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

Abstract

The fall armyworm (*Spodoptera frugiperda*) is a major maize pest, and while chemical insecticides are commonly used for control, their environmental impact and potential for resistance have driven the search for alternatives. *Metarhizium anisopliae*, an entomopathogenic fungus, is a promising biological control agent. The compatibility between insecticides and the entomopathogenic fungus *Metarhizium anisopliae* was evaluated to determine their impact on fungal growth. Six insecticides, representing different chemical classes, were tested for their inhibitory effects on fungal colony growth at various concentrations (50%, 75%, and recommended concentrations). Mycelial growth inhibition was measured at 7, 14, and 21 days after inoculation (DAI). Results showed that most insecticides exhibited varying degrees of compatibility with *M. anisopliae*, with growth inhibition ranging from 6.25% to 51.88% at 7 DAI. The lowest growth inhibition occurred with *Emamectin benzoate* 5 SG and *Novaluron* 5.25 + *Emamectin benzoate* 0.9 SC, showing minimal suppression of fungal growth. In contrast, *Spinetoram* 11.7 SC and *Thiodicarb* 75 WP caused significant inhibition at higher concentrations, with the latter showing up to 51.88% inhibition at 7 DAI. At 14 and 21 DAI, the growth inhibition generally decreased across treatments, with *Chlorantraniliprole* 9.3 + *Lambda-cyhalothrin* 4.6 ZC and *Emamectin benzoate* 5 SG demonstrating the best compatibility. Overall, the results suggest that most insecticides tested were compatible with *M. anisopliae*, with *Spinetoram* and *Thiodicarb* being exceptions, particularly at higher concentrations. This study provides valuable insights into selecting insecticide-fungus combinations for integrated pest management.

Keywords: Compatibility, fall armyworm,inhibition,*Metarhizium anisopliae*

Introduction

The battle against agricultural pests in maize crop production is a perpetual struggle for farmers worldwide. Among these pests, the fall armyworm (*Spodoptera frugiperda*) stands out as a formidable adversary, notorious for its rapid spread and devastating impact on maize crops. In recent years, the fall armyworm has emerged as a significant threat to global food security, causing

substantial yield losses and economic hardship for farmers, particularly in regions where maize is a staple crop.Traditional methods of pest control, such as chemical insecticides, have been widely employed to mitigate the damage caused by the fall armyworm. However, the indiscriminate use of chemical pesticides poses environmental risks, disrupts ecological balances, and may lead to the development of resistance in pest populations(Sparks &Nauen, 2015). In this context, the integration of biological control agents, such as entomopathogenic fungi, has garnered increasing attention as a sustainable and environmentally friendly alternative for pest management.Entomopathogenic fungi are capable of infecting and killing a wide range of insect species, including the fall armyworm. Unlike chemical pesticides, which often target specific biochemical pathways in insects, entomopathogenic fungi utilize multiple modes of action, making them less susceptible to resistance development. Moreover, these fungi are biodegradable and pose minimal risk to non-target organisms and the environment.Despite the potential of entomopathogenic fungi in controlling the fall armyworm, their effectiveness can be influenced by various factors, including environmental conditions and interactions with other pest management strategies, such as chemical insecticides. Understanding the compatibility between insecticides and entomopathogenic fungi is crucial for optimizing integrated pest management (IPM) programs and maximizing their efficacy in controlling fall armyworm infestations.Therefore, this study aims to investigate the compatibility of different insecticides commonly used against fall armyworm with entomopathogenic fungi strains. By assessing the impact of insecticide-fungus interactions on the viability and effectiveness of entomopathogenic fungi, this research seeks to provide valuable insights into the development of more sustainable and integrated approaches for fall armyworm management in maize crops.

Materials and Methods

It was reported that FAW is gaining resistance to certain insecticides as well asbiopesticides. It is essential to enhance the efficacy and effectiveness of biopesticides. Inthisregard,compatibilitystudiesbetweenentomopathogenicfungiandAd-hocrecommendedinsecticideswereundertaken(Table 1).Compatibilityof*Metarhiziumanisopliae*withAd-hocrecommended insecticides for fall armyworm management was studied in the laboratorycondition by employing poisoned food technique (Moorhouse *et al*., 1992). The effect ofinsecticidesontheradialgrowthandgerminationofentomopathogenicfungiwasevaluated(Table 2).The insecticide concentrations were calculated based on active ingredient (ai)recommended per

hectare. The different concentration of insecticides *viz.*, recommended,75percentoftherecommendedconcentration(3/4th)and50percentoftherecommendedconcentration(1/2)wastested forcompatibilitywiththeentomopathogenicfungi.

