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Compatibility and combined efficacy of EPF and insecticides against *Pentalonia nigronervosa* (Coquerel) (Hemiptera: Aphididae) infesting banana

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Abstract
The experiment was conducted at Biological Control Laboratory, Department of Agricultural Entomology, College of Agriculture, Dapoli. Dist. Ratnagiri (Maharashtra). EPF and insecticide combinations were found to be compatible at one-fourth of the recommended dose, whereas they were incompatible when concentration was increased to the recommended dose. Imidacloprid at ¼ RD showed a highly compatible nature with maximum radial growth of 67.98 mm in the treatment combination of Imidacloprid @ 0.0075 ml + *M. anisopliae* with an inhibition of 9.36 percent. This is followed by Imidacloprid @ 0.0075 ml + *B. bassiana* with a radial growth of 80.61 mm and a radial growth inhibition of 10.43 percent over the control. Insecticides and fungal biocontrol agents work together to increase the effectiveness of the control, allowing for lower insecticide dosages. Imidacloprid 17.8% SL @ 0.3 ml/l was found to be most effective, with 88.01 percent of *P. nigronervosa* mortality. Compatible treatment combination Imidacloprid 17.8% SL + *B. bassiana* 1x10^8 cfu/ml @ 0.075 ml + 4 g/l was found to be most effective, with 73.97 percent of *P. nigronervosa* mortality.

Keywords: EPF, *Pentalonia nigronervosa, M. anisopliae, B. bassiana*

1. Introduction

Banana (*Musa* spp.) is one of the leading fruit crop in India followed by mango. Banana and plantains are susceptible to various abiotic and biotic factors, which reduce its production drastically. Banana plants are constantly under the risk of being attacked by viruses, fungi, bacteria, nematodes and insects, which infect them and cause significant yield losses (Ghag, 2019) [4]. Among all of them the *Pentalonia nigronervosa* (Coquerel) is a one of major pest, the vector of Banana bunchy top virus (BBTV) (Magee, 1927) [8], the etiological agent of Banana bunchy top disease (BBTD). It is transmitted in a circulative, non-propagative and persistent manner. BBTD is considered in many regions of the world as the most important viral disease of this crop (Magee, 1927; Dale, 1987; Hu *et al*., 1996) [8, 3, 6].

Management of sucking pests is done mainly by chemical insecticides but their excessive and indiscriminate use has led to residue problems, adverse effect on environment, development of resistance to pesticides and health hazards (Pilkington *et al*., 2010 and Pappas *et al*., 2013) [16, 14]. So, there is need for alternative biocontrol methods to manage these pests. Management of these pests using entomopthroralales fungi is regarded as an important antagonist (Manfrino *et al*., 2014) [10]. The entomopathogenic fungi contain cuticle degrading enzymes like protease; lipase and chitinase which degrade the insect cuticle followed by penetration of fungal germ tube into insect body and thereby release several mycotoxins to kill the insect (Maina *et al*., 2018) [9]. These microbial pesticides offer an alternative to chemical insecticides having target specificity and ecological safe due to which that they are used either alone or in combination with other pest management programmes. Compatibility studies are essential for the integration and simultaneous use of chemical and biological pest control methods since they are necessary for an Integrated Pest Management (IPM) programme. Compatibility study leads to better control of the pest by EPF and insecticides which leads to delays the development of insecticide resistance. Effectiveness of entomopathogens can be enhanced with insecticides. Most of them have either positive synergistic or additive effect with insecticides indicating their selective use in IPM. Moreover, the issue of insecticide resistance can also be minimized as microbial biopesticides exhibit novel modes of actions, which is lacking in conventional chemical insecticides.

2. Material and Methods

2.1 Compatibility study

The two EPF *viz.*, *Beauveria bassiana* (Bals.) Vuill and *Metarhizium anisopliae* (Metchnikoff) Sorokin used in this study was collected from Biological Control Laboratory, Department of Agricultural Entomology, College of Agriculture, Dapoli. Both EPF are cultured on PDA medium in 9 cm petri dishes and incubated at 25±2 °C temperature. Three different insecticides *viz.*, Azadirachtin (1500 ppm) @ 3 ml/l, Imidacloprid 17.8% SL @ 0.3 ml/l and Dimethoate 30 EC @ 2 ml/l used to assess the compatibility with EPF. For compatibility tests the insecticides are used in three different concentrations, *i.e.*, recommended dose (RD) (lethal), half of the recommended dose (½ RD) (sub lethal) and one fourth of the recommended dose (¼ RD) (sub-sub lethal).

