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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(4): 2547-2551

www.thepharmajournal.com
Received: 27-02-2023
Accepted: 29-03-2023

SD Patil
M.Sc. Scholor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

AS Bagde
Assistant Professor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

UB Hole
Professor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

SD Wale
Assistant Professor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

SM Galande
Associate Professor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

AB Mohite
Associate Professor, Department of Agronomy, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

Corresponding Author:
SD Patil
M.Sc. Scholor, Department of Entomology, RCSM College of Agriculture, Kolhapur, MPKV, Rahuri, Maharashtra, India

Efficacy of some biopesticides against fall armyworm (FAW) *Spodoptera frugiperda* (Smith) infesting maize

SD Patil, AS Bagde, UB Hole, SD Wale, SM Galande and AB Mohite

Abstract
A field experiment comprised of three bio-pesticides (ten treatments) tested against fall armyworm on maize was conducted at the farm of Department of Entomology, Kolhapur (MH). Among the evaluated biopesticides in field condition, all the treatments were significantly superior over untreated control. The treatment with *Beauveria bassiana* 10 g/L was the most effective as compared to all other treatments in reducing the population of the *Spodoptera frugiperda* (FAW). The *Metarhizium anisopliae* 10 g/L was the next effective treatment and this was followed by EPN 10 g/L, *B. bassiana* 8 g/L and *M. anisopliae* 8 g/L.

Keywords: Fall armyworm, biopesticides, EPN, Maize, *B. bassiana*

Introduction
Maize, is also commonly known as corn. After paddy and wheat, maize is the 3rd most grown cereal crop within India. In terms of area, maize is the second-largest cereal crop in the world and is referred to as the "Queen of Cereals." In terms of area, Karnataka occupies first place (1.68 m ha) 17.00 percent, followed by Madhya Pradesh second (1.46 m ha) 14.82 percent and Maharashtra third (1.15 m ha) 11.62 percent. In terms of Production, Maharashtra ranks third (3.44 million tonnes) 10.91 percent after Karnataka (5.18 million tonnes) 16.45 percent and Madhya Pradesh (3.58 million tonnes) 11.37 percent. Production of some other states are Tamil Nadu (2.72 million tonnes), West Bengal (2.45 million tonnes), Rajasthan (2.27 million tonnes) and Bihar (2.22 million tonnes) (Anon, 2021) [1].

The *Spodoptera frugiperda* (FAW) is a generally noctuid pest of maize on the American continents. The outbreaks of fall armyworm in West and Central Africa were recorded for the first time in early 2016. This pest become a new invasive species and new threat to the maize crop in tropical Africa (Goergen *et al.*, 2016) [5].

In India, the pest reported in Karnataka in July 2018 for the first time and later it reported in few other states like Telangana, Tamil Nadu, Andhra Pradesh, Maharashtra and Odisha. The Indian Council of Agricultural Research (ICAR) and National Bureau of Agricultural Insect Resources (NBAIR) conducted surveys in July 2018 and recorded more than 70% prevalence of the FAW in a maize field in Chikkaballapur, Karnataka and based on results of surveys issued 'pest alert' on 30th July 2018 (Padhee and Prasanna, 2019) [6]. The incidence of FAW ranged from 9% to 62.5% at Hassan, Chikkaballapur, Shivamogga, Davanagere and Chitradurga (Shylesha *et al.*, 2018) [7].

The application of insecticide may develop insecticidal resistance, it is unsustainable, destroys natural enemies and causes environmental hazards, insect resurgence, bio accumulation and health hazards. Hence, it is important to reduce use of insecticides. For eco-friendly management practices in India, need to develop sustainable IPM technologies against fall armyworm *Spodoptera frugiperda* (Day *et al.*, 2017) [3]. The fall armyworm (FAW) larvae are susceptible to the different entomopathogenic microorganism, like nematodes, fungi, bacteria, viruses and protozoa. The EPF *Metarhizium anisopliae* and EPN *Heterorhabditis bacteriophora* are most used in biological control. They proved lethal as well as virulent to the *Spodoptera frugiperda* (Bissiwu *et al.*, 2016) [2].

In the present research paper, an attempt was made to study the efficacy of some biopesticides fall armyworm (FAW) in maize.

Material and Methods
Ten treatments with 3 replications were arranged in randomized block design.

Size of plot was 6 × 4 m. Knapsack sprayer was used for application of biopesticides. The treatments were imposed three times. The first spraying was done at 15 days after sowing. The second application was done 15 days after first spray and third spray was done after 15 days after second spray. A visual observation of the number of larvae per plant was recorded one DBS and 5, 10, 15 days after each treatment. The observations were recorded on 20 plants from each experimental unit. Marketable grain yield was recorded treatment-wise and later expressed in kg per ha (Deshmukh *et al.*, 2020) [4].

Table 1: Treatment details

Sr. No.	Treatment No.	Biopesticides	Dose (g/lit)
1.	T1	*Metarhizium anisopliae*	6
2.	T2	*Metarhizium anisopliae*	8
3.	T3	*Metarhizium anisopliae*	10
4.	T4	*Beauveria bassiana*	6
5.	T5	*Beauveria bassiana*	8
6.	T6	*Beauveria bassiana*	10
7.	T7	EPN	5
8.	T8	EPN	7
9.	T9	EPN	10
10.	T10	Control	0

Result and Discussion

The results obtained during the course of investigations are presented under the following heads.

Efficacy of some biopesticides against fall armyworm infesting maize under field conditions 1 First Spray

Data pertaining to the survival population of *Spodoptera frugiperda* on maize one DBS and 5, 10 and 15 days after first spray was given in Table No. 2

The mean population of *S. frugiperda* one DBS was ranged from 1.67 to 2.15 larvae per plant. The pre-treatment data was recorded non-significant shows the uniformity in larval population of pest throughout the experimental plot.