Table 1.Ad-hocrecommendedinsecticidesforfallarmywormmanagement

Sl. No.	Name ofinsecticides	Dosage/ha(mlorgma.i.)
1)	Chlorantraniliprole9.3+Lambda-cyhalothrin4.6ZC	35
2)	Spinetoram11.7SC	30
3)	Chlorantraniliprole18.5SC	40
4)	Thiodicarb75WP	750
5)	Emamectinbenzoate 5SG	20
6)	Novaluron5.25+Emamectinbenzoate0.9SC	92.25

Inoculum and Maintenance of Pure Culture of Entomopathogenic Fungi

Inoculum for pure culture of Metarhizium anisopliae was obtained by spraying commercial fungal spore products on different larval instars of fall armyworm, which were then incubated for one week. After incubation, the infected larvae, which exhibited mycelial growth, were used to maintain the pure culture. To maintain the culture, PDA medium was sterilized at 15 psi and 121°C for 30 minutes in an autoclave, then poured into sterilized petri plates and cooled. A loopful of inoculum from the infected larvae was transferred under aseptic conditions to the petri plates. The plates were incubated at room temperature (26 ± 2°C) for 10 days. The pure culture was subcultured for use in subsequent experiments.

Preparationoftestchemical insecticideconcentrations

Six insecticides were evaluated by poisoned food technique (Moorhouse *et al.*,1992) in Potato Dextrose Agar (PDA) medium mentioned in Table 2. Five hundredmlofPDAmediumwassterilizedinindividualboilingtubesandtheinsecticideemulsionsofrequiredconcentration were incorporated into the melted sterilePDA

aseptically,thoroughlymixed,pouredintosterilepetriplatesandallowedtosolidifyunderlaminarairflowcabinet.

Inoculationoftheentomopathogenic fungitothepoisonedPDAmedia

Anagardiscalongwithmyceliummatoffungiwillcoredfromtheperipheryof10daysoldcolonyoffungibyneedleandtransferredintothecentreofthePDAplateswhichare poisoned by test insecticides. The growth medium (PDA) without insecticide butinoculatedwithmycelialdiscservedasuntreatedcheck.Theplateswereincubatedatroomtemperature for 14 days to allow maximum growth. Each treatment was replicated threetimes.

Calculationofgrowthdiameter andgrowthinhibitionbythe testchemicals

The diameter of growing culture in excess of the plugs in each petri dish wasmeasured on 7 days after inoculation (DAI) (when radial growth in the control plate fullycoveredthemedium)andalsoon14and21daysafterinoculation.Thedatawasexpressedasdiameterof colonygrowthandpercentagegrowthinhibitionofentomopathogenicfungi(Hokkanen and Kotiluoto, 1992). The percent growth inhibition is calculated by using theformula,

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

Where, X, Y, Z stand for percentage of growth inhibition, radial growth of fungusin untreated check and radial growth of fungus in poisoned medium, respectively. Theinsecticides were classified into evaluation categories of 1- 4 scoring index in invitrotoxicity tests (Table 3) according to Hassan's classification scheme (Hassan, 1989). Alsotestinsecticides were classifiedinto evaluation categories of 1 - 4 scoring index ofCompatibility(Table 4)accordingto Jayasing'sclassification (Jayasing, 2011).

Table

2.Treatmentdetailsofcompatibilitystudiesbetweentestinsecticidesandentomopathogenicfungi

Sl. No.	Treatment details.	Concentration (%)
1	Chlorantraniliprole9.3+Lambda-cyhalothrin4.6ZC(RC)	0.050
2	Chlorantraniliprole9.3+Lambda-cyhalothrin4.6ZC(75%RC)	0.037
3	Chlorantraniliprole9.3+Lambda-cyhalothrin4.6ZC(50%RC)	0.025
4	Spinetoram11.7SC(RC)	0.050
5	Spinetoram11.7SC(75%RC)	0.037
6	Spinetoram11.7SC(50%RC)	0.025
7	Chlorantraniliprole18.5SC(RC)	0.043
8	Chlorantraniliprole18.5SC(75%RC)	0.032
9	Chlorantraniliprole18.5SC(50%RC)	0.021
10	Thiodicarb 75WP(RC)	0.200
11	Thiodicarb 75WP(75%RC)	0.150
12	Thiodicarb 75WP(50%RC)	0.100
13	Emamectinbenzoate5SG(RC)	0.080
14	Emamectinbenzoate 5SG(75%RC)	0.060
15	Emamectinbenzoate 5SG(50%RC)	0.040