Standard poisoned food technique was followed to assay the *in vitro* compatibility of entomopathogens with the different insecticides (Nene and Thapliyal, 1997) [13]. Quantity of insecticides used was based on field application rate with high volume sprayer. Standard PDA medium (30 ml) was autoclaved at 121 °C for 15 minutes, cooled to 40±5 °C and amended with 0.3 g/l of streptomycin sulphate. The required concentrations (RD, ½ RD and ¼ RD) of insecticides (30 ml each) was prepared and added to the media while, it was warm and agitated thoroughly to get a uniform distribution of insecticides in the media. For control plates, appropriate amount of streptomycin sulphate (0.3 g/l) alone was added. Approximately 15 ml of each of the amended media was poured aseptically into 9 cm sterilized petri dishes. The same amount of medium without the insecticides was used as control for comparison under the same conditions. Mycelial disc (5 mm diameter) of young fungal mycelium was cut with sterile cork borer and placed aseptically in the center of each petri dish containing the poisoned medium. Inoculated petri dishes were incubated at 27±1 °C and 80±5 percent relative humidity.

2.1.1 Observations recorded

For each treatment three replications were maintained. Fungal colony diameter was measured with a caliper ruler after every 24 hrs. of inoculation till full growth was observed in control plates. Percent inhibition of radial growth of fungal isolate over untreated check was worked out for the respective insecticides by following the formula:

$$\text{Percent inhibition of radial growth} = (C - T) / C \times 100$$

Where

C = colony diameter of EPF in control

T = colony diameter of EPF in treatments

2.1.2 Compatibility rating for test insecticides

The final compatibility status was determined on the basis of applying following ratings to percent inhibition growth of EPF in respective insecticide combinations (Patil, 2011) [15].

Table 1: Compatibility rating for testing insecticides

Sr. No.	Percent inhibition of radial growth over control (%)	Compatibility status
1	< 20	HC
2	20-50	C
3	50-80	PC
4	> 80	IC

HC = Highly compatible, C = Compatible,
PC = Partially compatible, IC = Incompatible

2.1.3 Statical method

The experimental data thus obtained was analysed statistically by applying OPSTAT package statistic program as applicable in Completely Randomized Block Design (CRD). The range, mean, standard error (S.E.) and critical difference (C.D.) at 5 percent probability was worked out for comparison between treatments.

2.2 Management study

The insecticides which resulted good compatibility status with EPF were selected for combined application against *P. nigronervosa*.

2.2.1 Maintenance of host plants and aphid culture

The study on management of *P. nigronervosa* was carried out at the Biological control unit, College of Agriculture, Dapoli, Dist. Ratnagiri, in controlled field conditions. Small healthy tissue cultured Grand nine banana plants required for the study was taken from the Plant Biotechnology Centre, College of Agriculture, Dapoli. Initial culture of aphid was collected from farmers field in Palghar district, Maharashtra. In order to mass rear the aphids, they were transferred to new banana plants and maintained.

2.2.2 Experimental Details

A field experiment was conducted in Randomized Block Design with eleven treatments and three replications during *Rabi* summer, 2022-2023 to study the management of black aphid, *P. nigronervosa* infesting banana using compatible treatment combinations of EPF and insecticides. The treatments of the experiment were T_1- Azadirachtin (1500 ppm) + *B. bassiana* $1x10^8$ cfu/ml, T_2- Imidacloprid 17.8% SL + *B. bassiana* $1x10^8$ cfu/ml, T_3- Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml, T_4- Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml, T_5- Dimethoate 30 EC + *B. bassiana* $1x10^8$ cfu/ml, T_6- Azadirachtin (1500 ppm), T_7- Imidacloprid 17.8% SL, T_8- Dimethoate 30 EC, T_9- *B. bassiana* $1x10^8$ cfu/ml, T_{10}- *M. anisopliae* $1x10^8$ cfu/ml and T_{11}- untreated control were evaluated.

