Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(3): 985-989

Received: 01-03-2019
Accepted: 03-04-2019

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Management of burrowing nematode, *Radopholus similis* in banana by using biocontrol agents

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Abstract
Field experiments were conducted during 2009-2010 and 2010-2012 for developing an effective methods for the management of burrowing nematode, *Radopholus similis* in banana. Results revealed that, the treatment *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 effectively reduced the burrowing nematode population in soil and roots. The next best treatments were *Paecilomyces lilacinus* @25g/ m^2 *Paecilomyces lilacinus* @12.5g /m^2 + *Bacillus subtilis* @12.5 g/m^2 and EPN *Heterorhabiditis indica* @1 x 10^9 (1 Js/ml). However, the treatment carbofuran @40g/plant was found effective and significantly superior over other treatments. With regards to yield, the highest yield was obtained in the treatment of carbofuran @40g/plant(28.76t/ha)followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (27.16t/ha) and *Paecilomyces lilacinus* @25g/ m^2 (25.38t/ha).The lowest yield was recorded in untreated control(17.57t/ha).The B/C ratio was more in the treatment of *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (5.74).

Keywords: Banana, burrowing nematode, *Radopholus similis*, bioagents

Introduction
Banana is one of the important tropical fruit crop. The crop is affected by many diseases caused by fungi, bacteria, viruses, nematodes and abiotic factors. Among these, burrowing nematode is most predominant nematode in northern parts of Karnataka. The burrowing nematode (*Radopholus similis* (Cobb, 1893) [1] Thorne, 1949 which occurs in tropical and subtropical regions of the world. It has wide host range of around 370 plant species causing severe damage to various fruit crops, spice crops, agricultural and plantation crops in many tropical countries. (Peachey, 1969) [8]. Crop losses caused by nematodes are very high with an average annual yield loss of about 20% worldwide (Sesser and Freckman, 1987) [9]. In many cases, the banana crop cannot be grown economically without the use of nematicides (Gowen *et al*., 2005) [2]. Hence, the present investigations was undertaken to find out the effective bio-agents for the management of burrowing nematode in banana.

Materials and Methods
An experiment was conducted during 2009-2010 and 2010-2012 at K.R.C.College of Horticulture, Arabhavi (UHS, Bagalkot). There were ten treatments viz., T_1 Dip suckers in AM cultures, T_2 *Pseudomonas fluorescens* @ 25 g/ m^2 T_3 *Paecilomyces lilacinus* @25g/ m^2, T_4 *Bacillus subtilis* @25 g/ m^2, T_5 EPN *Heterorhabiditis indica* @1 x 10^9 (1 Js/ml), T_6 *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2, T_7 *Paecilomyces lilacinus* @12.5g /m^2 + *Bacillus subtilis* @12.5 g/m^2, T_8 *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2, T_9 Carbofuran @ 40 g/plant and T_{10} Untreated control. Each treatment was replicated three times in a randomized block design. Susceptible cultivar Rajapuri (AAB) was planted with a spacing of 1.8x1.8m. Regular hand weeding and irrigation was done. Crop received recommended dosages of fertilizers. Observations were recorded with respect to nematode population from soil (250cc soil) and roots (10g) at vegetative, shooting and harvesting stages. Root necrosis was recorded at vegetative, shooting and harvesting stages. Growth parameters (plant height, pseudostem girth and leaf area) and yield parameters viz., hands/bunch, number of fingers in third hand, fingers/bunch, bunch length, bunch width, bunch weight and yield (t/ha) were recorded.

