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Assessment of Insecticide Compatibility with *Beauveria bassiana* for Fall Armyworm (*Spodoptera frugiperda*) Management in Maize

G. Sugeetha[1], M. V. Adwaitha[1], K. S. Nikhil Reddy[1*], P. Mahadevu[2] and J. Mahadevu[3]

[1]Dept. of Entomology, [2]Dept. of Genetics and Plant Breeding, [3]Dept. of Forestry and Environmental Sciences, College of Agriculture, V. C. Farm, Mandya, Karnataka (571 405), India

Corresponding Author

K. S. Nikhil Reddy
e-mail: vikkyvirat4@gmail.com

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Abstract

The study was conducted during March–April, 2021, in College of Agriculture, V. C. Farm, Mandya, Karnataka, India to assess their combined efficacy and potential synergistic or antagonistic effects. The compatibility between *Beauveria bassiana* and various insecticides was evaluated at 7, 14, and 21 days after inoculation to assess fungal growth inhibition and colony diameter for the management of maize fall armyworm (FAW). The results revealed that, at 7 days post-inoculation, significant differences were observed in fungal growth inhibition among all insecticide combinations with *Beauveria bassiana*. The inhibitory effects varied from 26 to 68% with Chlorantraniliprole 9.3+ λ-cyhalothrin 4.6 ZC at half recommended concentration (RC) exhibiting the least inhibition (26%) and good colony growth (33.3 mm). At 14 days post-inoculation, all treatments displayed significant differences compared to the control, with growth inhibition ranging from 15.67 to 62.7%. Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC at half RC exhibited the least inhibition (15.67%) and promoted larger colony growth. At 21 days post-inoculation, significant differences persisted among treatments, with Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC demonstrating high compatibility and harmlessness towards *B. bassiana*, even at lower concentrations. In contrast, Novaluron 5.25+Emamectin benzoate 0.9 SC exhibited the highest growth inhibition (59%) at full RC. Hence, the study accomplishes the combination of Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC, especially at lower concentrations, demonstrated high compatibility with *B. bassiana*, offering an effective and sustainable approach for managing FAW.

Keywords: Compatibility, *inoculation*, recommended concentration, fall armyworm (FAW)

1. Introduction

Maize is the second most important food grain crop under the family Gramineae, scientifically referred as *Zea mays,* (Linnaeus). In world it grown in an area of about 197.19 mha with the production and productivity of 1125.03 million mt ha^{-1} and 5.71 mt ha^{-1} respectively, in more than 150 countries, where in, United State of America, stand first in production of maize with a production of (360.25 million mt ha^{-1}), followed by China (260.67 million mt ha^{-1}) and Brazil (98.50 million mt) (Anonymous, 2021), accounting for about 38%, 23%, and 6.1%, respectively and per cent share in staple food, feed and Industrial purposes was 17%, 61% and 22% respectively. This crop play an important role in different farm sectors as a important food as well as fodder and 51% of maize is used as poultry feed, 20–25% utilized as human food, and 10% to 12% for starch and cattle feed respectively (Kumar et al., 2014).In India, the total area under maize cultivation was 9.70 mha, with the production of 30.25 million mt ha^{-1} and productivity of 3.12 mt ha^{-1} (Anonymous, 2021) and out of total food grain production in India, it accounts only 10%. Maize is attacked by many insect pests, of which, recently introduced one is fall armyworm, *Spodoptera frugiperda*, which is a devastating polyphagous pest (Goergen et al., 2016) that poses a significant threat to food security and agricultural productivity worldwide. Originating from the Americas, this nocturnal moth species has rapidly spread to various regions, causing extensive damage to a wide range of crops, including maize, rice, sorghum, and cotton. The adult moth has the ability to migrate long distance up to 500 km before an oviposition (Prasanna et al., 2018), due to wide host range. In India, it was first reported by Kalleshwaraswamy et al. (2018) in Karnataka, Chikkaballapur district on maize crop in July 2018. After sometimes its presence was confirmed in state of Maharashtra, Gujarat, Chhattisgarh, Andhra Pradesh, Telangana, Tamil Nadu, and Odisha (Padhee et al., 2019). By the end of 2018 it had spread to Thailand, Bangladesh and Sri Lanka. In July 2019 the presence of FAW was reported in Japan (Anonymous, 2020). The economic losses attributed to *S. frugiperda* infestations are substantial, with estimates reaching billions of dollars annually (Anonymous, 2020). Usually maize is mostly preferred by C-Strain fall armyworm, whereas rice is preferred by R-strain fall armyworm (Mahadevaswamy et al., 2018). The DNA bar coding of 44 test samples collected from eight districts of Andhra Pradesh confirmed that the pest is seen infesting paddy, chickpea, jowar and groundnut (Nayyar et al., 2021). Traditional pest management strategies for controlling *S. frugiperda* have relied heavily on synthetic chemical insecticides. While these chemicals can provide rapid and effective control of insect populations, their widespread use has raised concerns regarding environmental pollution, human health risks, and the development of insecticide resistance in target pests (Sparks and Nauen, 2015). Biological control using entomopathogenic fungi represents a strategy to control *S. frugiperda* where, a ubiquitous soil-borne fungus, *Beauveria bassiana*, is well-known for its ability to infect and kill a wide range of insect pests, including *S. frugiperda*, through the production of entomopathogenic spores (Lacey et al., 2015). However, the effectiveness of *B. bassiana* can be significantly impacted by the choice of insecticides used in conjunction with it. The compatibility of these insecticides with the fungus can influence the fungus growth, viability and overall biocontrol efficacy. *B. bassiana*-based products have been shown to exhibit varying degrees of efficacy against *S. frugiperda* under laboratory and field conditions (Sharma et al., 2020). Therefore, this investigation was planned to investigate the compatibility between *B. bassiana* and commonly used insecticides for *S. frugiperda* management.