Tissue cultured Grand nine banana plants were transferred to the plastic plant potters containing mixture of FYM and red earth. Adequate time was given for the establishment of banana plants. Ten matured adult aphids were transferred to each plant using fine camel hair brush and kept undisturbed for a week allowing the aphids to multiply. After multiplication of aphids, five plants were kept in each treatment cage of size 4x4x4 ft^3 covered with shade net and water is sprinkled frequently to maintain the temperature and relative humidity.

2.2.3 Method and time of insecticide application

Actual quantity of spray solution required was calibrated prior to each spraying using water. The spraying was done with hand sprayer. The desired concentration of various insecticides were prepared on the basis of percentage of active ingredient present in respective trade product and sprayed to the plants thoroughly in the form of fine droplets using hand sprayer. The sprayer was washed off thoroughly after completion of spraying in each treatment. The spraying was done in early morning hours after sufficient infestation of aphid on banana.

2.2.4 Method of recording observations

Observations about number of *P. nigronervosa*, were taken from five plants in each treatment at 2, 5, 7 and 10 days after spraying of EPF and insecticides along with their combinations. The *P. nigronervosa* count was taken from top, middle and bottom portions of the plant. The pre-count observations were recorded before application of insecticides. The first spray was taken after establishment of colony and the second spray was given at the interval of fourteen days. The average *P. nigronervosa* population per five plants was worked out and data obtained was analysed statistically. Effectiveness of the treatments were judged based on the efficacy of EPF and insecticides along with their combinations against *P. nigronervosa.*

The results were presented as percent mortality of aphid population with a comparison to densities found on the control. Percent mortality of aphid over control was calculated by using the following formula:

$$\text{Percent mortality} = \frac{\text{No. of aphids died}}{\text{No. of aphids released}} \times 100$$

2.2.5 Statistical methods

The experimental data thus obtained was analysed statistically by applying OPSTAT package statistic program as applicable in Randomized Block Design (RBD). The range, mean, standard error (S.E.) and critical difference (C.D.) at 5 percent probability was worked out for comparison between treatments. The results are presented in tables.

3. Results and Discussion

3.1 Compatibility study

In vitro, evaluation of compatibility of *B. bassiana* and *M. anisopliae* with insecticides showed that, both the EPF were compatible with the insecticides, at ¼ RD (sub-sub lethal dose) followed by ½ RD (sub lethal) and RD (lethal). Among the insecticides tested, Imidacloprid at ¼ RD showed maximum radial growth of 67.98 mm in the treatment combination of Imidacloprid @ 0.075% + *M. anisopliae* with inhibition of (9.36%) on growth of the fungus followed by 80.61 mm in the treatment Imidacloprid @ 0.075% + *B. bassiana* and 56.34 mm in the treatment Imidacloprid @ 0.075% + *M. anisopliae*. The percent inhibition of radial growth of *B. bassiana* and *M. anisopliae* over control was found to be 10.43 and 24.88 percent, respectively. Dimethoate at ¼ RD showed highest radial growth of 65.17 mm with growth inhibition of 27.59 percent in combination of *B. bassiana* followed by ½ RD possessing 42.93 mm growth and 52.29 percent growth inhibition. This was followed by RD with 32.26 mm of radial growth and 61.93 percent inhibition. The maximum radial growth of the EPF with Azadirachtin was recorded at ¼ RD. Azadirachtin @ 0.075% + *B. bassiana* showed 57.53 mm growth with 36.08 percent inhibition followed by Azadirachtin @ 0.15% + *B. bassiana* (42.92 mm and 52.31 percent) and Azadirachtin @ 0.075% + *M. anisopliae* (32.62 mm and 56.51 percent), respectively.