Results and Discussion
Burrowing nematode population: Soil
Vegetative stage
Results of 2009-2010 revealed that, the treatment carbofuran @40g/plant effectively reduced the burrowing nematode population (82/250cc soil). The treatment was statistically significant over the other treatments at vegetative stage. The next best treatments were *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (113.67/250cc soil), *Paecilomyces lilacinus* @12.5g /m^2 + *Bacillus subtilis* @12.5 g/m^2 (126/250cc soil), *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2 (130/250cc soil), *Paecilomyces lilacinus* @25g/ m^2(135/250cc soil).The highest nematode population was recorded in untreated control (265.33/250cc soil). During 2010-2012, the application of *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 found effective in reducing the nematode population (124/250cc soil), followed by *Paecilomyces lilacinus* @25g/ m^2(130/250cc soil), EPN *Heterorhabiditis indica* @1 x 10^9(132.33/250cc soil), *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2(136.67/250cc soil). However, the treatment Carbofuran @ 40 g/plant effectively reduced the burrowing nematode population (96.0/250cc soil). Average of two years data revealed that, the treatment *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 effectively reduced the burrowing nematode population (118.84/250ccsoil) followed by *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (131.35/250ccsoil) and *Paecilomyces lilacinus* @25g/ m^2(132.50/250ccsoil) (Table 1).

Shooting stage
2009-2010:Results revealed that, the lowest nematode population was recorded in the treatment of *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (130.67/250ccsoil) but this treatment at par with *Paecilomyces lilacinus* @12.5g /m^2 + *Bacillus subtilis* @12.5 g/m^2 (131.33/250ccsoil) and *Paecilomyces lilacinus* @25g/ m^2(142.00/250ccsoil). During 2010-2012, the treatment carbofuran @40g/plant effectively reduced the burrowing nematode population (112/250cc soil). It was followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (136/250ccsoil), *Paecilomyces lilacinus* @25g/ m^2(140.00/250ccsoil), EPN *Heterorhabiditis indica* @1 x 10^9(143.33/250cc soil) and *Paecilomyces lilacinus* @12.5g /m^2 + *Bacillus subtilis* @12.5 g/m^2 (144.00/250ccsoil). The highest nematode population was recorded in untreated control (301.33/250cc soil). Average of two years data revealed that, the application of *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (133.34/250ccsoil) found effective in reducing the nematode population.

Harvesting stage
2009-2010: The application of *Paecilomyces lilacinus* @25g/ m^2(167.33/250ccsoil) significantly reduced the burrowing nematode population followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces. lilacinus* @12.5 g/m^2 (172/250ccsoil). However, the treatment Carbofuran @ 40 g/plant effectively reduced the burrowing nematode population (143/250ccsoil) (Table 1).

In 2010-2012, The lowest population was obtained in the treatment of Carbofuran @ 40 g/plant (137/250ccsoil). The next best treatments were *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (166/250ccsoil) and *Paecilomyces lilacinus* @25g/ m^2(174.67/250ccsoil). Average of two years data revealed that, the treatments *Pseudomonas fluorescens* @12.5 g/ m^2 + *Paecilomyces lilacinus* @12.5 g/m^2 (169/250ccsoil) and *Paecilomyces lilacinus* @25g/ m^2(171/250ccsoil) effectively reduced the nematode population at harvesting stage.

The application of *Pseudomonas fluorescens* was most effective to manage nematodes until harvest as the populations of *Radopholus similis*, *Pratylenchus coffeae* and *Helicotylenchus multicinctus* were reduced by 48.70, 46.3 and 44.3%, respectively. Soil application of *Trichoderma viride* or carbofuran were the next best treatments followed by the application of *G. fasciculatum*, *B. subtilis* and *P. lilacinus*. Carbofuran was most effective to control nematodes until three months after planting, but its efficacy thereafter was reduced and remained at a level similar to *that of Pseudomonas fluorescens* (Shanti and Rajendran, 2006) [10]. The maximum level of reduction of burrowing nematode, *Radopholus similis* was recorded with a concentration of 6x10^6cfu/g dry soil of *Pseudomonas fluorescens* applied to the soil for three times (at six days before planting, at planting and as a plantlet drench). The results revealed that *Pseudomonas fluorescens* is an effective biocontrol agent against burrowing nematode (*Radopholus similis)* in banana (Mendoza *et al*., 2007) [7]. Harish and Gowda (2001) [3] reported that, the treatments neem cake+carbofuran+*Trichoderma viride* was found effective in reducing the nematode population. Control of *Radopholus similis* on banana, both in the roots and in the soil was greatest when *Monacrosporoum lysipagum* was applied alone (86%) or in combination with *Paecilomyces lilacinus* (96%), where the fungi were inoculated twice in 18weeks growth period. However, the combined application was most effective for reducing the nematode population (Khan *et al*., 2006) [4]. Soil application of native isolates of *Pseudomonas fluorescens* @10g/plant significantly reduced the infestation of *Radopholus similis*. The treatment PfB13 also enhanced the activity of defence enzymes responsible for induction of systemic resistance (Kumar *et al*. 2008) [5]. The effect of the fungus, *Paeciiomyces lilacinus* on multiplication of the burrowing nematode, *Radopholus similis* infesting betel vine was studied. *R. similis* alone (100/plant) caused maximum damage to plant growth and recorded maximum multiplication of nematodes. *P. lilacinus* reduced the damaging effect of *R. similis* on inoculation. Simultaneous inoculation of both the organisms or inoculation of the fungus 25 days after nematode inoculation were not effective in reducing the damage. (Sosamma *et al*., 1994) [11]. *Radopholus similis* was controlled substantially in single and combined application of *Fusarium oxysporum* with *Paecilomyces lilacinus* or *Bacillus firmus*. The combination of *Fusarium oxysporum* with *Paecilomyces lilacinus* caused a 68.5% reduction in nematode density whereas the individual applications reduced the intensity by 27.8% and 54.8% over the controls, respectively. Combined application of *Fusarium oxysporum* and *Bacillus firmus* was the most effective treatment in controlling *Radopholus similis* on banana (86.2%) followed by *Bacillus firmus* alone (63.7%) (Mendoza and Sikora, 2008) [7].