2. Materials and Methods

The experiment was conducted in 2021 for 2 months (March–April 2021) regarding the interaction of *B. bassiana* with different insecticides. It was reported that FAW is gaining resistance to certain insecticides as well as biopesticides. It is essential to enhance the efficacy and effectiveness of biopesticides. In this regard, compatibility studies between entomopathogenic fungi and Ad-hoc recommended insecticides were undertaken (Table 1 and Plate 1). Compatibility of *Beauveria bassiana* with Ad-hoc recommended insecticides for fall armyworm management was studied in the laboratory condition by employing poisoned food technique (Moorhouse et al., 1992). The effect of insecticides on the radial growth and germination of entomopathogenic fungi was evaluated (Table 2). The insecticide concentrations were calculated based on active ingredient (ai) recommended hectare^{-1}. The different concentration of insecticides viz., recommended, 75% of the recommended concentration (3/4th) and 50% of the recommended concentration (1/2) was tested for compatibility with the entomopathogenic fungi.

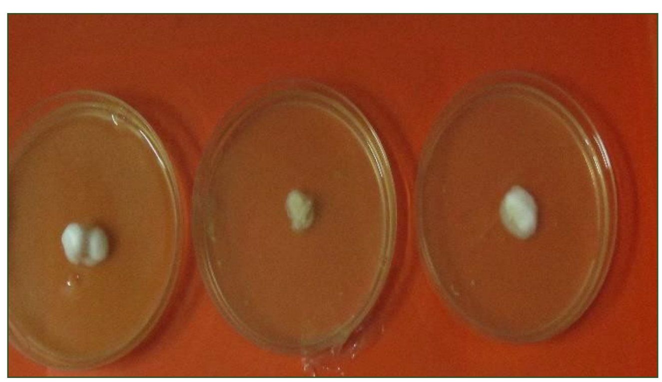
Table 1: Ad-hoc recommended insecticides for fall armyworm management

Sl. No.	Name of insecticides	Dosage ha^{-1} (ml or g a.i.)
1.	Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC	35
2.	Spinetoram 11.7 SC	30
3.	Chlorantraniliprole 18.5 SC	40
4.	Thiodicarb 75 WP	750
5.	Emamectin benzoate 5 SG	20
6.	Novaluron 5.25+Emamectin benzoate 0.9 SC	92.25

2.1. Inoculum for pure culture of entomopathogenic fungi

Inoculum for pure culture was obtained by spraying commercial products containing fungal spores of *B. bassiana* on the various larval instars of fall armyworm separately and left for the incubation for one week. After an incubation period, the infected larvae containing the mycelial growth were used for the maintenance of pure culture.

