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Assessment of Insecticide Compatibility with *Metarhizium (Nomuraea) rileyi* for Fall Armyworm (*Spodoptera frugiperda*) Management in Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The mycelial growth of *Metarhizium rileyi*, an entomopathogenic fungus, was evaluated in media treated with various insecticides and their inhibitory effects on fungal growth. The effects of insecticides Thiodicarb 75 WP, Spinetoram 11.7 SC, Emamectin benzoate 5 SG, Chlorantraniliprole

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18.5 SC, Novaluron 5.25 + Emamectin benzoate 0.9 SC, and Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC were tested at different concentrations (50%, 75% and 100% recommended concentration)1/2, 3/4, and full recommended concentrations, Recommended Concentration). Observations at 7, 14, and 21 days after inoculation revealed significant differences in fungal growth compared to the control. Thiodicarb 75 WP showed minimal inhibition, with the lowest growth inhibition (12.73%) at 3/4th RC, indicating high compatibility with *M. rileyi*. Emamectin benzoate 5 SG also showed low inhibition (0.61-24.85%) at various concentrations, supporting robust fungal growth. In contrast, Spinetoram 11.7 SC exhibited the highest growth inhibition (60.61-69.70%), particularly at full RC. The study concludes that lower concentrations of certain insecticides, particularly Thiodicarb, Emamectin benzoate, and Chlorantraniliprole, have minimal inhibitory effects on *M. rileyi*, while higher concentrations of Spinetoram and Novaluron + Emamectin benzoate had shown significant inhibition. These findings suggest that compatibility between *M. rileyi* and insecticides is concentration-dependent, highlighting the importance of formulation selection for integrated pest management strategies.

Keywords: Compatibility; Metarhizium rileyi; fall armyworm; inhibition.

1. INTRODUCTION

Maize (*Zea mays* L.), known as the "Queen of cereals," is a crucial food staple globally. However, its production faces significant threats, particularly from the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), which causes substantial yield losses. FAW is a polyphagous pest and cause extensive damage to a wide range of crops, including maize, rice, sorghum, and cotton. The economic losses attributed to *S. frugiperda* infestations are substantial, with estimates reaching billions of dollars annually (Anon, 2020). Farmers often rely on synthetic insecticides to control this pest, but this approach is costly, environmentally harmful, and detrimental to natural predators. Pesticides like methomyl, endosulfan, methyl parathion, and lindane, commonly used against FAW, are toxic and banned in many countries due to their risks to health and the environment. The intensive use of insecticides resulted in the reduction of natural enemy complex, poor quality of the environment and deleterious effects to human health (Lewis et al., 2015). Unlike chemical pesticides, entomopathogenic fungi target multiple biochemical pathways, making them less prone to resistance and safer for non-target organisms and the environment. However, their effectiveness against the FAW can be affected by factors like environmental conditions and interactions with chemical insecticides. This study aims to assess the compatibility of commonly used insecticides with entomopathogenic fungi strains, evaluating how insecticide-fungus interactions impact the fungi's viability and effectiveness. The goal is to provide insights for developing more sustainable, integrated pest management strategies for FAW control in maize crop.

2. MATERIALS AND METHODS

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 in College of Agriculture, V. C. Farm, Mandya (Table 1). Compatibility of *Metarhizium rileyi* with Ad-hoc recommended insecticides for FAW 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 per hectare. The different concentration of insecticides *viz*., recommended, 75 per cent of the recommended concentration (3/4th) and 50 per cent of the recommended concentration (1/2) was tested for compatibility with the entomopathogenic fungi.

Inoculum for pure culture of entomopathogenic fungi: Inoculum for pure culture was obtained by spraying commercial products containing fungal spores of *M. rileyi* on the various larval instars of FAW 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.

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

Sl. No.	Name of insecticides	Dosage/ha (ml or gm a.i.)
1)	Chlorantraniliprole 9.3 + Lambda-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

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

Sl. No.	Treatment details.	Concentration (%)
1	Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC (RC)	0.050
2	Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC (75% RC)	0.037
3	Chlorantraniliprole 9.3 + Lambda-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

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 %

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.

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 (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.

Inoculation of the entomopathogenic fungi to the poisoned PDA media: An agar disc along with mycelium mat of fungi were was cored from the periphery of 10 days old colony of fungi by needle and transferred into the centre of the PDA plates which was 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.

