7 d (2.469)	323.4 d (2.5097)	597.7 c (2.7764)	29.0 c (1.4622)	25.53	243.40	2.33

T4	Soil application of Tv@2.5kg/ha mixed with 50kg of FYM at planting	44.8	64.03	360.7 b (2.557)	329.9 d (2.5183)	595.7 c (2.775)	30.3 c (1.4819)	25.4	266.07	3.27
T5	T1 plus t3	44.3	66.31	373.3 b (2.572)	263.3 e (2.4205)	330 e (2.5188)	25.3 d (1.4073)	19.47	173.93	2.53
T6	T2 plus t4	44.0	65.11	360.3 b (2.557)	459.7 b (2.5963)	459.7 d (2.6624)	33.7 b (1.5260)	26	213.67	3.40
T7	Application of liquid formulation of Pf @ 2 lit.,/ha at planting	46.0	65.99	295.7 d (2.504)	265.2 e (2.4235)	337.0 e (2.5274)	25.7 d (1.4084)	18.47	200.67	2.80
T8	Application of formulation of Tv in liquid nature @ 2lit., /ha at planting	45.4	65.03	370.7 b (2.570)	336.8 d (2.5273)	459.7 d (2.6624)	31.3 bc (1.4946)	24.47	221.80	3.13
T9	IPM module (T5 along with 2kg Neem cake Plus T7 at three months interval starting from germination)	--	--	--	--*	--*	--*	--	--	--
T10	Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%	46.3	66.37	256.7 e (2.4091)	238.3 f (2.3740)	244.7 f (2.388)	24.7 e (1.3920)	16.07	177.40	1.87
T11	Untreated control	43.8	56.34	418.7 a (2.6218)	621.1a (2.7932)	721a (2.8579)	49.0 a (1.6900)	45.07	422.07	4.93
	Sed	0.26 **	0.64**	0.0245 **12.35	7.45**	8.46**	1.6079**			
	CD (0.05%)	0.55 **	1.34**	0.0515 **25.95	15.65*	17.78**	3.38**			

Figures in parenthesis are log transformed values.

* Replication data of standard check is taken under consideration for combined data.

**Statistics as per original values.

Table 1: Effect of various treatments on plant growth parameters and root knot nematode (Meloidogyne incognita) population in BSR2 turmeric -First year data (2012-13).

Treatments	***Particulars***	***Germination Per cent 50 DAS***	***Plant height at 60 DAS (cm)***	***Plant height at 120 DAS (cm)***	***Nematode population at 60 DAS (in 250 g soil)***	***Nematode population at 120 DAS (in 250 g soil)***	***Nematode population at termination of crop(in 250 g soil)***	***Nematode population at termination of crop(in 10 g root)***	***No.of egg mass/10 g root***	***No.of eggs/ egg mass***	***Gall index***
T1	Rhizome Treatment With Talc Formulation of Pf@ 10 g/Kg of Seed Rhizome	90.28 a (72.70)	28.43 (1.4593)	55.66 (1.7421)	333.0 b (2.5220)	367.0 c (2.5646)	395 b (2.5966)	76.0 b (1.8799)	34.33	353.60	3.08
T2	Rhizome Treatment With Talc Formulation of TV @ 4 g/Kg Seed Rhizome	90.28 a (72.18)	28.77 (1.4587)	52.59 (1.7203)	324.0 c (2.510)	380.0 b (2.5798)	387 b (2.5877	74.0 b (1.8683)	36.00	337.00	2.87