Pure culture of *Beauveria bassiana*



Novaluron 5.25%+Emamectin benzoate 0.9% SC

Control

Chlorantraniliprole 9.3%+λ-cyhalothrin 4.6% ZC

Plate 1: Compatibility of *Beauveria bassiana* with different test insecticides at various concentrations

2.2. Maintenance of pure culture of entomopathogenic fungi

PDA medium was sterilized to a pressure of 15 psi and to a temperature of 121°C for 30 minutes in an autoclave. Autoclaved PDA media was poured to sterilized petri plates, cooled and inoculated with A loopful of inoculum from the infected larvae by entomopathogenic fungi under aseptic condition. The plates were then incubated at room temperature (26±2°C) for ten days. The pure culture was further sub cultured and used for the experiment.

2.3. Preparation of test chemical insecticide concentrations

Six insecticides were evaluated by poisoned food technique (Moorhouse et al., 1992) in Potato Dextrose Agar (PDA) medium mentioned below (Table 2). Five hundred ml of PDA medium was sterilized in individual boiling tubes and the insecticide emulsions of required concentration were incorporated into the melted sterile PDA aseptically, thoroughly mixed, poured into sterile petri plates and allowed to solidify under laminar air flow cabinet.

Table 2: Treatment details of compatibility studies between test insecticides and entomopathogenic fungi

Sl. No.	Treatment details	Concentration (%)
1.	Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC (RC)	0.050
2.	Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC (75% RC)	0.037
3.	Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC (50% RC)	0.025
4.	Spinetoram 11.7 SC (RC)	0.050
5.	Spinetoram 11.7 SC (75% RC)	0.037
6.	Spinetoram 11.7 SC (50% RC)	0.025
7.	Chlorantraniliprole 18.5 SC (RC)	0.043
8.	Chlorantraniliprole 18.5 SC (75% RC)	0.032
9.	Chlorantraniliprole 18.5 SC (50% RC)	0.021
10.	Thiodicarb 75 WP (RC)	0.200
11.	Thiodicarb 75 WP (75% RC)	0.150
12.	Thiodicarb 75 WP (50% RC)	0.100
13.	Emamectin benzoate 5 SG (RC)	0.080
14.	Emamectin benzoate 5 SG (75% RC)	0.060
15.	Emamectin benzoate 5 SG (50% RC)	0.040
16.	Novaluron 5.25+Emamectin benzoate 0.9 SC (RC)	0.300
17.	Novaluron 5.25+Emamectin benzoate 0.9 SC (75% RC)	0.224
18.	Novaluron 5.25+Emamectin benzoate 0.9 SC (50% RC)	0.150

2.4. Inoculation of the entomopathogenic fungi to the poisoned PDA media

An agar disc along with mycelium mat of fungi will cored from the periphery of 10 days old colony of fungi by needle and transferred into the centre of the PDA plates which are poisoned by test insecticides. The growth medium (PDA) without insecticide but inoculated with mycelial disc served as untreated check. The plates were incubated at room temperature for 14 days to allow maximum growth. Each treatment was replicated three times.

2.5. Calculation of growth diameter and growth inhibition by the test chemicals

The diameter of growing culture in excess of the plugs in each petri dish was measured on 7 days after inoculation (DAI) (when radial growth in the control plate fully covered the medium) and also on 14 and 21 days after inoculation. The data was expressed as diameter of colony growth and percentage growth inhibition of entomopathogenic fungi (Hokkanen and Kotiluoto, 1992). The percent growth inhibition is calculated by using the formula,

X=(Y−Z)/Z×100

Where, X, Y, Z stand for percentage of growth inhibition, radial growth of fungus in untreated check and radial growth of fungus in poisoned medium, respectively. The insecticides were classified into evaluation categories of 1–4 scoring index in invitro toxicity tests (Table 3) according to Hassan's classification scheme (Hassan, 1989). Also test insecticides were classified into evaluation categories of 1–4 scoring index of Compatibility (Table 4) according to Jayasing's classification.

Table 3: Categories of 1–4 scoring index in *in vitro* toxicity tests according to Hassan's classification scheme (Hassan, 1989)

Score	Definition	Reduction in beneficial capacity
1	Harmless	<50%
2	Slightly harmful	50–79%
3	Moderately harmful	80–90%
4	Harmful	>90%

Table 4: Compatibility ratings for test insecticides were classified in evaluation categories of 1–4 scoring index according to Jayasing's classification

Sl. No.	Compatibility status	Average reduction in growth
1.	Highly compatible	<20%
2.	Compatible	20–50%
3.	Partially compatible	50–80%
4.	Incompatible	>80%