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,

$$X = \frac{Y - Z}{Z} \times 100$$

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.

3. RESULTS AND DISCUSSION

3.1 Mycelial Growth of *Metarhizium rileyi* on Insecticide Treated Media and Inhibitory Growth Effect of Various Test Insecticides

Observations at 7 days after inoculation: All the insecticides combined with *Metarhizium rileyi* showed significant effects with respect to control. Among the tested insecticides, the lowest growth inhibition recorded was 12.73 per cent in case of Thiodicarb 75 WP at the $3/4^{th}$ of RC, whereas highest growth inhibition recorded was 69.70 per cent, at RC of Novaluron 5.25 + Emamectin benzoate 0.9 SC, was found to be significantly different from one another (Table 5).

In case of Thiodicarb 75 WP tested at different concentrations, lowest growth inhibition (12.73%) was recorded at the $3/4^{th}$ of RC of Thiodicarb 75 WP which supported larger colony growth (72 mm), followed by 18.60 per cent inhibition in growth at a colony growth of 67 mm at the 1/2 of RC of the same insecticide. The insecticide concentrations were highly compatible and harmless towards the fungus *Metarhizium rileyi.* Whereas it showed partial compatibility and slightly harmful towards the fungus at RC with smaller colony growth of 37.5 mm and the growth inhibition of 54.55 per cent.

In case of Spinetoram 11.7 SC, the lowest growth inhibition recorded was 15.15 percent, at 1/2 of RC supported the colony growth of 70 mm. The insecticide was found to be highly compatible and harmless at this concentration. It was also found to be compatible and harmless with a growth inhibition percentage of 44.24 and with a mean colony growth of about 46mm at $3/4^{th}$ of RC of the insecticide. At RC it was found to be slightly harmful and partial compatible and supported colony growth of 32.5mm with 60.61 percent of inhibition in growth capacity of *M. rileyi*.

The moderate amount of growth inhibition of the beneficial fungus was recorded in case of Emamectin benzoate 5 SG irrespective of its concentrations, *i.e.,* 21.33, 24.85 and 36.97 percent of growth inhibition and promoted colony growth of 64.9, 62, 52mm at 1/2 of RC, $3/4^{th}$ of RC and full RC respectively. It indicated that Emamectin benzoate 5 SG had compatibility and harmless effect towards the *M. rileyi* irrespective of its concentration (Table 5).

Chlorantraniliprole 18.5 SC showed moderate amount of growth inhibition in the growth capacity of fungus. *M. rileyi* which promoted colony diameter of 64.3, 43.3 and 37.25 mm, with a growth inhibitory effect of 22.06, 47.52 and 55.15 per cent at their respective concentrations *i.e.,* 1/2 of RC, 3/4th of RC and full RC. At RC the insecticide showed partial compatibility and harmless effect. Whereas in the other lower concentrations the insecticide showed compatibility and harmless effect towards the *M. rileyi.*

At 1/2 of RC, the insecticide Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC showed 43.52 per cent inhibition in mycelial growth of the fungus and supported the fungal colony growth of 46.6 mm in diameter. At this concentration the insecticide was compatible and harmless towards the fungus. At higher concentrations *i.e.,* 3/4th of RC and full RC the insecticide was found to show partial compatibility and slightly harmful towards the *N. rileyi.* There was inhibition in the percentage growth of 60.73 and 58.79, respectively. The mean colony growth observed was 32.4 and 34 mm in the respective concentrations.

At the 7 days after inoculation of fungus the highest growth inhibition observed was 69.70% with a mean colony growth of 25mm at the RC of Novaluron 5.25 + Emamectin benzoate 0.9 SC. *M. rileyi* colony was able to grow up to 43.3 and 53.2 mm in respective concentration of same insecticide *i.e.,* 3/4th of RC and 1/2 of RC. The toxic inhibitory effect of insecticide at these concentrations were 47.52 and 35.52 per cent respectively. Novaluron 5.25 + Emamectin benzoate 0.9 SC showed partial compatibility with the entomopathogenic fungus *M. rileyi* and the effect was slightly harmful at RC, whereas at two lower concentrations than RC, showed compatible and harmless effect towards the fungus (Table 5).