Burrowing nematode population (Roots)
In 2009-10, the treatment *Paecilomyces lilacinus* @25g/ m^2(16.67/10g roots) significantly reduced the burrowing

nematode population at vegetative stage but this treatment at par with Carbofuran @ 40 g/plant (12.33/10g roots).The next best treatments were *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (18.67/10g roots) and *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (20.00/10g roots).The highest nematode population was recorded in untreated control(54/10g roots). In 2010-12, the lowest nematode population was recorded in the treatment of *Paecilomyces lilacinus* @25g/ m^2(18.00/10g roots) followed by EPN *Heterorhabiditis indica* @1 x 10^9(20.67/10g roots) and *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (23.00/10g roots). At shooting stage, the treatment, Carbofuran @ 40 g/plant (16.84/10g roots) significantly reduced the burrowing nematode population. The next best treatments were EPN *Heterorhabiditis indica* @1 x 10^9(20/10g roots), *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (20.00/10g roots)and *Paecilomyces lilacinus* @25g/ m^2(20.50/10g roots).While at harvesting stage, the lowest nematode population was recorded in the treatment of carbofuran @40g/plant(25.0/10g roots).The next best treatments were EPN *Heterorhabiditis indica* @1 x 10^9(30/10g roots) and *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (31.34/10g roots) (Table 1).

Root necrosis

In vegetative stage, the lowest necrosis was recorded in the treatment of Carbofuran @ 40 g/plant (12.23%) followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (14.81%), *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (16.89%) and EPN *Heterorhabiditis indica* @1 x 10^9(17.26%).While at shooting and harvesting stage, the root necrosis was highest(56.27% and 71.81 % respectively) in untreated control. The lowest root necrosis was recorded in the treatment of EPN *Heterorhabiditis indica* @1 x 10^9 and *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (Table 2).

Growth Parameters

Plant height at flowering (m): During 2009-10, the plant height was highest (1.72m) in the treatment of *Paecilomyces lilacinus* @25g/ m^2. However the data was not significant among the treatments. In 2010- 2012,the highest plant height (1.76m) was recorded in the treatment of *Paecilomyces lilacinus* @25g/ m^2 followed by Carbofuran @ 40 g/plant (1.74m) and it was lowest in untreated control(1.49m)(Table 3).

Pseudostem girth

The highest stem girth (61cm) was recorded in the treatment of *Paecilomyces lilacinus* @25g/ m^2 followed by Carbofuran @ 40 g/plant (59.87cm).However the data was not significant among the treatments(Table3).

