Journal of Entomology and Zoology Studies 2019; 7(3): 376-379

Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(3): 376-379

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

GG Chaware
College of Agriculture,
Nagpur, Maharashtra, India

PS Neharkar
College of Agriculture,
Nagpur, Maharashtra, India

Jayashri D Ughade
College of Agriculture,
Nagpur, Maharashtra, India

BN Chaudhari
College of Agriculture,
Nagpur, Maharashtra, India

Correspondence
GG Chaware
College of Agriculture,
Nagpur, Maharashtra, India

Evaluation of entomopathogenic fungi on larval abundance of defoliator on soybean

GG Chaware, PS Neharkar, Jayashri D Ughade and BN Chaudhari

Abstract
Efficacy of entomopathogenic fungi for the management of soybean defoliators, green semilooper and tobacco leaf eating caterpillar in field condition at Entomology section, College of Agriculture, Nagpur during *kharif* season of 2017-18, in randomized block design with three replications with the *Metarhizium anisopliae*, *Beauveria bassiana* and *Nomuraea rileyi* at 1×10^8 and 1×10^9 cfu/ml formulations were evaluated in comparisons with Spinosad 45 SC @ 0.25 ml/L. Based on data of two sprays, it was observed that Spinosad 45 SC @ 0.25ml/L had offered maximum larval reduction (67.29 %) and found significantly superior over all the other treatments. Among the entomopathogenic fungi *M. anisopliae* 1×10^9 cfu/ml had maximum larval reduction and was found most effective. The maximum yield was recorded in plot treated with Spinosad 45 SC @ 0.25ml/L (18.48 q/ha) and recorded lowest ICBR (1:4.36) as it was expensive. Maximum net profit was recorded in the treatment of *M. anisopliae* $1x10^9$ cfu/ml with highest ICBR (1:10.70).

Keywords: Entomopathogenic fungi, larval abundance, defoliator, soybean

Introduction
Soybean (*Glycine max* L.) is one of the important oilseed crop of the Leguminosae family and genus *Glycine.* It contains 20% oil and contributes more than 50% to the global production of edible oil. Soybean contains 40% protein rich in all essential amino acids and vitamins A, B and D. Among the major constraints in economic losses of soybean the different pest and diseases are important on [3]. Among different pest, major losses are due to defoliators which include tobacco leaf eating caterpillar *Spodoptera litura* (Fab.), green semilooper *Chrysodeixis acuta* (Walker) which feeds on foliage, flower and pods causing significant yield loss. Green semilooper infestation can result into 30 percent undeveloped pods and about 50 percent yield loss. In case of heavy attack, the caterpillar also found to feed on flower and pods [2].

The management of this pest using chemical insecticides causes insecticide resistance. Even though, chemical pesticides are used to control the pest, but the indiscriminate use of these chemical pesticides leads to various health hazards and insecticide resistance. On the other hand entomopathogenic fungus if used in pest management, it exists saprophytically in the soil and often causes widespread epizootics wiping out insect pest population on crop [5].

Use of microorganisms for control of pest in recent year offered several advantages over the chemical pesticides viz. safety, targeted activity to the desired pests and effective in lower quantities thereby offers lower exposure and due to quick decomposition leaves no residues on plant and allowing field re-entry immediately after application and amenability to use in rotation with chemical pesticides as part of IPM programmes. Hence, research interest in augmentation and application of biopesticides has also been growing with the ultimate objective of improving commercial production and sustainable utilization of the biopesticides.

Materials and Methods
The experiment was conducted on Soybean, var. JS-335 during *Kharif* 2017 on the field of Agricultural Entomology Section, College of Agriculture, Nagpur, Maharashtra (Dr. PDKV, Akola, M.S. India) under field conditions with three replications and eight treatments for the management of soybean defoliators green semilooper and tobacco leaf eating caterpillar. Three biopesticides viz. *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi* (1×10^8 and 1×10^9 cfu/ml) were assessed in comparison with Spinosad 45 SC @ 0.25ml/L along with control (water spray). The plot size was kept 4.5 m x 3.0 m gross with a spacing of 45 cm x 5 cm between rows and plants respectively and recommended agronomical practices were followed.

To study the efficacy of entomopathogenic fungi on soybean two foliar spray was given first at 45 days after germination and second at 60 days after germination. Observations on the larval population of green semilooper and tobacco caterpillar were recorded 1 day before spray (BDS) and mean in larval population was computed on 3rd, 7th and 14th days after spray (DAS) at randomly selected 5 spot of per meter row length and average mean computed.