EPF and insecticide combinations were found to be compatible at one-fourth of the recommended dose, whereas they were incompatible when concentration was increased to the recommended dose (Raj *et al*. 2011) [17]. Similar studies in these regards were made by Kakati *et al*. (2018) [7], who revealed that the maximum growth of the BCAs were recorded at ¼ RD (sub-sub lethal dose) in the treatment combination of imidacloprid @ 0.025% + *B. bassiana* with 72.15 mm of radial growth and this was followed by ½ RD (sub lethal) and RD (lethal). Hiremath *et al*. (2020) [5] and Abidin *et al*. (2017) [1] also reported that insecticides are highly compatible at their ¼ of recommended dose with *B. bassiana*.

Table 2: Compatibility of insecticides with EPF

Sr. No	Testing combinations (Insecticides + EPF)	Dose per litre (ml)	Radial growth of EPF (mm)	Percent inhibition of radial growth over control
T_1	Azadirachtin (1500 ppm) + *B. bassiana*	3 ml	20.96	76.71
T_2	Azadirachtin (1500 ppm) + *B. bassiana*	1.5 ml	42.92	52.31
T_3	Azadirachtin (1500 ppm) + *B. bassiana*	0.075 ml	57.53	36.08
T_4	Azadirachtin (1500 ppm) + *M. anisopliae*	3 ml	19.54	73.95
T_5	Azadirachtin (1500 ppm) + *M. anisopliae*	1.5 ml	22.14	70.48
T_6	Azadirachtin (1500 ppm) + *M. anisopliae*	0.075 ml	32.62	56.51
T_7	Imidacloprid 17.8% SL + *B. bassiana*	0.3 ml	30.12	66.53
T_8	Imidacloprid 17.8% SL + *B. bassiana*	0.15 ml	39.84	55.73
T_9	Imidacloprid 17.8% SL + *B. bassiana*	0.075 ml	80.61	10.43
T_{10}	Imidacloprid 17.8% SL + *M. anisopliae*	0.3 ml	30.66	59.12
T_{11}	Imidacloprid 17.8% SL + *M. anisopliae*	0.15 ml	56.34	24.88
T_{12}	Imidacloprid 17.8% SL + *M. anisopliae*	0.075 ml	67.98	9.36
T_{13}	Dimethoate 30 EC + *B. bassiana*	2 ml	34.26	61.93
T_{14}	Dimethoate 30 EC + *B. bassiana*	1 ml	42.93	52.29
T_{15}	Dimethoate 30 EC + *B. bassiana*	0.5 ml	65.17	27.59
T_{16}	Dimethoate 30 EC + *M. anisopliae*	2 ml	25.16	66.45
T_{17}	Dimethoate 30 EC + *M. anisopliae*	1 ml	34.19	54.41
T_{18}	Dimethoate 30 EC + *M. anisopliae*	0.5 ml	31.46	58.05
T_{19}	*B. bassiana*	-	90.00	
T_{20}	*M. anisopliae*	-	75.00	
	SE(m)		1.68	
	CD (P=0.05)		4.81	
	CV		6.48	

3.2 Management study

The mean percent mortality after first spray revealed that the treatment T_7 - Imidacloprid 17.8% SL @ 0.3 ml/l was most effective treatment which recorded 86.30 percent aphid mortality. The treatment T_8 - Dimethoate 30 EC @ 2 ml/l was found at par with treatment T_7 -Imidacloprid 17.8% SL @ 0.3 ml/l possessing 82.05 percent. It was followed by T_6 - Azadirachtin (1500 ppm) @ 3 ml/l (72.96%), T_2 - Imidacloprid 17.8% SL + *B. bassiana* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l (72.36%), T_3 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.15 ml + 4 g/l (68.04%), T_4 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l (65.50%), T_9 - *B. bassiana* $1x10^8$ cfu/ml @ 4 g/l (64.99%), T_5 - Dimethoate 30 EC + *B. bassiana* $1x10^8$ cfu/ml @ 0.5 ml + 4 g/l (64.54%), T_1 - Azadirachtin (1500 ppm) + *B. bassiana* $1x10^8$ cfu/ml @ 0.75 ml + 4 g/l (62.85%) and T_{10} - *M. anisopliae* $1x10^8$ cfu/ml @ 4 g/l (58.21%) mortality. Treatment T_{11} - untreated control showed 11.36 percent mortality which was least among all of them.