Leaf area (m^2)

The maximum leaf area(8.78m^2) was obtained in the treatment of EPN *Heterorhabiditis indica* @1 x 10^9 followed by *Paecilomyces lilacinus* @25g/ m^2 (8.48m^2), Carbofuran @ 40g/plant (8.46m^2)and it was lowest in untreated control (5.55m^2) (Table 3). Kumar *et al.* (2008) [5] reported that the native isolate of PfB13 treated banana plants increased plant height, pseudostem girth, leaf area and number of leaves. The improvement of plant growth was recorded by application of neemcake+carbofuran and *Trichodernma viride* (Harish and Gowda, 2001) [3].

Yield parameters

The bunch length of two years data revealed that, the maximum bunch length(42.61cm) was recorded in the treatment of Carbofuran @ 40 g/plant followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (41.64cm), *Paecilomyces lilacinus* @25g/ m^2 (38.38cm) and it was lowest in untreated control(33.97cm).With regards to bunch width, the maximum bunch width was recorded in the treatment of Carbofuran @ 40 g/plant (36.26cm)followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (34.88cm) and EPN *Heterorhabiditis indica* @1 x 10^9 (33.00cm). The lowest bunch width was recorded in untreated control (28.63cm) (Table 4).

The number of hands/bunch was maximum in Carbofuran @ 40 g/plant (7.76) followed by *Paecilomyces lilacinus* @25g/ m^2 (7.60) and *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (7.53). The number of fingers in third hand was more (12.53) in the treatment of *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 followed by *Paecilomyces lilacinus* @25g/ m^2 (12.42) and Carbofuran @ 40 g/plant (12.28). With regards to fingers/bunch, the maximum number of fingers /bunch (93.99)was recorded in Carbofuran @ 40 g/plant followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (90.31) and it was lowest in untreated control (68.21) (Table 4).

Shanthi and Rajendran (2006) [10] reported that, application of *P. fluorescens* at 20 g/plant recorded the highest bunch length (95cm), bunch weight (24 kg), number of hands per bunch (10) and number of fingers per bunch (176). The yield parameters increased from 59 to 110%.

In 2009-2010, the highest bunch weight (9.12kg/plant) was recorded in the treatment of Carbofuran @ 40 g/plant but this treatment at par with *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (8.69kg/plant).The next best treatments were *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (8.25kg/plant) and *Paecilomyces lilacinus* @25g/ m^2 (8.10kg/plant). In 2010-2012,the highest bunch weight per plant was recorded in Carbofuran @ 40 g/plant (9.52kg/plant) followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (8.91kg/plant) and *Paecilomyces lilacinus* @25g/ m^2 (8.34kg/plant). The lowest bunch weight (5.74kg/plant) was recorded in untreated control. Average of two years data revealed that, the treatment Carbofuran @ 40 g/plant recorded the highest bunch weight of 9.32kg/plant followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (8.80kg/plant) and *Paecilomyces lilacinus* @25g/ m^2 (8.22kg/plant).

With regards to yield (t/ha), the highest yield (28.76t/ha)was recorded in the treatment of Carbofuran @ 40 g/plant followed by *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 (27.16t/ha), *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (25.24t/ha) and *Paecilomyces lilacinus* @25g/ m^2 (25.38t/ha). The lowest yield was obtained in untreated control (17.57t/ha). The B/C ratio was more (5.74) in *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2 followed by Carbofuran @ 40 g/plant (5.52), *Paecilomyces lilacinus* @25g/ m^2 (5.35) and *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2 (5.23) (Table 5). Increased fruit yield with high cost:benefit ratio was recorded in the treatment of neem cake+carbofuran+*Trichoderma viride*. (Harish and Gowda, 2001) [3].

Acknowledgement
We thank the Project Co-Ordinator, Indian Institute of Horticultural Research, Bengaluru for providing necessary facilities.