3. Results and Discussion

3.1. Compatibility between Beauveria bassiana and different insecticides

3.1.1. Observations at 7 days after inoculation

The combination of all insecticides with *Beauveria bassiana* showed significant difference relating to control. The growth inhibition of *B. bassiana* when compared with different insecticides varied from 26 to 68% and found to be significant with one other. The least growth inhibition (26%) and good colony growth (33.3 mm) were observed in the combination with Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC at a concentration of 1/2 of RC. The combination at 3/4th of RC and full RC with the *B. bassiana* showed more inhibitory effect of 43.33 and 38.89% that induced mean colony growth of 25.5 and 27.5 mm respectively. Totally the insecticide showed compatible effect and at all the concentration the insecticide was harmless against *Beauveria bassiana.*

In case of Emamectin benzoate 5 SG, the lowest concentration (1/2 of RC) allowed the fungal colony to grow up to a mean mycelial growth of 32.2 mm, with 28.44% of inhibition. Same insecticide molecule at higher concentrations i.e., 3/4th of RC and full RC, there was more inhibition of 37.78 and 45.56% of fungal growth with the mean colony growth of 28 and 24.5 mm. The insecticide was found to be harmless and compatible (according to Hassans toxicity index and Jaysings compatibility index).

Chlorantraniliprole 18.5 SC at the half of the RC encouraged the fungal colony growth upto 29.9 mm diameter and had an inhibition effect of 33.56%. The other concentrations like 3/4th of RC and full RC recorded growth inhibition of 40.89 and 43.33% , respectively. The insecticide molecule was compatible with the fungus and the effect was harmless.

Spinetoram 11.7 SC at the half of the RC inhibited the beneficial growth capacity of fungus by 33.56% and allowing the fungal colony to grow 29.9 mm within one week. The high concentrations of the insecticide molecule reduced the mycelial colony growth by reducing the beneficial growth capacity up to 45.78 and 58.22% at 3/4th of RC and full RC respectively. The effect of Low concentrations of the Spinetoram 11.7% SC on fungus was compatible and harmless, while the effect at RC showed partial compatibility and slightly harmful effect to the fungus *Beauveria bassiana* (Table 5).

Thiodicarb 75 WP at low concentrations (1/2 of RC and 3/4th of RC) showed compatible and harmless effect with inhibition of growth capacity (48.22 and 50%) and comparatively better colony growth of 22.5 and 23.3 mm respectively. The RC of insecticide was partially compatible and slightly harmful with 55.56% mycelial growth inhibition of fungus.

The least colony growth (14.4 mm) and highest growth inhibition (68%) was observed in case of recommended concentration (RC) of Novaluron 5.25+Emamectin benzoate 0.9 SC. The insecticide Novaluron 5.25+Emamectin benzoate 0.9 SC which gives spectacular and quick effect in the field against the lepidopteran pests showed partial compatibility and slightly harmful effect against the *B. bassiana* in irrespective of its concentrations. The mean colony mycelial growth recorded during the first week after inoculation was 14.4, 16.5 and 17.5 mm growth in their respective concentrations. Here the insecticide inhibits the growth of fungus by an extent of 60.67% at the 1/2 of RC and 68% at the RC (Table 5).

3.1.2. Observations at 14 days after inoculation

All the treatments showed significant difference in relating to the control, the growth inhibition obtained from various concentrations of insecticides varied from 15.67 to 62.7% having significant difference among one another. The lowest growth inhibition (15.67%) with comparatively better colony growth (42.5 mm) was observed in case of Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC at the 1/2 of RC. Insecticide at this concentration showed highly compatible and harmless effect towards the entomopathogenic fungus *B. bassiana*. In

Table 5: Effect of insecticides on the growth of entomopathogenic fungus, *Beauveria bassiana* at 7 days after inoculation

Sl. No.	Treatments	Growth inhibition (%)			Colony growth (mm)		
		RC	75% of RC	50% of RC	RC	75% of RC	50% of RC
1.	Chlorantraniliprole 9.3+ λ-cyhalothrin 4.6 ZC	38.89 (38.59)*	43.33 (41.18)	26.00 (30.66)	27.50	25.50	33.30
2.	Spinetoram 11.7 SC	58.22 (49.74)	45.78 (42.58)	33.56 (35.4)	18.80	24.40	29.90
3.	Chlorantraniliprole 18.5 SC	43.33 (41.18)	40.89 (39.76)	33.56 (35.4)	25.50	26.60	29.90
4.	Thiodicarb 75 WP	55.56 (48.2)	48.22 (43.99)	50.00 (45.01)	20.00	23.30	22.50
5.	Emamectin benzoate 5 SG	45.56 (42.46)	37.78 (37.93)	28.44 (32.24)	24.50	28.00	32.20
6.	Novaluron 5.25+Emamectin benzoate 0.9 SC	68.00 (55.56)	63.11 (52.61)	60.67 (51.17)	14.40	16.50	17.50
7.	Control		0.00			45	
	Particulars		SEm±			CD (p=0.01)	
	Insecticides (I)		0.84			3.23	
	Concentration I		0.59			2.28	
	I×C		1.45			5.59	