Observations at 14 days after inoculation: All the insecticides in combination with entomopathogenic fungus *Metarhizium rileyi* showed significant difference with respect to control. The growth inhibition ranged from 3.03 to 60.61 per cent. Among the insecticides, the lowest growth inhibition was recorded at 14 days after inoculation was 3.03 per cent, in case of Thiodicarb 75 WP at the 3/4th of RC. The highest growth inhibition recorded was 60.61 per cent in case of Spinetoram 11.7 SC at RC and were found to be significance with other insecticides. except Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC at RC, which inhibited the fungal colony growth by 58.79 per cent and was found to be on par with each other (Table 6).

Table 5. Effect of insecticides on the growth of entomopathogenic fungus, *Metarhizium rileyi* 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 + Lambda-cyhalothrin 4.6 ZC	58.79 (50.07)*	60.73 (51.2)	43.52 (41.28)	34.00	32.40	46.60
2	Spinetoram 11.7 SC	60.61 (51.13)	44.24 (41.7)	15.15 (22.91)	32.50	46.00	70.00
3	Chlorantraniliprole 18.5 SC	55.15 (47.96)	47.52 (43.58)	22.06 (28.02)	37.20	43.30	64.30
4	Thiodicarb 75 WP	54.55 (47.62)	12.73 (20.9)	18.79 (25.69)	37.50	72.00	67.00
5	Emamectin benzoate 5 SG	36.97 (37.45)	24.85 (29.9)	21.33 (27.51)	52.00	62.00	64.90
6	Novaluron 5.25 + Emamectin benzoate 0.9 SC	69.70 (56.61)	47.52 (43.58)	35.52 (36.59)	25.00	43.30	53.20
7	Control	0.00			82.50		
	Particulars	S.E m ±			CD @ 1%		
	Insecticides (I)	0.95			3.67		
	Concentration I	0.67			2.59		
	I*C	1.65			6.35		

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

Table 6. Effect of insecticides on the growth of entomopathogenic fungus, *Metarhizium rileyi* 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 + Lambda-cyhalothrin 4.6 ZC	58.79 (50.07)*	43.52 (41.28)	36.61 (37.24)	34.00	46.60	52.30
2	Spinetoram 11.7 SC	60.61 (51.13)	30.18 (33.33)	6.06 (14.25)	32.50	57.60	77.50
3	Chlorantraniliprole 18.5 SC	49.09 (44.49)	23.27 (28.85)	18.79 (25.69)	42.00	63.30	67.00
4	Thiodicarb 75 WP	36.97 (37.45)	3.03 (10.03)	9.09 (17.55)	52.00	80.00	75.00
5	Emamectin benzoate 5 SG	36.97 (37.45)	24.85 (29.90)	6.67 (14.97)	52.00	62.00	77.00
6	Novaluron 5.25 + Emamectin benzoate 0.9 SC	51.52 (45.88)	43.03 (41.00)	33.33 (35.27)	40.00	47.00	55.00
7	Control	0.00			82.50		
	Particulars	S.E m ±			CD @ 1%		
	Insecticides (I)	0.83			3.19		
	Concentration I	0.59			2.26		
	I*C	1.44			5.53		

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

The lowest growth inhibition (3.03%) was recorded at 3/4th of RC of Thiodicarb 75 WP and promoted larger colony growth of 80 mm, followed by 9.09 per cent inhibition in growth with a colony growth of 75mm at 1/2 of RC of same insecticide. The insecticide concentrations were highly compatible and harmless towards the fungus *Metarhizium rileyi.* Whereas it showed compatible and harmless towards the fungus at RC with colony growth of 52 mm which had a growth inhibition of 36.97 per cent.

Among the insecticides, second lowest growth inhibition of *Metarhizium rileyi* (6.67%) was observed in case of Emamectin benzoate 5 SG at 1/2 of RC, where it promoted 77 mm of mean colony growth of fungal mycelia. The insecticide concentration was found to be highly compatible and harmless towards the fungus. Same insecticide molecule at higher concentrations of 3/4th of RC and RC, reduced the ability of fungal colony by 24.85 and 36.97 per cent, and restricted the fungal colony growth of 62 and 52 mm. Emamectin benzoate 5 SG showed compatible and harmless at the higher concentrations (Table 6).