Table 1: Effect of biocontrol agents for the management of burrowing nematode, *Radopholus similis* in banana

Treatments	Nematodes population 250cc soil: Vegetative stage 2009-10	2010-12	Mean	Shooting 2009-10	2010-12	Mean	Harvesting 2009-10	2010-12	Mean
T_1 Dip suckers in AM cultures	162.00^{e}	169.00^{d}	165.50	172.33^{d}	186.00^{d}	179.17	230.00^{c}	242.00^{e}	236.00
T_2 *Pseudomonas fluorescens* @ 25 g/ m^2	142.33^{d}	150.67^{c}	146.50	154.00^{c}	163.37^{c}	158.84	214.00^{c}	223.00^{d}	218.50
T_3 *Paecilomyces lilacinus* @25g/ m^2	135.00^{cd}	130.00^{b}	132.50	142.00^{bc}	140.0^{b}	141.00	167.33^{ab}	174.67^{bc}	171.00
T_4 *Bacillus subtilis* @25 g/ m^2	146.00^{cd}	156.00^{c}	151.00	159.33	172.00^{b}	165.67	192.00^{c}	219.00^{d}	205.50
T_5 EPN *Heterorhabiditis indica* @1 x 10^9 (1 Js/ml)	-	132.33^{b}	132.33	-	143.33^{b}	143.33	-	183.00^{c}	183.00
T_6 *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2	113.67^{b}	124.00^{b}	118.84	130.67^{b}	136.00^{b}	133.34	172.00^{b}	166.00^{b}	169.00
T_7 *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2	126.00^{c}	136.67^{bc}	131.35	131.33^{b}	144.00^{b}	137.67	176.67^{b}	182.00^{c}	179.34
T_8 *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2	130.00^{c}	146.00^{c}	138.00	143.67^{c}	159.00^{c}	151.34	210.67^{c}	214.00^{d}	212.34
T_9 Carbofuran @ 40 g/plant	82.00^{a}	96.00^{a}	89.00	107.33^{a}	112.00^{a}	109.67	143.00^{a}	137.00^{a}	140.00
T_{10} Untreated control	265.33^{f}	279.00	272.17	282.67^{e}	301.33^{e}	292.00	372.00^{d}	386.00^{f}	379.00
SEm$\pm$	3.68	7.09		4.12	6.34		4.79	4.43	
CD at 5%	10.94	20.92		12.37	18.85		14.36	13.15	

Treatments	Nematodes population 10 g roots: Vegetative stage 2009-10	2010-12	Mean	Shooting 2009-10	2010-12	Mean	Harvesting 2009-10	2010-12	Mean
T_1 Dip suckers in AM cultures	33.00^{c}	39.00^{c}	36.00	41.33^{d}	46.00^{c}	43.64	58.00^{c}	54.33^{d}	56.17
T_2 *Pseudomonas fluorescens* @ 25 g/ m^2	31.33^{c}	34.33^{b}	32.83	34.33^{c}	41.33^{c}	37.83	43.67^{b}	45.67c	44.67
T_3 *Paecilomyces lilacinus* @25g/ m^2	16.67^{ab}	18.00^{a}	17.34	22.00^{ab}	19.00^{a}	20.50	36.23^{b}	32.00^{b}	34.15
T_4 *Bacillus subtilis* @25 g/ m^2	29.67^{c}	36.33^{c}	33.00	32.33^{c}	47.33^{c}	39.83	44.00^{b}	40.67^{b}	42.34
T_5 EPN *Heterorhabiditis indica* @1 x 10^9 (1 Js/ml)	-	20.67^{a}	20.67	-	20.00^{a}	20.00	-	30.00^{a}	30.00
T_6 *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2	18.67^{b}	23.00^{a}	20.83	22.67^{ab}	17.33^{a}	20.00	34.00^{a}	28.67^{a}	31.34
T_7 *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2	20.00^{b}	26.00^{b}	23.00	24.33^{b}	28.00^{b}	26.17	38.00^{ab}	34.67^{b}	36.34
T_8 *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2	28.33^{c}	34.33^{b}	31.33	26.00^{b}	34.67^{b}	30.34	40.00^{a}	46.00^{c}	43.00
T_9 Carbofuran @ 40 g/plant	12.33^{a}	18.00^{a}	15.16	16.67^{a}	17.00^{b}	16.84	26.00^{a}	24.00^{a}	25.00
T_{10} Untreated control	54.00^{d}	61.32	57.66	58.00^{c}	69.00^{d}	63.50	74.00^{d}	86.00^{e}	80.00
SEm$\pm$	1.76	2.94		2.10	2.28		3.09	2.59	
CD at 5%	5.23	8.74		6.30	6.77		9.26	7.70	