16	Novaluron5.25+Emamectinbenzoate 0.9SC(RC)	0.300
17	Novaluron5.25+Emamectin benzoate 0.9SC(75%RC)	0.224
18	Novaluron5.25+Emamectin benzoate 0.9SC(50%RC)	0.150

Table 3.Categoriesof1-4scoringindexininvitrotoxicitytestsaccordingtoHassan'sclassification scheme(Hassan, 1989)

Score	Definition	Reductioninbeneficial capacity
1	Harmless	<50%
2	Slightlyharmful	50-79%
3	Moderatelyharmful	80-90%
4	Harmful	>90%

Table 4.Compatibilityratingsfortestinsecticideswereclassifiedinevaluationcategoriesof1 -4 scoringindex

Sl.No.	Compatibilitystatus	Average reductioningrowth
1	Highlycompatible	< 20 %
2	Compatible	20-50%
3	Partiallycompatible	50-80%
4	Incompatible	> 80 %

Results and Discussion

Tounderstandtheextentofcompatibilitybetweentheinsecticidesandentomopathogenicfungi, thebeneficialfungalgrowthinhibitionwascalculatedbymeasuringthediameterofthefungalcolonygrowth.Sixinsecticidesbelongingtodifferentgrouporclassesofinsecticidesweretestedforthecompatibilitywiththecommonentomopathogenic fungi that affects fall armyworm.

Mycelialgrowthof*Metarhiziumanisopliae*oninsecticidetreatedmediaandinhibitory growtheffectofvarioustest insecticidesobservationsat7daysafter inoculation

The compatibility between *Metarhizium anisopliae* and insecticides were showedsignificant reduction in mycelial growth when compared with the control. The mycelialgrowth inhibition by the tested insecticides varied from 6.25 to 51.88 per cent and weresignificantwithoneother.Alltheinsecticidescombinedwith*Metarhiziumanisopliae*werehighlycompatibleandharmlessexceptChlorantraniliprole18.5SC,Thiodicarb75WPandSpinetoram11.7 SC(Table 5).

The lowest colony growth inhibition (6.25 %) and highest colony growth (75 mm)were recorded in case of half the RC of Emamectin benzoate 5 SG, followed by 15.38 percent reduction in growth capacity and 67.5 mm colony growth in case of 3/4th of RC. AtRC the insecticidesuppressed the fungal colony by 18.75 per cent. The Emamectinbenzoate 5% SG showed high compatibility and harmless effect to the *Metarhiziumanisopliae.*

Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC showed high compatibilityandharmlesseffectto*Metarhiziumanisopliae*.Thecolonygrowthoffunguswas73.2,72.2 and 67.5 mm of mean mycelial growth with 8.5, 9.75 and 15.63 percentage ofreduction in growth capacity of fungal colony at different concentrations *i.e.*, 1/2 of RC,3/4thofRC and RCrespectively.

Novaluron 5.25 + Emamectin benzoate 0.9 SC showed high compatibility andharmless effect to *Metarhizium anisopliae* irrespective of their concentrations. The bettercolonygrowthwasobserved(70,72.5and67.5mm)withlessergrowthinhibition(12.5,9.38 and 15.63%) at the various concentrations *i.e.,* 1/2 of RC, 3/4th of RC and full RCrespectively.At low concentrations (1/2 of RC and 3/4th of RC) of Chlorantraniliprole 18.5 SChigh compatibility and harmless effect were observed, with the 9.38 and 16.75 per centsuppressionoffungalcolonyovercontrolwiththecolonygrowthof72.5mmand66.6mm respectively.WhereasthesamemoleculeattheRCshowedcompatibilityandharmlesseffect with 32.5 percentof growthinhibition.