The yield data from each treated plot were used to calculate economics of spraying. The cost of entomopathogenic fungi, cost of spray applications i.e. labour charges prevailing during the course of investigations were taken into consideration to work out the cost of each treatment per hectare. Similarly, income obtained from the sale of soybean as per the prevailing market rates was also calculated for each treatment to work out the cost benefit ratio.

Statistical analysis

The field data collected during the course of experimentation were subjected to statistical analysis after appropriate transformation for interpretation of results. Randomized block design used in order to test level of significance among the various treatments as per [4].

Results and Discussion

Reduction in Larval Population

Green semilooper

After first spray

The data on larval population after application of different treatments on green semilooper in soybean recorded after first spray revealed that all the treatments recorded significantly superior results. Treatment Spinosad 45 SC@ 0.25 ml/L was found significantly superior (0.75 larvae/mrl) in recording larval population after first spray over remaining treatments. Among the entomopathogenic fungi *M. anisopliae* 1×10^9 cfu/ml (1.38 larvae/mrl) proved to be the next best treatment followed by *B. bassiana* 1×10^9cfu/ml (1.44 larvae/mrl), *N. rileyi*1×10^9 cfu/ml (1.54 larvae/mrl), *M. anisopliae* 1×10^8 cfu/ml (1.55 larvae/mrl), *B. bassiana* 1×10^8 cfu/ml (1.59 larvae/mrl) and *N. rileyi*1×10^8 cfu/ml (1.64 larvae/ meter row length), respectively in controlling the incidence of green semilooper. Maximum number of green semilooper found in control treatment i.e. 2.10 larva/mrl (Table 1).

After second spray

Same trend of result was recorded after second spray. Lowest larval population was recorded in treatment Spinosad 45 SC @ 0.25 ml/L followed by *M. anisopliae* 1×10^9 cfu/ml, *B. bassiana* 1×10^9cfu/ml, *N. rileyi* 1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi* 1×10^8 cfu/ml. Maximum larval population was recorded in control treatment i.e. 2.16 larva/mrl.

Cumulative mean

Spinosad 45 SC@ 0.25 ml/L was found significantly superior by recording 0.75 larvae/mrl larval population of soybean semilooper. Among the entomopathogenic fungi *M. anisopliae* 1×10^9 cfu/ml proved to be the next best treatment by recording 1.38 larvae/mrl followed by *B. bassiana* 1×10^9 cfu/ml, *N. rileyi* 1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi* 1×10^8 cfu/ml recorded larval population in the range of 1.44 to 1.64 larvae/mrl. Control treatment recorded maximum cumulative mean population of green semilooper i.e. 2.13 larvae/mrl.

The present investigation is in accordance with [8] who reported that the entomopathogenic fungi such as *M. anisopliae* is one of the famous option to control *S. litura* in soybean integrated pest management [7].

However, [1] reported that formulation of *M. anisopliae* can serve as an effective broad spectrum biocontrol agent for soybean and various other cash crops pest control.

Tobacco leaf eating caterpillar

After first spray

All the treatments recorded significantly superior result on larval population of tobacco leaf eating caterpillar after application of first spray. Lowest larval population was recorded by Spinosad 45 SC @ 0.25 ml/L i.e. 0.66 larvae /mrl followed by *M. anisopliae* 1×10^9 cfu/ml, recorded lowest larval population followed by *B. bassiana* 1×10^9 cfu/ml *N. rileyi* 1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi* 1×10^8 cfu/ml entomopathogenic fungi, ranges from 1.24 to 1.54 larvae/mrl. Maximum number of tobacco leaf eating caterpillar found in control treatment i.e. 2.17 larva/mrl.

After second spray

Same trend of result was recorded in larval population of tobacco leaf eating caterpillar after application of second spray. Lowest larval population was recorded in treatment Spinosad 45 SC @ 0.25 ml/L followed by *M. anisopliae* 1×10^9 cfu/ml, *B. bassiana* 1×10^9 cfu/ml, *N. rileyi*1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi* 1×10^8 cfu/ml in the range of 0.73 to 1.50 larva/mrl. Control treatment with 2.10 larva/mrl recorded highest larval population of tobacco leaf eating caterpillar after second spray.

Cumulative mean

Control treatment recorded maximum cumulative mean population of tobacco leaf eating caterpillar i.e. 2.14 larvae/mrl. Spinosad 45 SC@ 0.25 ml/L was found significantly superior by recording 0.70 larvae/mrl larval population. *M. anisopliae* 1×10^9 cfu/ml proved to be the next best treatment by recording 1.38 larvae/mrl among the entomopathogenic fungi followed by *B. bassiana* 1×10^9 cfu/ml, *N. rileyi*1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi*1×10^8 cfu/ml recorded larval population in the range of 1.23 to 1.52 larvae/mrl. Control treatment recorded maximum cumulative mean population of green semilooper i.e. 2.13 larvae/mrl.