The best mean treatment found during second spray was T_7 - Imidacloprid 17.8% SL @ 0.3 ml/l with 89.73 percent mortality. It was followed by T_8 - Dimethoate 30 EC @ 2 ml/l (83.29%), T_6 - Azadirachtin (1500 ppm) @ 3 ml/l (78.11%), T_2 - Imidacloprid 17.8% SL + *B. bassiana* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l (75.41%), T_3 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.15 ml + 4 g/l (72.35%), T_4 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l (70.55%), T_9 - *B. bassiana* $1x10^8$ cfu/ml @ 4 g/l (69.39%), T_5 - Dimethoate 30 EC + *B. bassiana* $1x10^8$ cfu/ml @ 0.5 ml + 4 g/l (68.11%), T_1 - Azadirachtin (1500 ppm) + *B. bassiana* $1x10^8$ cfu/ml @ 0.75 ml + 4 g/l (67.38%) and T_{10} - *M. anisopliae* $1x10^8$ cfu/ml @ 4 g/l (62.00%) mortality. The least percent mortality was observed in T_{11} - Untreated Control (10.12%).

The overall mean percent mortality after two sprays revealed that the treatment T_7 - Imidacloprid 17.8% SL @ 0.3 ml/l was most effective treatment which recorded 88.01 percent mortality of aphids. The treatment T_8 - Dimethoate 30 EC @ 2 ml/l with 82.67 percent of aphid mortality was found at par with T_7 - Imidacloprid 17.8% SL @ 0.3 ml/l. It was followed by treatment T_6 - Azadirachtin (1500 ppm) @ 3 ml/l with mortality 75.54 percent, T_2 - Imidacloprid 17.8% SL + *B. bassiana* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l with mortality 73.97 percent, T_3 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.15 ml + 4 g/l with mortality 70.19 percent, T_4 - Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml @ 0.075 ml + 4 g/l with mortality 68.02 percent, T_9 - *B. bassiana* $1x10^8$ cfu/ml @ 4 g/l with mortality 67.19 percent, T_5 - Dimethoate 30 EC + *B. bassiana* $1x10^8$ cfu/ml @ 0.5 ml + 4 g/l with mortality 66.33 percent, T_1 - Azadirachtin (1500 ppm) + *B. bassiana* $1x10^8$ cfu/ml @ 0.75 ml + 4 g/l with mortality 65.11 percent and T_{10} - *M. anisopliae* $1x10^8$ cfu/ml @ 4 g/l with mortality 60.11 percent. The least mortality was found in treatment T_{11} - Untreated Control with mortality of 10.74 percent.

The finding of this investigation coincides with the results of Mathew *et al.* (1998a) [11], who recorded that *B. bassiana* ($1x10^7$ spores/ml) and *M. anisopliae* ($1x10^7$ spores/ml) caused 96.6 and 55.1 percent mortality in banana aphid, respectively. Amsavalli *et al.* (2023) [2] observed that Imidacloprid 17.8% SL @ 0.3 ml/l was highly suitable against banana aphids with 90.07 percent mortality. Nawaz *et al.* (2022) [12], studied the combined application of *M. anisopliae* with imidacloprid and revealed that, after 72 hours 88.59 percent of mortality was observed in *A. gossypii*.

Table 3: Effect of compatible treatment combinations of EPF and insecticides against *P. nigronervosa* infesting banana after first spray