$^{a, b, c, cd, ...}$=indicates significant differences among treatments

Table 2: Management of burrowing nematode, *Radopholus similis* in banana by using biocontrol agents

Treatments	Root necrosis (%): Vegetative stage 2009-10	2010-12	Mean	Shooting 2009-10	2010-12	Mean	Harvesting 2009-10	2010-12	Mean
T_1 Dip suckers in AM cultures	27.00^{d}	35.63^{c}	31.32	41.38^{c}	45.75^{c}	43.57	45.08^{b}	51.08^{c}	48.08
T_2 *Pseudomonas fluorescens* @ 25 g/ m^2	34.46^{c}	22.85^{b}	28.66	27.78^{b}	31.29^{b}	29.54	32.38^{a}	35.00^{b}	33.69
T_3 *Paecilomyces lilacinus* @25g/ m^2	20.67^{a}	16.57^{ab}	18.62	28.27^{b}	16.53^{a}	22.40	33.49^{a}	22.35^{a}	27.92
T_4 *Bacillus subtilis* @25 g/ m^2	24.29^{bc}	22.38^{b}	23.34	31.78^{b}	27.57^{b}	29.68	30.56^{a}	33.16^{b}	31.86
T_5 EPN *Heterorhabiditis indica* @1 x 10^9 (1Js/ml)	-	17.26^{ab}	17.26	-	17.41^{a}	17.41	-	20.62^{a}	20.62
T_6 *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2	15.00^{a}	14.61^{a}	14.81	24.03^{a}	18.88^{a}	21.46	23.80^{a}	18.21^{a}	21.01
T_7 *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2	15.33^{a}	18.45^{ab}	16.89	25.83^{ab}	21.92^{a}	23.88	28.11^{a}	24.39^{a}	26.25
T_8 *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2	26.69^{bc}	23.89^{b}	25.29	19.66^{a}	25.93$_{b}$	22.80	33.51^{a}	30.00^{b}	31.76
T_9 Carbofuran @ 40 g/plant	12.10^{a}	12.44^{a}	12.23	24.99^{a}	16.56$_{a}$	20.78	24.00^{a}	18.68^{a}	21.34
T_{10} Untreated control	53.81^{e}	47.59^{d}	50.70	55.24^{d}	57.29$_{d}$	56.27	64.92^{c}	78.69^{d}	71.81
SEm$\pm$	3.67	2.64		2.50	2.93		5.87	3.00	
CD at 5%	10.90	7.77		7.51	8.70		17.61	8.91	

Table 3: Management of burrowing nematode in banana by using bio-control agents: Growth parameters

Treatments	Plant height at flowering (m) 2009-10	2010-12	Mean	Stem girth at flowering (cm) 2009-10	2010-12	Mean	Leaf area (m^2) 2009-10	2010-12	Mean
T_1 Dip suckers in AM cultures	1.58	1.63^{b}	1.61	55.81	55.05	55.43	6.42	7.60^{b}	7.01
T_2 *Pseudomonas fluorescens* @ 25g/ m^2	1.64	1.72^{a}	1.68	54.92	60.72	57.82	6.23	7.54^{b}	6.89
T_3 *Paecilomyces lilacinus* @25g/ m^2	1.72	1.76^{a}	1.74	57.92	64.08	61.00	7.26	9.70^{a}	8.48
T_4 *Bacillus subtilis* @25 g/ m^2	1.63	1.59^{b}	1.61	55.69	59.69	57.69	7.54	7.24^{b}	7.39
T_5 EPN *Heterorhabiditis indica* @1 x 10^9 (1Js/ml)	--	1.64^{a}	1.64	--	58.22	58.22	--	8.78^{a}	8.78
T_6 *Pseudomonas fluorescens* @12.5 g/ m^2 + *P. lilacinus* @12.5 g/m^2	1.66	1.70^{a}	1.68	53.58	60.66	57.12	6.85	8.90^{a}	7.88
T_7 *Paecilomyces lilacinus* @12.5g /m^2 + *B. subtilis* @12.5 g/m^2	1.58	1.60^{a}	1.66	53.22	61.14	57.18	6.63	8.72^{a}	7.68
T_8 *Bacillus subtilis* @12.5g / m^2 + *Pseudomonas fluorescens* @12.5 g/m^2	1.62	1.70^{a}	1.66	56.78	62.03	59.41	6.62	7.81^{a}	7.22
T_9 Carbofuran @ 40 g/plant	1.66	1.74^{a}	1.70	55.39	64.35	59.87	**7.70**	9.21^{a}	8.46
T_{10} Untreated control	1.50	1.49^{b}	1.50	49.25	51.91	50.58	5.25	5.84^{b}	5.55
SEm$\pm$	0.03	0.05		1.68			0.57	0.50	
CDat 5%	NS	0.15		NS	NS		NS	1.51	