RC: Recommended Concentration; *Figures in parenthesis are arcsine transformed values

case of other two concentrations i.e., 3/4th of RC and full RC showed 20.63 and 30.55% growth inhibition in *B. bassiana* by allowing the colony to grow to diameter of 40.0 and 35.4 mm respectively. At this concentration the insecticide was compatible and harmless towards *B. bassiana*.

The half of the RC of Emamectin benzoate 5 SG showed highly compatible and harmless effect towards fungal colony. In the treated media the fungal colony grows up to 42.2 mm and the insecticide hinders the colony growth about 16.27%. The insecticide inhibits the growth of fungus 34.52 and 40.48%at the respective concentration of 3/4th of RC and RC, which shows compatible and harmless effect (Table 6).

Spinetoram 11.7 SC at the half of RC inhibits the fungal colony growth by 24.6%, the mean colony growth recorded was 38.0 mm. At the other two higher concentrations (3/4th of RC and full RC), 40.48 and 40.87% of colony growth inhibition was recorded with 30 and 29.8 mm mycelial growth respectively. The insecticide concentrations were compatible and harmless towards fungus.

Average mycelial colony growth of 36.6 mm with 28.57% growth inhibition was recorded in case of half the RC of Chlorantraniliprole 18.5 SC, in case of other two concentrations i.e., 3/4th of RC and full RC the insecticide reduced the fungal beneficial capacity about 35.52 to 36.11%. Chlorantraniliprole 18.5 SC showed compatible and harmless effect towards *B. bassiana*.

Thiodicarb 75 WP showed compatible and harmless effect towards *B. bassiana* at low concentrations like 1/2 of RC and 3/4th of RC by allowing the fungal colony to grow to a mean size of 30.0 and 26.6 mm with the growth inhibition of 40.48 and 47.22%, respectively. At full RC the insecticide showed partially compatible and slightly harmful to the fungus with 51.59% suppression in growth capacity and the fungal colony able to grow only about 24.4 mm due to the toxic effect.

The highest growth inhibition (62.70%) was observed at RC of Novaluron 5.25+Emamectin benzoate 0.9 SC contributes least mycelial colony diameter (18.8 mm). At the 3/4th of RC, the insecticide inhibited fungal growth to about 60.52% and at the half of the RC the fungal colony grew up to 25 mm with the 50.40% inhibitory effect of insecticide. The insecticide had partial compatibility and slightly harmful effect towards fungus irrespective of its concentrations (Table 6).

Spinetoram 11.7 SC at the half of RC inhibits the fungal colony growth by 24.6%, the mean colony growth recorded was 38.0 mm. At the other two higher concentrations (3/4th of RC and full RC), 40.48 and 40.87% of colony growth inhibition was recorded with 30 and 29.8 mm mycelial growth respectively. The insecticide concentrations were compatible and harmless towards fungus.

Average mycelial colony growth of 36.6 mm with 28.57% growth inhibition was recorded in case of half the RC of Chlorantraniliprole 18.5 SC, in case of other two concentrations

Table 6: Effect of insecticides on the growth of entomopathogenic fungus, *Beauveria bassiana* at 14 days after inoculation