Tr. No.	Treatments	Dose (ml) or (g) per litre	Pre-count (Mean no. of *P. nigronervosa*/5 plants)	Percent *P. nigronervosa* mortality				Mean Percent Mortality after first spray
				2 DAS*	5 DAS	7 DAS	10 DAS	
T_1	Azadirachtin (1500 ppm) + *B. bassiana* $1x10^8$ cfu/ml	0.75 ml + 4 g	50.52	25.39 (30.25)**	52.74 (46.57)	84.55 (66.86)	88.70 (70.36)	62.85 (52.44)
T_2	Imidacloprid 17.8% SL + *B. bassiana* $1x10^8$ cfu/m*l*	0.075 ml + 4 g	49.97	33.28 (35.23)	69.26 (56.33)	92.99 (74.65)	93.92 (75.72)	72.36 (58.28)
T_3	Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml	0.15 ml + 4 g	53.67	29.45 (32.87)	64.18 (53.24)	88.45 (70.13)	90.08 (71.64)	68.04 (55.57)
T_4	Imidacloprid 17.8% SL + *M. anisopliae* $1x10^8$ cfu/ml	0.075 ml + 4 g	50.90	28.74 (32.42)	57.91 (49.55)	86.19 (68.18)	89.16 (70.78)	65.50 (54.03)
T_5	Dimethoate 30 EC + *B. bassiana* $1x10^8$ cfu/ml	0.5 ml + 4 g	49.82	31.38 (34.07)	60.23 (50.90)	84.35 (66.70)	82.21 (65.05)	64.54 (53.45)
T_6	Azadirachtin (1500 ppm)	3 ml	52.50	62.07 (51.98)	76.69 (61.13)	79.54 (63.11)	73.55 (59.05)	72.96 (58.67)
T_7	Imidacloprid 17.8% SL	0.3 ml	56.11	83.38 (65.94)	86.11 (68.12)	89.06 (70.69)	86.64 (68.56)	86.30 (68.27)
T_8	Dimethoate 30 EC	2 ml	54.12	81.28 (64.36)	83.62 (66.13)	84.88 (67.12)	78.40 (62.31)	82.05 (64.93)
T_9	*B. bassiana* $1x10^8$ cfu/ml	4 g	53.67	19.83 (26.44)	60.44 (51.03)	87.94 (69.68)	91.76 (73.32)	64.99 (53.72)
T_{10}	*M. anisopliae* $1x10^8$ cfu/ml	4 g	58.04	15.94 (23.53)	49.00 (44.43)	81.43 (64.47)	86.47 (68.42)	58.21 (49.73)
T_{11}	Untreated Control	-	52.61	9.08 (17.54)	11.20 (19.55)	13.14 (21.25)	12.00 (20.27)	11.36 (19.69)
	S.Em. (±)		1.83	0.90	1.39	2.77	2.28	1.83
	CD at 5%		NS	2.65	4.10	8.19	6.75	5.42

*DAS - Days After Spraying

** Figures in parentheses are arcsine values

Table 4: Effect of compatible treatment combinations of EPF and insecticides against *P. nigronervosa* infesting banana after second spray

Tr. No.	Treatments	Dose (ml) or (g) per litre	Pre-count (Mean no. of *P. nigronervosa*/5 plants)	Percent *P. nigronervosa* mortality				Mean Percent Mortality after second spray
				2 DAS*	5 DAS	7 DAS	10 DAS	
T_1	Azadirachtin (1500 ppm) + *B. bassiana* 1x10^8 cfu/ml	0.75 ml + 4 g	51.61	20.75 (27.10)**	72.72 (58.51)	85.49 (67.61)	90.55 (72.10)	67.38 (55.17)
T_2	Imidacloprid 17.8% SL + *B. bassiana* 1x10^8 cfu/m*l*	0.075 ml + 4 g	50.84	33.91 (35.61)	79.54 (63.10)	92.38 (73.94)	95.82 (78.21)	75.41 (60.27)
T_3	Imidacloprid 17.8% SL + *M. anisopliae* 1x10^8 cfu/ml	0.15 ml + 4 g	48.62	30.34 (33.42)	73.28 (58.87)	90.43 (71.98)	95.34 (77.53)	72.35 (58.27)
T_4	Imidacloprid 17.8% SL + *M. anisopliae* 1x10^8 cfu/ml	0.075 ml + 4 g	51.70	28.79 (32.45)	69.81 (56.67)	89.34 (70.94)	94.25 (76.13)	70.55 (57.13)
T_5	Dimethoate 30 EC + *B. bassiana* 1x10^8 cfu/ml	0.5 ml + 4 g	54.32	25.34 (30.22)	68.91 (56.11)	87.19 (69.03)	91.00 (72.54)	68.11 (55.62)
T_6	Azadirachtin (1500 ppm)	3 ml	50.06	73.48 (59.01)	76.35 (60.90)	83.92 (66.36)	78.69 (62.51)	78.11 (62.11)
T_7	Imidacloprid 17.8% SL	0.3 ml	55.54	87.09 (68.94)	89.07 (70.69)	92.09 (73.67)	90.65 (72.20)	89.73 (71.30)
T_8	Dimethoate 30 EC	2 ml	56.42	79.29 (62.93)	82.17 (65.02)	88.43 (70.11)	83.28 (65.86)	83.29 (65.87)
T_9	*B. bassiana* 1x10^8 cfu/ml	4 g	51.07	27.98 (31.93)	66.70 (54.76)	89.63 (71.21)	93.24 (74.93)	69.39 (56.41)
T_{10}	*M. anisopliae* 1x10^8 cfu/ml	4 g	53.47	19.60 (26.28)	60.18 (50.87)	79.38 (63.00)	88.85 (70.49)	62.00 (91.95)
T_{11}	Untreated Control	-	50.60	8.53 (16.98)	11.49 (19.81)	10.60 (19.00)	9.86 (18.30)	10.12 (18.55)
	S.Em. (±)		1.79	1.02	1.68	2.98	2.70	2.09
	CD at 5%		NS	3.01	4.98	8.80	7.96	6.18