Table 4: Management of burrowing nematode in banana by using biocontrol agents: Yield parameters

Treatments	Hands/ bunch			No. of fingers in 3rd hand			Fingers/bunch		
	2009-10	2010-12	Mean	2009-10	2010-12	Mean	2009-10	2010-12	Mean
T$_{1}$ Dip suckers in AM cultures	6.86^{b}	7.11^{c}	6.99	11.53^{b}	11.43^{b}	11.48	74.39^{c}	76.78^{c}	75.59
T$_{2}$ *Pseudomonas fluorescens* @ 25 g/ m^{2}	7.36^{a}	7.36^{b}	7.36	11.67^{b}	12.44^{a}	12.06	80.39^{b}	86.42^{b}	83.41
T$_{3}$ *Paecilomyces lilacinus* @25g/ m^{2}	7.61^{a}	7.58^{b}	7.60	11.97^{a}	12.86^{a}	12.42	76.61^{b}	89.42^{b}	83.02
T$_{4}$ *Bacillus subtilis* @25 g/ m^{2}	6.97^{b}	7.06^{c}	7.02	11.78^{a}	11.67^{b}	11.73	78.89	77.72^{c}	78.31
T$_{5}$ EPN *Heterorhabiditis indica* @1 x 10^{9} (1Js/ml)	-	7.0^{c}	7.0	-	12.23^{a}	12.23	-	79.78^{c}	79.78
T$_{6}$ *Pseudomonas fluorescens* @12.5 g/ m^{2} + *P. lilacinus* @12.5 g/m^{2}	7.42^{a}	7.64^{b}	7.53	12.50^{a}	12.56a	12.53	87.83^{a}	92.78^{a}	90.31
T$_{7}$ *Paecilomyces lilacinus* @12.5g /m^{2} + *B. subtilis* @12.5 g/m^{2}	7.17^{a}	7.22^{c}	7.20	12.39^{a}	12.10^{a}	12.25	79.70^{b}	79.39^{c}	79.55
T$_{8}$ *Bacillus subtilis* @12.5g / m^{2} + *Pseudomonas fluorescens* @12.5 g/m^{2}	6.83^{b}	7.0^{c}	6.92	11.72^{a}	11.49^{a}	11.61	74.00^{b}	72.61^{c}	73.31
T$_{9}$ Carbofuran @ 40 g/plant	7.56^{a}	7.95^{a}	7.76	12.11^{a}	12.44^{a}	12.28	89.00^{a}	98.97^{a}	93.99
T$_{10}$ Untreated control	6.67^{b}	6.78^{d}	6.73	10.89^{b}	11.06^{b}	10.98	67.00^{c}	69.42^{d}	68.21
SEm$\pm$	0.20	0.24		0.28	0.26		2.30	2.71	
C.D at 5%	0.61	0.72		0.84	0.78		6.90	8.00	