Sl. No.	Treatments	Growth inhibition (%)			Colony growth (mm)		
		RC	75% of RC	50% of RC	RC	75% of RC	50% of RC
1.	Chlorantraniliprole 9.3+ λ-cyhalothrin 4.6 ZC	30.55 (33.56)*	20.63 (27.02)	15.67 (23.33)	35.40	40.00	42.50
2.	Spinetoram 11.7 SC	40.87 (39.75)	40.48 (39.52)	24.60 (29.74)	29.80	30.00	38.00
3.	Chlorantraniliprole 18.5 SC	36.11 (36.94)	35.52 (36.59)	27.38 (31.56)	32.20	32.50	36.60
4.	Thiodicarb 75 WP	51.59 (45.92)	47.22 (43.41)	40.48 (39.52)	24.40	26.60	30.00
5.	Emamectin benzoate 5 SG	36.11 (36.94)	33.93 (35.63)	16.27 (23.79)	32.20	33.30	42.20
6.	Novaluron 5.25+Emamectin benzoate 0.9 SC	62.70 (52.36)	60.52 (51.08)	50.40 (45.23)	18.80	19.90	25.00
7.	Control		0.00			50.40	
	Particulars		SEm±			CD (p=0.01)	
	Insecticides (I)		0.79			3.03	
	Concentration I		0.56			2.14	
	I×C		1.36			5.25	

RC: Recommended Concentration; *Figures in parenthesis are arcsine transformed values

i.e., 3/4th of RC and full RC the insecticide reduced the fungal beneficial capacity about 35.52 to 36.11%. Chlorantraniliprole 18.5 SC showed compatible and harmless effect towards *B. bassiana*.

Thiodicarb 75 WP showed compatible and harmless effect towards *B. bassiana* at low concentrations like 1/2 of RC and 3/4th of RC by allowing the fungal colony to grow to a mean size of 30.0 and 26.6 mm with the growth inhibition of 40.48 and 47.22% respectively. At full RC the insecticide showed partially compatible and slightly harmful to the fungus with 51.59% suppression in growth capacity and the fungal colony able to grow only about 24.4 mm due to the toxic effect.

The highest growth inhibition (62.70%) was observed at RC of Novaluron 5.25+Emamectin benzoate 0.9 SC contributes least mycelial colony diameter (18.8 mm). At the 3/4th of RC, the insecticide inhibited fungal growth to about 60.52% and at the half of the RC the fungal colony grew up to 25 mm with the 50.40% inhibitory effect of insecticide. The insecticide had partial compatibility and slightly harmful effect towards fungus irrespective of its concentrations (Table 6).

3.1.3. Observations at 21 days after inoculation

At 21 days after inoculation in case of Chlorantraniliprole 9.3+λ- cyhalothrin 4.86 ZC the growth inhibition at half of RC was less (4.86%) and high growth inhibition was observed at RC of Novaluron 5.25+Emamectin benzoate 0.9 SC (59%). The treatments showed significant difference among one another, whereas 3/4th of the RC of Novaluron 5.25+Emamectin benzoate 0.9 SC (57.14%) was on par with RC of Novaluron 5.25+Emamectin benzoate 0.9 SC (59%).

Chlorantraniliprole 9.3+λ-cyhalothrin 4.6 ZC showed high compatibility and harmless effect towards the fungus *B. bassiana* at low concentrations i.e., half the RC and 3/4th of the RC with the 4.86 and 14.29% of colony growth inhibition and contributed larger colony growth of 66.6 and 60 mm, respectively. The molecule at the RC showed compatibility and harmless effect with inhibition of 20.86% (Table 7).

Emamectin benzoate 5% SG showed highly compatible and harmless effect at the half of the RC with the colony growth inhibition of 11%. Other two insecticide concentration treated medias (3/4th of RC and full RC) recorded colony growth of 50 and 45 mm diameter with suppression of 28.57 and 35.71% respectively. At the higher concentration insecticide become compatible and harmless.

The fungal colony growth of 56.6 mm in diameter and the growth inhibition of 19.14% was recorded in case of half of the RC of Chlorantraniliprole 18.5 SC. At this concentration insecticide molecule was highly compatible and harmless towards the fungus, whereas at other two concentration (3/4th of RC and full RC) the colony growth recorded were 49.8 and 44.4 mm respectively, which showed compatibility and harmless effect with growth inhibition of 28.86 and 36.57%.