*DAS - Days After Spraying
** Figures in parentheses are arcsine values

Table 5: Overall mean effect of compatible treatment combinations of EPF and insecticides against *P. nigronervosa* infesting banana (Average of first and second spray)

Tr. No.	Treatments	Dose (ml) or (g) per litre	Pre-count (Mean no. of *P. nigronervosa*/5 plants)	Percent *P. nigronervosa* mortality				Mean Percent Mortality (Average of first and second spray)
				2 DAS*	5 DAS	7 DAS	10 DAS	
T_1	Azadirachtin (1500 ppm) + *B. bassiana* 1x10^8 cfu/ml	0.75 ml + 4 g	51.06	23.07 (28.71)**	62.73 (52.38)	85.02 (67.23)	89.63 (71.21)	65.11 (53.80)
T_2	Imidacloprid 17.8% SL + *B. bassiana* 1x10^8 cfu/m*l*	0.075 ml + 4 g	50.40	33.59 (35.42)	74.40 (59.60)	92.68 (74.31)	95.20 (66.78)	73.97 (59.32)
T_3	Imidacloprid 17.8% SL + *M. anisopliae* 1x10^8 cfu/ml	0.15 ml + 4 g	51.15	29.90 (33.15)	68.73 (56.00)	89.44 (71.04)	92.71 (64.56)	70.19 (56.91)
T_4	Imidacloprid 17.8% SL + *M. anisopliae* 1x10^8 cfu/ml	0.075 ml + 4 g	51.30	28.77 (32.43)	63.86 (53.05)	87.77 (69.53)	91.71 (63.46)	68.02 (55.56)
T_5	Dimethoate 30 EC + *B. bassiana* 1x10^8 cfu/ml	0.5 ml + 4 g	52.07	28.36 (32.18)	64.57 (53.47)	85.77 (67.84)	86.61 (61.77)	66.33 (54.53)
T_6	Azadirachtin (1500 ppm)	3 ml	51.28	67.78 (55.41)	76.52 (61.02)	81.73 (64.70)	76.12 (61.39)	75.54 (60.36)
T_7	Imidacloprid 17.8% SL	0.3 ml	55.83	85.24 (67.40)	87.59 (69.37)	90.58 (72.12)	88.65 (70.31)	88.01 (69.74)
T_8	Dimethoate 30 EC	2 ml	55.27	80.29 (63.64)	82.90 (65.57)	86.66 (68.57)	80.84 (65.12)	82.67 (65.40)
T_9	*B. bassiana* 1x10^8 cfu/ml	4 g	52.37	23.90 (29.27)	63.57 (52.87)	88.78 (70.43)	92.50 (62.70)	67.19 (55.05)
T_{10}	*M. anisopliae* 1x10^8 cfu/ml	4 g	55.76	17.77 (24.93)	54.59 (47.64)	80.41 (63.73)	87.66 (59.05)	60.11 (50.83)
T_{11}	Untreated Control	-	51.61	8.81 (17.26)	11.35 (19.68)	11.87 (20.15)	10.93 (19.31)	10.74 (19.13)
	S.Em. (±)		1.81	0.96	1.53	2.87	2.49	1.96
	CD at 5%		NS	2.83	4.54	8.49	7.25	5.80