In case of Thiodicarb 75 WP at the low concentrations (1/2 of RC and 3/4th of RC)the fungus was able to grow to a mean growth of 68.8 and 70 mm and showed highlycompatible and harmless

effect towards the fungus, with a growth inhibitory effect of 14and 12.5 percent respectively. At RC of insecticide suppresses more *i.e.,* 41.75 per centwithlessermycelialcolonygrowthof46.6mm.AtfullRCtheinsecticideshowedcompatibleand harmlesseffecttowardsthefungus(Table 5).

The highest inhibition of Spinetoram 11.7 SC was observed in case of RC and themean fungal diameter was 38.5 mm. The insecticide had an inhibitory effect on growthabout 51.88 percent, which found to be partially compatible and slightly harmful to thefungus.Incaseof3/4thofRCofsamemoleculethefungalgrowthwasinhibitedupto40.63percentwithac olonygrowthof47.5mmwasfoundtobecompatibleandharmless(Table 5). At the half of RC, the insecticide was found to be highly compatible and harmless tothe fungus *Metarhizium anisopliae* with a mycelial growth of 71 mm and with lessergrowthsuppression(11.25 %).

Table 5.Effectofinsecticidesonthegrowthofentomopathogenicfungus, *Metarhizium anisopliae* at7daysafter inoculation

Sl. No.	Treatments	Growthinhibition(%)			Colonygrowth(mm)		
		RC	75% ofRC	50% ofRC	RC	75% ofRC	50% ofRC
1	Chlorantraniliprole9.3+ Lambda-cyhalothrin4.6ZC	15.63(23.29)*	9.75 (18.20)	8.50 (16.95)	67.50	72.20	73.20
2	Spinetoram11.7SC	51.88 (46.08)	40.63 (39.60)	11.25 (19.60)	38.50	47.50	71.00
3	Chlorantraniliprole 18.5SC	32.50 (34.76)	16.75 (24.16)	9.38 (17.83)	54.00	66.60	72.50
4	Thiodicarb75 WP	41.75 (40.26)	12.50 (20.71)	14.00 (21.98)	46.60	70.00	68.80

5	Emamectinbenzoate5SG	18.75 (25.66)	15.38 (23.09)	6.25 (14.48)	65.00	67.70	75.00
6	Novaluron 5.25 +Emamectinbenzoate0.9SC	16.00 (23.58)	9.75 (18.20)	12.50 (20.71)	67.20	72.20	70.00
7	Control	0.00			80.00		
	Particulars	S.E m ±			CD@1%		
	Insecticides(I)	0.69			2.67		
	Concentration I	0.49			1.89		
	I*C	1.20			4.63		

RC:RecommendedConcentration,*Figuresinparenthesisarearcsinetransformedvalues.

Observationsat14daysafter inoculation

All the insecticides combined with the entomopathogenic fungus *Metarhiziumanisopliae*showedsignificantdifferencewithrespecttocontrol.Amongthetestedinsecticides at various concentrations showed significant difference with one another. Thefungal mycelial growth inhibition ranged from 2.94 to 32.12 per cent. The lowest growthinhibition (2.94 %) was recorded in case of half the RC of Novaluron 5.25 + Emamectinbenzoate0.9SC,withameanmycelialcolonydiameterof82.5mm.Themoleculeshowed5.88and11.76percentgrowthinhibitionwith80-and75-mmcolonygrowthatrespectiveconcentrationsof3/4thofRCandfullRCofNovaluron5.25+Emamectinbenzoate0.9SC(Table 6).

The lowest growth inhibition of 3.53 percent, with 82 mm colony growth wererecordedatthehalfofRCofChlorantraniliprole9.3+Lambda-cyhalothrin4.6ZC, whereas in other two concentrations, (3/4th of RC and full RC) the mean mycelial colonygrowthrecordedwere80and77.7mmrespectively,with5.88and8.59percentofgrowthinhibitiontowardsthefungus.Theinsecticideatallconcentrationshowedhighcompatibilityand harmlesseffecttowardsthe*Metarhiziumanisopliae.*

Emamectinbenzoate5%SGattwolowerconcentrations*i.e.*,at1/2ofRCand3/4thofRCinhibitedthe*Metarhiziumanisopliae*fungalcolonygrowthwithonly4.71and5.88percentage, followed by 11.76 per cent inhibition in growth at full RC. The mean fungalcolonydiameterrecordedat1/2and3/4thofRCwas81and80mmrespectivelyandincaseof RC the mean colony diameter was 75 mm. Emamectin benzoate 5 SG was found to behighlycompatibleand harmlesstowards*M. anisopliae.*