Spinetoram 11.7 SC showed compatible and harmless effect

Table 7: Effect of insecticides on the growth of entomopathogenic fungus, *Beauveria bassiana* at 21 days after inoculation

Sl. No.	Treatments	Growth inhibition (%)			Colony growth (mm)		
		RC	75% of RC	50% of RC	RC	75% of RC	50% of RC
1.	Chlorantraniliprole 9.3+ λ-cyhalothrin 4.6 ZC	20.86 (27.18)*	14.29 (22.21)	4.86 (12.73)	55.40	60.00	66.60
2.	Spinetoram 11.7 SC	42.86 (40.90)	35.00 (36.28)	22.29 (28.17)	40.00	45.50	54.40
3.	Chlorantraniliprole 18.5 SC	36.57 (37.22)	28.86 (32.50)	19.14 (25.95)	44.40	49.80	56.60
4.	Thiodicarb 75 WP	49.14 (44.52)	44.86 (42.05)	36.43 (37.13)	35.60	38.60	44.50
5.	Emamectin benzoate 5 SG	35.71 (36.71)	28.57 (32.32)	11.00 (19.37)	45.00	50.00	62.30
6.	Novaluron 5.25+Emamectin benzoate 0.9 SC	59.00 (50.19)	57.14 (49.11)	46.29 (42.88)	28.70	30.00	37.60
7.	Control		0.00			70.00	
	Particulars		SEm±			CD (*p*=0.01)	
	Insecticides (I)		0.76			2.76	
	Concentration I		0.50			1.95	
	I×C		1.24			4.78	

RC: Recommended Concentration; *Figures in parenthesis are arcsine transformed values

towards the *B. bassiana* irrespective of the concentrations. 54.4 mm colony growth with 22.29% growth inhibition was observed at half the RC. Colony growth of 45.5 mm with 35.00% growth inhibition was recorded in case of 3/4th of RC. At the RC the colony growth recorded was 40 mm and observed 42.86% inhibition in growth capacity of *B. bassiana*.

Thiodicarb 75 WP showed compatible and harmless effect at all the three concentrations. The growth of *B. bassiana* was 44.5, 38.6 and 35.6 mm in diameter with growth suppression of 36.43, 44.86 and 49.14% at the concentration of 1/2 of RC, 3/4th of RC and RC respectively.

The highest growth inhibition with lesser colony growth was observed at different concentrations of the test insecticide Novaluron 5.25+Emamectin benzoate 0.9 SC. At the 1/2 of RC the insecticide concentration suppressed the colony growth with 46.29%, in which at this concentration the insecticide was compatible and harmless. The High concentrations (3/4th of RC and RC) hindered the colonies more i.e., 57.14 and 59% inhibition of growth capacity of fungal colonies respectively. The colony growth recorded were 30.0 and 28.7 mm respectively. At the high concentration it showed partial compatibility and slight harmful effect (Table 7).

Beauveria bassiana thrived well in Chlorantraniliprole 9.3+λ-cyhalothrin 4.86 ZC, Emamectin benzoate 5 SG and Chlorantraniliprole 18.5 SC at all the concentrations. These chemicals showed harmless effect towards the fungus and the chemicals were compatible with the entomopathogenic fungus *Beauveria bassiana.* Whereas in case of Thiodicarb 75 WP and Novaluron 5.25+Emamectin benzoate 0.9 SC at 7 days after inoculation showed more detrimental effect towards the fungus (Table 8).

Table 8: Mean effect of insecticides on growth inhibition of *Beauveria bassiana* at weekly intervals

Sl. No.	Treatments	Growth inhibition (%)		
		7 DAI	14 DAI	21 DAI
1.	Chlorantraniliprole 9.3+ λ-cyhalothrin 4.6 ZC	36.07	22.29	13.33
2.	Spinetoram 11.7 SC	45.85	35.32	33.38
3.	Chlorantraniliprole 18.5 SC	39.26	33.00	28.19
4.	Thiodicarb 75 WP	51.26	46.43	43.48
5.	Emamectin benzoate 5 SG	37.26	28.77	25.10
6.	Novaluron 5.25+ Emamectin benzoate 0.9 SC	63.93	57.87	54.14

DAI: Days after incubation

The present findings were in conformity with the Hirapara et al. (2023) who reported that, Chlorantraniliprole 18.5 SC and Emamectin benzoate 5 SG were found to be compatible with *Beauveria bassiana.* But they reported more susceptibility of *Beauveria bassiana* towards the λ cyhalothrin 4.9 CS. The contradictory results were observed in the present study, it may be because of the combined effect of Chlorantraniliprole 9.3+ λ-cyhalothrin 4.86 ZC towards the fungus or may be due to the change in formulations.

4. Conclusion

Various insecticides had differing impacts on the fungal growth, with some showing high compatibility and others inhibiting growth to varying degrees. Insecticides like

Chlorantraniliprole and Emamectin benzoate were found to be highly compatible, while others like Novaluron showed harmful effects, suggesting a need for careful selection in integrated pest management strategies.

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6. References

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