The present investigation is in accordance with [8] against tobacco caterpillar, *Spodoptera litura* and *Spodoptera obliqua.* [7] also found that both *Metarhizium anisopliae* and *Beauveria bassiana* 10^8 cfu/ml were most effective against 3rd instar larvae of *Spodoptera litura* [12].

Per Cent Reduction of Larval Population

Green semilooper

Per cent reduction in larval population of green semilooper on soybean on the basis of cumulative mean of two sprays showed maximum 64.79 per cent larval reduction recorded in treatment Spinosad 45 SC @ 0.25 ml/L over control followed by *M. anisopliae* (1×10^9 cfu/ml) with 35.21. Remaining entomopathogenic fungi recorded per cent reduction in larval population in the range of 32.39 to 23.00 in *B. bassiana* 1×10^9 cfu/ml, *N. rileyi* 1×10^9 cfu/ml, *M. anisopliae* 1×10^8 cfu/ml, *B. bassiana* 1×10^8 cfu/ml and *N. rileyi* 1×10^8 cfu/ml over control.

Tobacco leaf eating caterpillar

Treatment Spinosad 45 SC @ 0.25 ml/L recorded highest per cent reduction over control in larval population of tobacco leaf eating caterpillar on soybean on the basis of cumulative mean of two sprays i.e. 67.29 per cent. Among entomopathogenic fungi *M. anisopliae* ($1x10^9$ cfu/ml) recorded 42.52 per cent larval reduction followed by *B. bassiana* $1×10^9$ cfu/ml, *N. rileyi* $1×10^9$ cfu/ml, *M. anisopliae* $1×10^8$ cfu/ml, *B. bassiana* $1×10^8$ cfu/ml and *N. rileyi*$1×10^8$ cfu/ml over control in the range of 38.32 to 28.97 per cent. [6] reported that entomopathogenic fungi cause 35, 31 and 23 per cent reduction of the larvae over untreated check.

Average Grin Yield of Crop

Effect of different treatment and larval population on yield of soybean is presented in table 2. Maximum grain yield was recorded in treatment Spinosad 45 SC @ 0.25 ml/L i.e. 18.48 q/ha with an increase of 7.27 q/ha yield over control. The treatment of *M. anisopliae* ($1x10^9$ cfu/ml) recorded 17.41q/ha with 6.2 q/ha yield increase over control followed by the treatment *B. bassiana* ($1 x10^9$ cfu/ml), *M. anisopliae* ($1 x10^8$ cfu/ml), *B. bassiana* ($1x10^8$ cfu/ml), *N. rileyi* ($1x10^9$ cfu/ml), *N. rileyi* ($1 x10^8$ cfu/ml) which recorded yield of soybean in the range of 15.49 q/ha to 14.10 q/ha with 4.28 q/ha to 2.89 q/ha increase yield over control. Control treatment recorded lowest yield of soybean i.e. 11.21 q/ha.

Incremental Cost Benefit Ratio (ICBR)

The data presented in table 2 showed that, highest incremental cost benefit ratio (ICBR) 1:8.49 was found in *M. anisopliae* $1x10^9$ cfu/ml followed by *M. anisopliae* $1x10^8$ cfu/ml (1:7.10). *B. bassiana* $1x10^8$ cfu/ml, *B. bassiana* $1x10^9$ cfu/ml, *N. rileyi* $1 x10^9$ cfu/ml and *N. rileyi* $1 x10^8$ cfu/ml recorded 1:5.92, 1:5.90, 1.5.03 and 1:3.93. Spinosad 45 SC @ 0.25 ml/L recorded lowest incremental cost benefit ratio due to high cost of insecticide i.e. 1:3.35.

The present finding are in agreement with [11] studied the fungus *Metarhizium anisopliae* and reported that it is one of the best characterized entomopathogens used for the biological control of insects [6]. reported that entomopathogenic fungi are more effective in control of soybean leaf defoliators [9].