Chlorantraniliprole 18.5 SC showed high compatibility and harmless effect at twoconcentrations*i.e.*,at1/2ofRCand3/4thofRC.Theinsecticideconcentrationinhibitedthebeneficialcapacityoffungusinanegligiblepercentage*i.e.*,7.29and17.65%respectively.The insecticide was found to be compatible at the RC by inhibiting the fungal colonygrowth up to 20.35 per cent. The mean colony growth was 78.8, 70 and 67.7 at the 1/2 ofRC,3/4thof RCand RCrespectively(Table 6).

Thiodicarb 75 WP showed 9.65, 14.71 and 23.53 per cent of growth inhibitoryeffect towards the *M. anisopliae* at the concentrations 1/2 of RC, 3/4th of RC and RCrespectively. The colony growth recorded were 76.8, 72.5 and 65 mm respectively. Theinsecticideconcentrationsshowedhighcompatibilityandharmlesseffectat1/2ofRCand3/4thof

RC,attheRC theinsecticidewasfound to becompatibleand harmless.

Table 6.Effectofinsecticidesonthegrowthofentomopathogenicfungus, *Metarhizium anisopliae*at14daysafterinoculation

Sl. No.	Treatments	Growthinhibition(%)			Colonygrowth(mm)		
		RC	75% ofRC	50% ofRC	RC	75% ofRC	50% ofRC
1	Chlorantraniliprole9.3+ Lambda-cyhalothrin4.6ZC	8.59(17.04)*	5.88 (14.04)	3.53 (10.83)	77.70	80.00	82.00
2	Spinetoram11.7SC	32.12 (34.53)	20.59 (26.99)	8.82 (17.28)	57.70	67.50	77.50
3	Chlorantraniliprole 18.5SC	20.35 (26.82)	17.65 (24.84)	7.29 (15.67)	67.70	70.00	78.80
4	Thiodicarb75 WP	23.53 (29.02)	14.71 (22.55)	9.65 (18.1)	65.00	72.50	76.80
5	Emamectinbenzoate5SG	11.76 (20.06)	5.88 (14.04)	4.71 (12.53)	75.00	80.00	81.00
6	Novaluron 5.25 +Emamectinbenzoate0.9SC	11.76 (20.06)	5.88 (14.04)	2.94 (9.88)	75.00	80.00	82.50
7	Control	0.00			85.00		
	Particulars	S.E m ±			CD@1%		
	Insecticides(I)	0.55			2.13		
	Concentration I	0.39			1.50		
	I*C	0.96			3.68		

RC:RecommendedConcentration,*Figuresinparenthesisarearcsinetransformedvalues.

At 14 days after inoculation the highest growth inhibition was recorded in case ofSpinetoram 11.7 SC. At RC of insecticide, there was 32.12 percent reduction in growthcapacityof*M.anisopliae*andcontributedthegrowthof57.7mm.At3/4thofRCthegrowthinhibition was reduced to 20.59 percentage. Spinetoram 11.7 SC showed compatible andharmless effect against *M. anisopliae* while 1/2 of RC showed high compatibility andharmlesseffectwithonly8.82percentreductioningrowthcapacityoffungus.Thecolonygrowthrecorded were77.5, 67.5and57.7mmattheconcentrations1/2ofRC, 3/4thofRCandfullRCrespectively(Table 6).

Pureculture of *Metarhiziumanisopliae*

Spinetoram 11.7%SC

Control

Chlorantraniliprole 9.3% + Lambda-cyhalothrin 4.6% ZC

Plate1.Compatibilityof*Metarhiziumanisopliae*withdifferenttestinsecticidesatvariousconcentrations

Observationsat21daysafterinoculation

All the insecticide concentrations when combined with *M. anisopliae* were foundto be significant in relation to the control. The growth inhibition by the insecticides variedfrom 0.71 to 20 percent and all the treatments were significant among one another. Thelowest growth inhibition (0.71%) with highest colony growth found to be 84.4mm wasobserved at 1/2 of RC of Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC. Whereasmaximum growth inhibition (20%) with smallest colony growth (68mm) was observed inRCofThiodicarb75WP(Table 7).Atthe21daysafterinoculationallthetestinsecticidesshowshighlycompatibleandharmlesseffecttowardsthe fungus*M.anisopliae.*