T3	Soil application of Pf@2.5 kg/ha mixed with 50kg of FYM at planting	89.81 a (72.79)	30.03 (1.4680)	50.67 (1.6987)	312.0 d (2.494)	333.0 e (2.5224)	373 b (2.5773)	66.0 c (1.8183)	25.53	243.40	2.33
T4	Soil application of Tv@2.5kg/ha mixed with 50kg of FYM at planting	87.50 a (69.83)	28.50 (1.4544)	50.47 (1.7016)	318.0 c (2.502)	345.0 d (2.5378)	327 c (2.5145)	76.0 b (1.8720)	25.40	266.07	3.27
T5	T1 plus t3	77.78 b (61.92)	25.43 (1.4038)	52.23 (1.7147)	278.0 e (2.444)	313.0 f (2.4955)	322 c (2.5078)	60.0 d (1.7767)	19.47	173.93	2.53
T6	T2 plus t4	97.22 a (82.11)	30.80 (1.4871)	54.92 (1.7374)	282.0 d (2.450)	312.0 f (2.4942)	334 c (2.5237)	62 .0 d (1.7886)	26.00	213.67	3.40
T7	Application of liquid formulation of Pf @ 2 lit.,/ha at planting	92.59 a (74.36)	28.83 (1.4592)	53.72 (1.7295)	234.0 h (2.369)	275.0 h (2.4393)	287 d (2.4471)	54.0 e (1.7306)	18.47	200.67	2.80
T8	Application of formulation of Tv in liquid nature @ 2lit., /ha at planting	87.04 a (70.05)	30.43 (1.4802)	53.78 (1.7287)	242.0 g (2.383)	287.0 g (2.4578)	280 d (2.4521)	50.0 e (1.6969)	24.47	221.80	3.13
T9	IPM module (T5 along with 2kg Neem cake Plus T7 at three months interval starting from germination)	94.90 a (76.93)	**30.77** (1.4877**)**	52.70 (1.7201)	223.0 i (2.3496)	256.0 j (2.4081)	266 d (2.4248)	40.0 g (1.5988)	18.47	177.40	1.87
T10	Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%	87.04 a (69.13)	26.93 (1.4186)	53.37 (1.7235)	267.0 f (2.4270)	278.0 i (2.4439)	258 d (2.4116)	44 .0 f (1.6416)	16.07	177.40	1.87
T11	Untreated control	79.17 b (66.35)	27.83 (1.4248)	53.87 (1.7221)	366.0 a (2.5638)	412.0 a (2.6149)	457 a (2.6596)	116.0 a (2.0680)	45.07	422.07	4.93
	Sed	7.01	NS	0.52	0.0057	0.0028	0.0088	0.0181	0.73592	3.67	0.10
	CD (0.05%)	14.61		1.10	0.0119	0.0058	0.0184	0.0377	1.5351	7.37	0.20

Figures in parenthesis are log transformed values.

* Replication data of standard check is taken under consideration for combined data.

**Statistics as per original values.

Table 2: Effect of various treatments on plant growth parameters and root knot nematode (Meloidogyne incognita) population in BSR2 turmeric Second year confirmatory year data (2013-14).

Treatments	***Particulars***	***Germination Per cent 50 DAS***	***Plant height at 60 DAS (cm)***	***Plant height at 120 DAS (cm)***	***Nematode population at 60 DAS (in 250 g soil)***	***Nematode population at 120 DAS (in 250 g soil)***	***Nematode population at termination of crop(in 250 g soil)***	***Nematode population at termination of crop(in 10 g root)***	***No.of egg mass/10 g root***	***No.of eggs/ egg mass***	***Gall index***
T1	Rhizome Treatment With Talc Formulation of Pf@ 10 g/Kg of Seed Rhizome	90.28 a (72.70)	36.85 a (1.5654)	57.98 a (1.76)	307.8 b (2.4864)	396.9 (2.486)	456.7 b (2.6670)	52.3 b (1.6685)	34.33 c	353.60 b	3.07 c