The *Metarhizium rileyi* colony growth in Chlorantraniliprole 18.5 SC treated media at the 1/2 of RC, was 67 mm and recorded growth inhibition of 18.79 per cent. It showed highly compatible and harmless effect. At 3/4th of RC the growth inhibition recorded was 23.27 per cent with the mean colony growth of 63.3 mm and at full RC, the insecticide inhibited the fungus growth of 49.09 per cent which supported mean colony growth of 42 mm. At these two higher concentrations, the insecticide showed compatibility and harmless effect with the entomopathogenic fungus.

The fungal growth was hindered up to 33.33 and 43.03 percent in case of Novaluron 5.25 + Emamectin benzoate 0.9 SC at 1/2 of RC and 3/4th of RC respectively. The fungal colony growth had a mean mycelial diameter of 55 and 47 mm and the insecticide showed compatibility and harmless effect at these concentrations. At full RC the insecticide showed partial compatibility and slightly harmful effect to the fungus and promoted 40 mm growth in diameter.

Comparatively high percent of growth hinderance was observed in case of Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC. At 1/2 of RC and 3/4th of RC the insecticide showed compatible and harmless effect and promoted mean colony diameter of 52.3 and 46.6 mm with the 36.6 and 43.52 percentage of growth inhibition respectively. It showed partial compatible and slightly harmful effect of 58.79 per cent of growth inhibition and the mean colony growth of 34 mm at the full RC of same test insecticide.

The maximum growth hinderance and smaller colony growth of fungal mycelia was recorded in case of RC of Spinetoram 11.7 SC. The growth inhibition recorded was 60.61 per cent and supported the fungus growth to a mean diameter of 32.5 mm. At full RC the insecticide showed partial compatibility and slightly harmful effect with an inhibition of 30.18 per cent at the 3/4th of RC. The insecticide becomes compatible and harmless with 57.60 mm of mycelial colony growth. At 1/2 of RC the fungal colony growth was enormous with 77.5 mm, where the insecticide concentration was highly compatible and harmless with only 6.06 percentage of growth inhibition (Table 6).

Observations at 21 days after inoculation: All the insecticides tested showed significant difference with respect to control. The growth inhibition by the insecticides at 21 days after inoculation varied from 0.61 to 46.67 percent. The negligible growth inhibition (0.61%) was recorded in case of Emamectin benzoate 5 SG at 1/2 of RC. Whereas the highest growth inhibition (46.67%) was recorded at RC of Spinetoram 11.7 SC was found to be significant difference from one another except Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC at RC, which inhibited the fungal colony growth by 46.18 per cent which was on par (Table 7).

The larger colony growth (82 mm) with negligible amount of growth hinderance (0.61%) was observed in case of Emamectin benzoate 5 SG at 1/2 of RC. At 3/4th of RC the growth inhibition recorded was 10.3 per cent and supported the colony growth of 74 mm. The two low concentrations showed highly compatible and harmless effect towards *M. rileyi.* At full RC the insecticide was found to be compatible and harmless with the 22.42 per cent growth inhibition.

It was noticed another lowest growth inhibition of 1.82 per cent, at 3/4th of RC of Thiodicarb 75 WP that promoted the mean colony growth of 81 mm, followed by 3.03 per cent growth inhibition and mycelial colony growth of 80 mm at 3/4th of RC. At RC of same insecticide molecule inhibited the colony growth of 17.58 per cent and supported the fungal colony growth of 68 mm. irrespective of the concentrations Thiodicarb 75 WP showed highly compatible and harmless effect towards the *M. rileyi* (Table 7).

Control

Novaluron 5.25%+ Emamectin benzoate 0.9% SC

Plate 1. Compatibility of *Metarhizium rileyi* with different test insecticides at various concentrations

Table 7. Effect of insecticides on the growth of entomopathogenic fungus, *Metarhizium rileyi* 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% + Lambda-cyhalothrin 4.6 ZC	46.18 (42.82)*	29.70 (33.03)	18.79 (25.69)	44.40	58.00	67.00
2	Spinetoram 11.7 SC	46.67 (43.10)	16.36 (23.86)	3.03 (10.03)	44.00	69.00	80.00
3	Chlorantraniliprole 18.5 SC	34.55 (36.00)	7.88 (16.30)	3.03 (10.03)	54.00	76.00	80.00
4	Thiodicarb 75 WP	17.58 (24.79)	1.82 (7.75)	3.03 (10.03)	68.00	81.00	80.00
5	Emamectin benzoate 5 SG	22.42 (28.27)	10.30 (18.73)	0.61 (4.47)	64.00	74.00	82.00
6	Novaluron 5.25 + Emamectin benzoate 0.9 SC	30.30 (33.41)	24.85 (29.90)	18.79 (25.69)	57.50	62.00	67.00
7	Control	0.00			82.50		
	Particulars	S.E m ±			CD @ 1%		
	Insecticides (I)	0.66			2.52		
	Concentration I	0.46			1.78		
	I*C	1.14			4.37		