Table 1: Effect of different entomopathogenic fungi on cumulative mean of larval population of soybean defoliators

S.N.	Treatments	Green semilooper				Tobacco leaf eating caterpillar			
		I spray	II spray	Mean	% reduction	I spray	II spray	Mean	% reduction
T1	*Beauveria bassiana* ($1 x10^8$ cfu/ml)	1.72 (1.31)	1.45 (1.21)	1.59 (1.26)	25.35	1.46 (1.21)	1.42 (1.18)	1.44 (1.20)	32.71
T2	*Beauveria bassiana* ($1 x10^9$ cfu/ml)	1.56 (1.25)	1.33 (1.15)	1.44 (1.20)	32.39	1.33 (1.15)	1.31 (1.16)	1.32 (1.15)	38.32
T3	*Metarhizium anisopliae* ($1 x10^8$ cfu/ml)	1.70 (1.30)	1.41 (1.19)	1.55 (1.24)	27.23	1.42 (1.19)	1.40 (1.18)	1.41 (1.19)	34.11
T4	*Metarhizium anisopliae* ($1 x10^9$ cfu/ml)	1.46 (1.21)	1.29 (1.14)	1.38 (1.17)	35.21	1.24 (1.11)	1.22 (1.15)	1.23 (1.11)	42.52
T5	*Nomuraea rileyi* ($1 x10^8$ cfu/ml)	1.76 (1.33)	1.51 (1.23)	1.64 (1.28)	23.00	1.54 (1.24)	1.50 (1.22)	1.52 (1.23)	28.97
T6	*Nomuraea rileyi* ($1 x10^9$ cfu/ml)	1.63 (1.28)	1.44 (1.20)	1.54 (1.24)	27.70	1.41 (1.19)	1.40 (1.21)	1.41 (1.19)	34.11
T7	Spinosad 45 SC @ 0.25 ml/L	0.71 (0.84)	0.80 (0.89)	0.75 (0.87)	64.79	0.66 (0.81)	0.73 (0.87)	0.70 (0.83)	67.29
T8	Control (water spray)	2.10 (1.45)	2.16 (1.47)	2.13 (1.46)	0.00	2.17 (1.47)	2.10 (1.45)	2.14 (1.46)	0.00
	F Test	Sig.	Sig.	Sig.		Sig.	Sig	Sig	
	SEm±	0.08	0.07	0.08		0.08	0.08	0.08	
	C.D at 5%	0.24	0.23	0.24		0.24	0.23	0.24	
	CV	11.46	11.34	11.40		11.35	11.35	11.36	

Figures in parenthesis indicate square root transformation.

Table 2: Incremental cost benefit ratio (ICBR) for different treatments

Sr. No.	Treatments	Yield of soybean (q/ha)	Yield increased over control (q/ha)	Gross income (Rs/ha) (B)	Cost of treatment Rs/ha (A)	Net income Over control (C) (B-A)	ICBR (C/A)
T_1	*Beauveria bassiana* ($1 x10^8$ cfu/ml)	15.27	4.06	12180	1760	10420	1:5.92
T_2	*Beauveria bassiana* ($1 x10^9$ cfu/ml)	15.49	4.28	12840	1860	10980	1:5.90
T_3	*Metarhizium anisopliae* ($1 x10^8$ cfu/ml)	16.23	5.02	15060	1860	13200	1:7.10
T_4	*Metarhizium anisopliae* ($1 x10^9$ cfu/ml)	17.41	6.2	18600	1960	16640	1:8.49
T_5	*Nomuraea rileyi* ($1 x10^8$ cfu/ml)	14.10	2.89	8670	1760	6910	1:3.93
T_6	*Nomuraea rileyi* ($1 x10^9$ cfu/ml)	14.95	3.74	11220	1860	9360	1:5.03
T_7	Spinosad 45 SC @ 0.25 ml/L	18.48	7.27	21810	5010	16800	1:3.35
T_8	Control	11.21	-	-	-	-	-

1. Cost of inputs 2 Labour charges for one spray/ha. @ Rs. 200 / Labour / day,
2. Charges for hiring 2 spray, @ Rs30/day/pump.
3. Considering 500 lit of water required for one application /ha area of the crop.
4. Sale price of soybean @ RS.3000/q

Conclusion

Effect of different entomopathogenic fungi with Spinosad on soybean defoliators indicated that *Metarhizium anisopliae* ($1x10^9$ cfu/ml and $1x10^8$ cfu/ml) proved promising in recording lower population of defoliators, per cent reduction in larval population over control and yield among the entomopathogenic fungi followed by Spinosad but both the concentration of *Metarhizium anisopliae* recorded highest incremental cost benefit ratio due to low cost of plant protection than Spinosad followed by *Beauveria bassiana* and *Nomuraea rileyi*. Thus, it can be concluded from data obtained based on ICBR, that the entomopathogenic fungi were found best substitute to chemical insecticides like Spinosad 45 SC.

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