T2	Rhizome Treatment With Talc Formulation of TV @ 4 g/Kg Seed Rhizome	90.28 a (72.18)	36.60 a (1.5701)	55.50 f (1.74)	319.0 b (2.5034)	419.9 (2.503)	502.7 b (2.6919)	52 b (1.6726)	36.00 b	337.00 c	2.87 d
T3	Soil application of Pf@2.5 kg/ha mixed with 50kg of FYM at planting	89.81 a (72.79)	37.92 a (1.5772)	54.24 h (1.73)	303.8 b (2.4816)	328.2 (2.482)	465.3 b (2.6769)	47.5 bc (1.6403)	25.53 c	243.40 e	2.33 e
T4	Soil application of Tv@2.5kg/ha mixed with 50kg of FYM at planting	87.50 a (69.83)	36.63 a (1.5772)	53.86 i (1.70)	339.3 b (2.5294)	337.4 (2.529)	470.3 b (2.6448)	53.2 b (1.6770)	25.40 c	266.07 d	3.27 b c
T5	T1 plus t3	77.78 b (61.92)	34.85 a (1.5638)	55.75 (1.74)	327.67 b (2.5080)	288.2 (2.508)	321.5 c (2.5133)	42.7 cd (1.5920)	19.4 7 e	173.93 i	2.53 e
T6	T2 plus t4	97.22 a (82.11)	37.42 a (1.5419)	57.47 (1.76)	321.17 b (2.5034)	385.9 (2.503)	385.8 c (2.5930)	47.7 b (1.6573)	26.00 c	213.67 g	3.40 b
T7	Application of liquid formulation of Pf @ 2 lit.,/ha at planting	92.59 a (74.36)	37.40 a (1.5728)	56.79 (1.75)	264.83 d (2.4366)	270.1 (2.437)	306.0 d (2.4872)	39.8de (1.5695)	18.47 e	200.67 h	2.80
T8	Application of formulation of Tv in liquid nature @ 2lit., /ha at planting	87.04 a (70.05)	37.90 a (1.5781)	56.60 (1.75)	306.33 b (2.4760)	311.9 (2.476)	373.3 c (2.5572)	40.7 d (1.5958)	24.47 d	221.80 f	3.13 c
T9	IPM module (T5 along with 2kg Neem cake Plus T7 at three months interval starting from germination)	94.90 a (76.93)	30.77 b* (1.4877)	52.70 * (1.72)	223.0 d (2.3794)	247.2 (2.5638)	250.3 e (2.4064)	32.3 f (1.4954)	18.47 e	177.40 i	1.87 f
T10	Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%	87.04 a (69.13)	36.62 a (1.5623)	56.62 (1.75)	261.8 c (2.4180)	258.2 (2.3794)	261.3 e (2.3998)	34.3 e (1.5168)	16.07 f	177.40 i	1.87 f
T11	Untreated control	79.17 b (66.35)	35.83 a (1.5215)	54.49 (1.73)	392.3 a (2.5928)	516.6 (2.5244)	566.5 a (2.7587)	82.5 a (1.8790)	45.07 a	422.07 a	4.93 a
	Sed	7.01	0.0282	0.08	0.0277	1.35418	0.03017	0.0281	0.47	3.67	0.10
	CD (0.05%)	14.61	0.0587	0.16	0.0555	NS	0.0606	0.0564	0.93	7.37	0.20

Table 3: Effect of various treatments on plant growth parameters and root knot nematode (Meloidogyne incognita) population in BSR2 turmeric Combined two year data (2012-14).

Sl. No.	*Treatments*	*First year crop 2012-13*	*Second year Crop 2013-14*	*Combined crop data*
1	Rhizome Treatment with Talc Formulation of Pf@ 10 g/Kg of Seed Rhizome	17,678 c (4.2473)	5034 b (3.6825)	11,356 c (3.9650)
2	Rhizome Treatment with Talc Formulation of TV @ 4 g/Kg Seed Rhizome	15,747 d (4.1971)	5034 b (3.6484)	11,346 b (4.0110)
3	Soil application of Pf@2.5 kg/ha mixed with 50kg of FYM at planting	15,883 d (4.1998)	5972 a (3.7731)	10,928 c (3.9860)
4	Soil application of Tv@2.5kg/ha mixed with 50kg of FYM at planting	15,661 d (4.1949)	4757 b (3.6479)	10,209 c (3.9210)

5	T1 plus t3	19,578 b (4.2918)	4861 b (3.6621)	12,220 c (3.9770)
6	T2 plus t4	18,475 c (4.2663)	7465 a (3.8573)	12,970 b (4.0620)
7	Application of liquid formulation of Pf @ 2 lit.,/ha at planting	19,817 b (4.2969)	6215 a (3.7636)	12,599 c (3.9840)
8	Application of formulation of Tv in liquid nature @ 2lit., /ha at planting	18,375 c (4.2642)	5382 b (3.6705)	12,295 b (4.0140)
9	IPM module (T5 along with 2kg Neem cake Plus T7 at three months interval starting from germination)	--	9930 a (3.9868)	16,638 a * (4.1775)
10	Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%	23,344 a (4.3682)	6946 a (3.8245)	14,190 b (4.0083)
11	Untreated control	11,508 e (4.0605)	3368 b (3.4408)	7,438 d (3.7506)
	SED	0.0085	0.1391	0.0725
	CD (0.05%)	0.0178	0.2901	0.1457

Figures in parenthesis are log transformed values.

* Replication data of standard check is taken under consideration for combined data.

**Statistics as per original values.

Table 4: Yield of BSR 2 turmeric fresh wet rhizomes with regard to various treatments.