*DAS - Days after Spraying
** Figures in parentheses are arcsine values

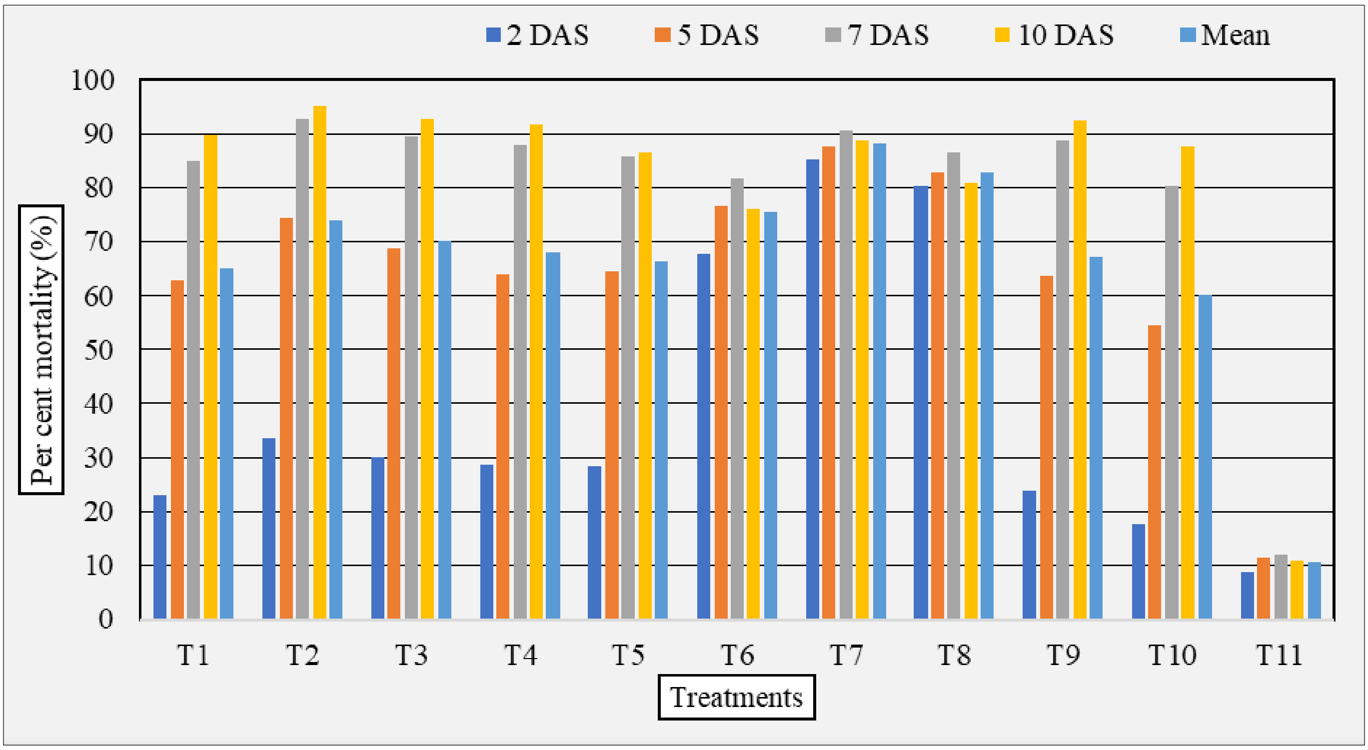

Fig 1: Mean percent mortality of *P. nigronervosa* infesting banana (Average of first and second spray)

4. Conclusion

Compatibility studies of EPF with different insecticides showed that the radial growth of *B. bassiana* and *M. anisopliae* was significantly affected by all insecticides at different levels of concentration. The maximum radial growth of the EPF was measured at ¼ RD (sub-sub-lethal), followed by ½ RD (sub-lethal) and RD (lethal). Insecticides and fungal biocontrol agents work together to increase the effectiveness of the control, allowing for lower insecticide dosages.

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