The insecticide Chlorantraniliprole 9.3 + Lambda-cyhalothrin 4.6 ZC recordedleast growth inhibition of 0.71 per cent and promoted the colony growth of 84.4mm at 1/2ofRC.Therewasa3.29percentgrowthinhibitionwithameancolonygrowthof82.2mmat 3/4th of RC, but at RC of insecticide the fungal colony grew up to 80 mm with 5.88 percentinhibitoryeffecton the growth capacitywasrecorded.

The fungal colony grew to a mean diameter of 83.8 mm, with negligible growthinhibitionof1.41percentwas recorded incaseof 1/2of RC ofNovaluron5.25+Emamectinbenzoate0.9SC.athighconcentrations*i.e.*,3/4thofRCandRC,3.29and8.24percent inhibition in growth capacity of *M. anisopliae* respectively, was recorded with themean colony growth of 82.2 and 78mm.

Emamectin benzoate 5 SG recorded 4.71 per cent growth inhibition and promotedgrowth of about 81 mm in diameter at 1/2 of RC. At 3/4th of RC, the fungal colony wasable to grow to a mean size of 82 mm, with the 3.53 per cent inhibitory effect. At RC, theinsecticide supressed the growth up to 8.82 per cent, and promoted colony growth to amean diameterof 77.5mm.

Chlorantraniliprole 18.5 SC recorded an inhibition of 5.88, 11.76 and 17.65 percent of growth capacity of entomopathogenic fungus, *M. anisopliae* respectively with acolonygrowthof80,75and70mmattherespectiveconcentrationsofinsecticides*i.e.*,1/2ofRC, 3/4thof RC and fulloftheRC (Table 7). Therewas7.29,11.06and17.65percentoffungalgrowthinhibitionwererecordedwith a colony growth of 78.8, 75.6 and 70 mm at the respective concentrations *i.e.*, 1/2 ofRC,3/4thofRC andfullRC oftheinsecticideSpinetoram11.7 SC.

At21daysafterinoculationthehighpercentageoffungalgrowthinhibition(20%)with a colony growth

of (68 mm) were recorded in case of Thiodicarb 75 WP, at the RC.At the other respective concentration of 1/2 of RC and 3/4th of RC the growth inhibitionrecorded were 11.18 and 16.47 per cent with the colony growth of 75.5 and 70 mmrespectively(Table 7).

Alltheinsecticideshowedbestresultswiththe*Metarhiziumanisopliae*exceptfullrecommended concentration of Spinetoram 11.7 SC and Thiodicarb 75 WP, all the otherchemicals showed compatible relationship with the *Metarhizium anisopliae* (Table 8).This may be due to the inherent variability in the chemical insecticides on the suppressionofentomopathogenicfungalgrowthcapacity(Rajeshwari*etal.*,2020).Inthepresentstudy,th e highest growth inhibition towards the *Metarhizium anisopliae* was observed in case ofSpinetoram11.7SCandThiodicarb75WP.Theresultsobtainedareinagreementwiththeearlier reports by Rachappa*et al.* (2007). They reported that collectively carbamate groupof insecticides inhibits the *Metarhizium anisopliae* by 45.45%, wherein the Thiodicarbshowed comparatively detrimental effect towards the mycopathogen by inhibiting 53.5percent. Similar results were recorded by Ali *et al.*, (2007) who reported that Lorsban wasthemost toxicinsecticide tomycelial growthandconidialgerminationfollowedbyLannate,LarvinandPirate.Atthesametime,Cascade,Match ,StewardandProclaimwerecomparativelylesstoxictomycelialgrowth(36.78-48.67%inhibition)andconidialgermination(40.32-49.97% inhibition)ofthe fungalpathogen.