Sl.No.	***Treatments***	***First year crop 2012-13***	***Second year Crop 2013-14***	***Combined crop data***
1.	Rhizome Treatment With Talc Formulation of Pf@ 10 g/Kg of Seed Rhizome	1:2.35	1:10.25	1:6.30
2.	Rhizome Treatment With Talc Formulation of TV @ 4 g/Kg Seed Rhizome	1:2.08	1:22.02	1:12.05
3.	Soil application of Pf@2.5 kg/ha mixed with 50kg of FYM at planting	1:2.16	1:52.08	1:27.12
4.	Soil application of Tv@2.5kg/ha mixed with 50kg of FYM at planting	1:2.13	1:27.77	1:14.95
5.	T1 plus t3	1:2.59	1:7.03	1:4.81
6.	T2 plus t4	1:2.44	1:19.28	1:10.86
7.	Application of liquid formulation of Pf @ 2 lit.,/ha at planting	1:2.68	1:23.00	1:12.84
8.	Application of formulation of Tv in liquid nature @ 2lit., /ha at planting	1:2.49	1:32.54	1:17.52
9.	IPM module (T5 along with 2kg Neem cake Plus T7 at three months interval starting from germination)	--	1:14.70	1:14.70
10.	Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%	1:2.98	1:12.12	1:7.55

Figures in parenthesis are log transformed values.

* Replication data of standard check is taken under consideration for combined data.

**Statistics as per original values.

Table 5: Benefit cost ratio with regard to various treatments.

Results and Discussion

The germination percentage of BSR 2 turmeric was significantly at its peak of 94.90 per cent in IPM module viz., turmeric rhizome treatment with talc formulations of *Pseudomonas flouresens* (*Pf*) @ 10 g/kg seed rhizome plus soil application of *Pf* @ 2.5 Kg/ha along with 50 kg of FYM plus foliar liquid formulation of P.f application @ 2 lit/ha at three months interval & less mortality of rhizome. Enhanced plant height was observed at 60 DAS in the treatments where bioinoculants were treated either in BSR 2 turmeric seed rhizome or when it is incorporated in the soil before planting of BSR 2 turmeric seed rhizome.

With regard to nematode load/population at two months after sowing, (IPM module) recorded significantly least injury causing nematode population of 223.0/250 g of soil followed by standard check, carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25% recorded 261.8/250 g of soil respectively. At four months after sowing, there was no significant difference exists between the treatments.

At termination of the crop, The IPM module recorded significantly least injury causing nematode population of 250.3/250 g of soil, in roots (32.3/10 grams of root sample), least number of egg mass/10 g root (18.47), No. of eggs/egg mass (177.40), Gall index (1.87) and it is on par with Standard check Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25% recorded 261.3/250 g of soil respectively.

The injury causing insects were enumerated in the second year confirmatory crop. The per cent damage of plants affected by turmeric thrips *Panchaetothrips indicus* (rolling of leaves from the margins) ranged from 10-50 per cent with a mean of 31.51 per cent at 110 DAS. The widespread occurrence& damage by biting & chewing insect (army worm-*Spodoptera*) in caterpillar stage was quantified. The damage was cent per cent (100%) due to the unusual prevalence of climatic conditions coupled with rainfall within 72 hours was evident in 48 & 49 standard weeks.

Fresh rhizome yield per hectare was significantly higher in IPM module registering 16,638 kg/ha & found to be the best. It is followed by the standard check and rhizome treatment with talc formulation of TV @ 4 g/Kg seed rhizome plus soil application of *Trichoderma viridi @2.5kg/ha* mixed with 50kg of FYM at planting recording 14,190 & 12,970 Kg of fresh wet turmeric rhizome/ha respectively.

The results obtained in this study showed that nematode population/load in soil, root galling and egg production by *M. Incognita* related to the applied levels of bioinoculants at different stages of crop growth through proper timing and delivery system of bionemagation where greatest inhibition of nematode damage was observed in IPM module. The present findings corroborates with the results of earlier investigators on the nematicidal properties of the effective tested bioinoculants (Ali et al.,2002).

In nutshell, IPM module viz., turmeric rhizome treatment with talc formulations of *Pseudomonas flouresens* (*Pf*) @ 10 g/kg seed rhizome plus soil application of *Pf* @ 2.5 Kg/ha along with 50 kg of FYM plus foliar liquid formulation of *Pf* application @ 2 lit/ha at three months interval recorded higher germination of 94.90 per cent, least injury causing nematode population of 223.0/250 g of soil at two months after sowing, 250.3 numbers/250 g of soil at termination, 32.3 endoparasitic nematodes/10 grams of root sample, 18.47 egg mass/10 g root,177.40 eggs/egg mass, lower Gall index of 1.87 with 16,638 kg of wet turmeric rhizome/ha & found to be the best treatment followed by standard check viz.,Carbofuran 3G @ 1 kg a.i/ha, 2 rounds at 3rd and 5th month after planting and drenching with copper oxy chloride 0.25%. The bioinoculants treatments have higher BC ratio when compared to standard chemical check treatment.

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