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

Table 8. Mean effect of insecticides on growth inhibition of *Metarhizium rileyi* at weekly intervals

Sl.No.	Insecticides	Mean growth inhibition (%)		
		7 DAI	14 DAI	21 DAI
1	Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC	54.94	46.31	32.53
2	Spinetoram 11.7 SC	40.49	32.71	22.02
3	Chlorantraniliprole 18.5 SC	40.58	30.65	15.15
4	Thiodicarb 75 WP	29.09	16.61	7.48
5	Emamectin benzoate 5 SG	28.02	23.20	11.51
6	Novaluron 5.25 + Emamectin benzoate 0.9 SC	51.90	42.95	24.85

DAI: Days after inoculation

In case of Chlorantraniliprole 18.5 SC the two lower concentrations *i.e.,* 1/2 of RC and 3/4th of RC promoted the fungal mycelial colony growth of 80 and 76 mm with the growth hinderance of 3.03 and 7.88 per cent respectively. The insecticide showed highly compatible and harmless effect. In case of RC the same insecticide molecule inhibited the fungal colony growth by 34.55 per cent and had compatibility and harmless effect towards the *M. rileyi.*

There was a moderate amount of growth hinderance in case of Novaluron 5.25 + Emamectin benzoate 0.9 SC at all the three concentrations. The insecticide showed high compatibility and harmless effect at 1/2 of RC by reducing 18.79 per cent growth capacity and promoted the fungal colony growth to a diameter of 67 mm. High concentrations like 3/4th of RC and RC showed compatible and harmless effect with the 24.85 and 30.3 per cent of growth hinderance respectively and promoted 62- and 57.5-mm colony growth of fungus *Metarhizium rileyi.*

Highly compatible and harmless effect were observed at 1/2 of RC of the Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC, with 18.79 per cent of growth inhibition. Whereas at higher concentrations *i.e.,* 3/4th of RC and RC showed compatible and harmless effect with 29.7 and 46.18 per cent reduction in the colony growth respectively. The colony growth recorded were 67, 58 and 44.4 mm in the respective concentrations *i.e.,* 1/2 of RC, 3/4th of RC and RC.

At 21 days after inoculation of *M. rileyi,* the highest colony growth inhibition of 46.67 per cent in case of Spinetoram 11.7 SC at RC and 44 mm of mean colony growth was recorded. Whereas the other two lower concentrations (3/4th of RC and 1/2 of RC) was showing highly compatible and harmless effect with only 16.36 and 3.03 per cent growth inhibition and mean colony growth of 69 and 80mm respectively (Table 7).

Metarhizium rileyi can grow enormously with lesser detrimental effect were observed in case of Emamectin benzoate 5 SG and Thiodicarb 75 WP at irrespective of concentrations. The detrimental effect was comparatively less in lower concentrations (3/4th of RC and 1/2 of RC) of insecticides like Chlorantraniliprole 18.5 SC and Spinetoram 11.7% SC (Table 8). The present findings were similar with Kachadiyan et al*.* (2014) who reported that Thiodicarb found less compatible against the *Metarhizium rileyi.* Generally, the reasons for compatibility between the entomopathogenic fungi and insecticidal molecules is due to physiological mechanism of fungi to metabolize the insecticides which liberate compounds that act as a secondary nutrient for the establishment of entomopathogenic fungi or the substances present in the insecticide formulations may provide nutrition for the development of vegetative growth and conidial production of fungus (Rajeshwari et al., 2020; Rachappa et al., 2007).

4. CONCLUSION

The present study concluded that lower concentrations of certain insecticides, particularly Thiodicarb, Emamectin benzoate, and Chlorantraniliprole, have minimal inhibitory effects on M. rileyi, while higher concentrations of Spinetoram and Novaluron and Emamectin benzoate had shown significant inhibition. The findings also suggestded that compatibility between M. rileyi and insecticides is concentration-dependent, highlighting the importance of formulation selection for integrated pest management strategies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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