Treatments	Bunch length (cm)			Bunch width (cm)		
	2009-10	2010-12	Mean	2009-10	2010-12	Mean
T$_{1}$ Dip suckers in AM cultures	36.56 ^{b}	37.22^{b}	36.89	29.03^{b}	31.0^{b}	30.02
T$_{2}$ *Pseudomonas fluorescens* @ 25 g/ m^{2}	36.22 ^{b}	38.83^{b}	37.53	29.72 ^{b}	32.0^{b}	30.86
T$_{3}$ *Paecilomyces lilacinus* @25g/ m^{2}	36.11 ^{b}	40.64^{a}	38.38	30.44 ^{b}	34.22^{a}	32.33
T$_{4}$ *Bacillus subtilis* @25 g/ m^{2}	37.44 ^{a}	37.33^{b}	37.89	30.78 ^{b}	30.05^{b}	30.42
T$_{5}$ EPN *Heterorhabiditis indica* @1 x 10^{9} (1Js/ml)	-	38.78^{b}	38.78		33.00^{b}	33.00
T$_{6}$ *Pseudomonas fluorescens* @12.5 g/ m^{2} + *P. lilacinus* @12.5 g/m^{2}	41.42 ^{a}	41.86^{a}	41.64	35.92 ^{a}	33.83^{a}	34.88
T$_{7}$ *Paecilomyces lilacinus* @12.5g /m^{2} + *B. subtilis* @12.5 g/m^{2}	37.03 ^{b}	38.17^{b}	37.60	32.25 ^{b}	31.72^{b}	31.99
T$_{8}$ *Bacillus subtilis* @12.5g / m^{2} + *Pseudomonas fluorescens* @12.5 g/m^{2}	36.58 ^{b}	36.69^{b}	36.64	30.94 ^{b}	31.75^{b}	31.35
T$_{9}$ Carbofuran @ 40 g/plant	41.55 ^{a}	43.67^{a}	42.61	36.55 ^{a}	35.97^{a}	36.26
T$_{10}$ Untreated control	33.72 ^{b}	34.22^{c}	33.97	28.45 ^{b}	28.81 ^{c}	28.63
SEm$\pm$	1.43	1.12		1.18	0.97	
CD at 5%	4.28	3.29		3.54	2.86	

Table 5: Management of burrowing nematode in banana by using biocontrol agents: Yield parameters

Treatments	Bunch weight (kg)			Yield (t/ha)			B/C ratio		
	2009-10	2010-12	Mean	2009-10	2010-12	Mean	2009-10	2010-12	Mean
T$_{1}$ Dip suckers in AM cultures	6.19^{d}	6.82^{c}	6.51	19.10^{d}	21.05	20.08	4.01	4.33	4.17
T$_{2}$ *Pseudomonas fluorescens* @ 25 g/m^{2}	7.36^{c}	7.49^{c}	7.43	22.70^{c}	23.11	22.91	4.80	4.46	4.63
T$_{3}$ *Paecilomyces lilacinus* @25g/ m^{2}	8.10^{bc}	8.34^{b}	8.22	25.01^{bc}	25.74	25.38	5.26	5.43	5.35
T$_{4}$ *Bacillus subtilis* @25 g/ m^{2}	7.03^{c}	6.95^{c}	6.19	21.68^{c}	21.45	21.57	4.49	3.84	4.17
T$_{5}$ EPN *Heterorhabiditis indica* @1 x 10^{9} (1Js/ml)	-	7.78^{b}	7.78	-	24.01	24.01	-	5.04	5.04
T$_{6}$ *Pseudomonas fluorescens* @12.5 g/ m^{2} + *P. lilacinus* @12.5 g/m^{2}	8.69^{a}	8.91^{a}	8.80	26.83^{a}	27.49	27.16	5.79	5.68	5.74
T$_{7}$ *Paecilomyces lilacinus* @12.5g /m^{2} + *B. subtilis* @12.5 g/m^{2}	8.25^{b}	8.1^{b}	8.18	25.46^{b}	25.01	25.24	5.50	4.96	5.23
T$_{8}$ *Bacillus subtilis* @12.5g / m^{2} + *Pseudomonas fluorescens* @12.5 g/m^{2}	7.79^{bc}	7.56^{c}	7.68	24.05^{bc}	23.32	23.69	5.14	4.41	4.78
T$_{9}$ Carbofuran @ 40 g/plant	9.12^{a}	9.52^{a}	9.32	28.13^{a}	29.38	28.76	5.66	5.38	5.52
T$_{10}$ Untreated control	5.61^{d}	5.74^{d}	5.68	17.31^{d}	17.82	17.57	-	-	-
SEm$\pm$	0.27	0.25		0.86	0.76				
CD at 5%	0.80	0.73		2.58	2.24				

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