Table 7.Effectofinsecticidesonthegrowthofentomopathogenicfungus, *Metarhiziumanisopliae*at21daysafterinoculation

Sl. No.	Treatments	Growthinhibition(%)			Colony growth(mm)		
		RC	75% ofRC	50% ofRC	RC	75% ofRC	50% ofRC
1	Chlorantraniliprole9.3+ Lambda-cyhalothrin4.6ZC	5.88(14.04)*	3.29 (10.46)	0.71 (4.82)	80.00	82.20	84.40
2	Spinetoram11.7SC	17.65 (24.84)	11.06 (19.43)	7.29 (15.67)	70.00	75.60	78.80
3	Chlorantraniliprole18.5SC	17.65 (24.84)	11.76 (20.06)	5.88 (14.04)	70.00	75.00	80.00
4	Thiodicarb75 WP	20.00 (26.57)	16.47 (23.95)	11.18 (19.53)	68.00	71.00	75.50
5	Emamectinbenzoate5SG	8.82 (17.28)	3.53 10.83)	4.71 (12.53)	77.50	82.00	81.00
6	Novaluron 5.25 + Emamectinbenzoate0.9 SC	8.24 (16.68)	3.29 (10.46)	1.41 (6.82)	78.00	82.20	83.80
7	Control	0.00			85.00		
	Particulars	S.E m ±			CD@1%		
	Insecticides (I)	0.49			1.88		
	ConcentrationI	0.34			1.33		
	I*C	0.84			3.25		

RC:RecommendedConcentration,*Figuresinparenthesisarearcsinetransformedvalues.

Table 8.Meaneffectofinsecticidesongrowth inhibitionof*Metarhiziumanisopliae* at weeklyintervals

Sl. No.	Insecticides	Mean growth inhibition(%)		
		7DAI	14DAI	21DAI
1	Chlorantraniliprole9.3+Lambda-cyhalothrin 4.6 ZC	11.29	6.00	3.29
2	Spinetoram11.7SC	34.58	20.51	12.00
3	Chlorantraniliprole18.5SC	19.54	15.10	11.76
4	Thiodicarb75 WP	22.75	15.96	15.88
5	Emamectinbenzoate5SG	13.46	7.45	5.69
6	Novaluron5.25+Emamectinbenzoate 0.9SC	12.75	6.86	4.31

DAI:Daysafterincubation.

References

Alizadeh, A., Samih, M. A., Khezri, M. A. S. O. O. D., Riseh, R. S. (2007). Compatibility of Beauveria bassiana (Bals.) Vuill. with several pesticides. *International journal of agriculture and biology*, *9*(1), 31-34.

Hassan, S. A. (1989). Testing methodology and concepts of the IOBC/WPRS working group. *Pesticides and Non-Target Investebrates,* 1-18.

Hokkanen, H.M.,Kotiluoto, R. (1992). Bioassay of thesideeffects ofpesticideson*Beauveriabassiana*and*Metarhiziumanisopliae*:standardizedsequentialtesting procedure. Egyptian Journal of Plant Protection Institute2**,** 1- 8.

Jayasing PK. Studies on compatibility of Beauveria bassiana (balsam) vuillemin with some pesticides. M.sc. (Agri) Thesis, Mahatma Phule Krishi Vidyapeeth Rahuri 413722, dist. Ahmednagar Maharashtra State (India), 2011, 1-65

Kachhadiya,N.M.,Kapadia,M.N.,JethvaDharmrajsinh.(2014).Compatibilityof*Nomuraearileyi* (farlow)samsonwithdifferentinsecticides.*The Indian Journal of Agricultural Sciences*38,44-46.

Moorhouse,E.R.,Gillsepie,A.T.,Sellers,E.K.,Charnley,A.K. (1992).Influenceoffungicidesandinsecticidesontheentomogenousfungus,*Metarhizium anisopliae*, a pathogen of the vine weevil, *Otiorhynchussulcatus*.Biocontrol Science and Technology82,404 - 407.

Rachappa, V., Lingappa, S., Patil, R.K.(2007). Effect of agrochemicalsongrowthandsporulationof*Metarhiziumanisopliae*(Metschnikoff)Sorokin.Karnataka Journal of Agricultural Sciences 20(2),410-413.

Rajeshwari,H.,Vijaykumar,N.G.,Arunkumar,H.,Shivaleela,Amaresh, Y. S.(2020). Compatibility of entomopathogenic fungus *Beauveriabassiana*(Bals.) with selected chemical insecticides. Journal of entomology and zoology studies8,1542-1548.

Sparks, T.C.,Nauen, R.(2015). IRAC: Mode of action classification and insecticide resistance management. Pesticide Biochemistryand Physiology 121, 122-128.