Observations recorded at five days after spray showed that all the treatments were significantly superior over untreated control. The treatment of *Beauveria bassiana* 10 g/L (0.90 larvae/plant) was found effective and superior over all other treatments. However, this treatment was at par with *Metarhizium anisopliae* 10 g/L (0.92 larvae/plant), EPN 10 g/L (0.98 larvae/plant). The treatment *Beauveria bassiana* 8 g/L and *Metarhizium anisopliae* 8 g/L (1.05 larvae/plant) were also at par. The treatment of EPN 5 g/L (1.45 larvae/plant) was found less effective among all the treatments. However, the highest population of fall armyworm was noticed (2.20 larvae/plant) in untreated control plant.

At ten DAS, the mean number of survival population of fall armyworm ranged from 0.80 to 2.03 larvae per plant. The treatment of *Beauveria bassiana* 10 g/L (0.80 larvae/plant) was found effective and superior over all other treatments. However, this treatment was at par with *Metarhizium anisopliae* 10 g/L (0.87 larvae/plant), EPN 10 g/L (0.93 larvae/plant). The treatment of EPN was also at par with *Beauveria bassiana* 8 g/L (1 larvae/plant) and *Metarhizium anisopliae* 8 g/L (1.08 larvae/plant). The treatment of EPN 5 g/L (1.30 larvae/plant) was found less effective among all the treatments. However, the highest population of fall armyworm was noticed (2.03 larvae/plant) in untreated control plant.

At fifteen DAS, the mean number of survival population ranged from 0.87 to 2.10 larvae/plant. The highest survival population was recorded in untreated control plot (2.10 larvae/plant). Again treatment with *Beauveria bassiana* 10 g/L (0.87 larvae/plant) emerged as best over all other treatments; however, this was at par with *Metarhizium anisopliae* 10 g/L, EPN 10 g/L, *Beauveria bassiana* 8 g/L and *Metarhizium anisopliae* 8 g/L; where 1.07, 1.17, 1.25 and 1.30 larvae per plant were recorded, respectively.

The overall results on efficacy of various treatments indicated *Beauveria bassiana* 10 g/L (0.85 larvae/plant) was the most effective treatment as compared to all other treatments in reducing the population of *Spodoptera frugiperda*. The *Metarhizium anisopliae* 10 g/L (0.95 larvae/plant) was the next effective treatment, followed by EPN 10 g/L (1.02 larvae/plant), *Beauveria bassiana* 8 g/L (1.10 larvae/plant), and *Metarhizium anisopliae* 8 g/L (1.14 larvae/plant).

Table 2: Efficacy of biopesticides against fall armyworm under field conditions (First Spray)

Sr. No.	Treatments	Dose g/L	Mean No. of survival					Reduction over control (%)
			Pre Count	First spray				
				5 DAS	10 DAS	15 DAS	Mean	
1.	*Metarhizium anisopliae*	6	1.78 (1.51)*	1.38 (1.37)	1.28 (1.33)	1.47 (1.40)	1.37 (1.36)	35.08
2.	*Metarhizium anisopliae*	8	1.77 (1.50)	1.05 (1.24)	1.08 (1.26)	1.30 (1.34)	1.14 (1.28)	45.98
3.	*Metarhizium anisopliae*	10	1.87 (1.54)	0.92 (1.19)	0.87 (1.17)	1.07 (1.25)	0.95 (1.20)	54.98
4.	*Beauveria bassiana*	6	1.72 (1.49)	1.40 (1.38)	1.32 (1.35)	1.53 (1.42)	1.41 (1.38)	33.18
5.	*Beauveria bassiana*	8	1.78 (1.51)	1.05 (1.24)	1.00 (1.22)	1.25 (1.32)	1.10 (1.26)	47.87
6.	*Beauveria bassiana*	10	1.82 (1.52)	0.90 (1.18)	0.80 (1.14)	0.87 (1.16)	0.85 (1.16)	59.72
7.	EPN	5	1.73 (1.49)	1.45 (1.39)	1.30 (1.34)	1.58 (1.44)	1.44 (1.39)	31.76
8.	EPN	7	1.77 (1.50)	1.37 (1.36)	1.25 (1.32)	1.40 (1.38)	1.34 (1.35)	36.50
9.	EPN	10	1.67 (1.47)	0.98 (1.21)	0.93 (1.20)	1.17 (1.29)	1.02 (1.23)	51.66
10.	Control	0	2.15	2.20	2.03	2.10	2.11	

			(1.63)	(1.64)	(1.59)	(1.61)	(1.61)	-
	SE±		0.057	0.062	0.060	0.063	-	-
	CD at 5%		NS	0.19	0.18	0.19	-	-
	CV%		6.57	8.20	8.12	8.02	-	-

DAS- Days after spraying *Figures in the parentheses are √x+0.5 transformed values.

Beauveria bassiana 10 g/L showed 59.72 percent reduction over control. The next treatment in order of efficacy were *Metarhizium anisopliae* 10 g/L, EPN 10 g/L, *Beauveria bassiana* 8 g/L and *Metarhizium anisopliae* 8 g/L which showed 54.98, 51.66, 47.87 and 45.98 percent reduction over untreated control, respectively.

2. Second Spray

Data pertaining to survival population of fall armyworm on maize one DBS and 5, 10 and 15 days after second spray was presented in Table No. 3

The population of fall armyworm (FAW) reached ETL after first spray therefore, second spray was taken up at 15 days after first spray. Observations were recorded at five days after the spray; all the treatments were observed significantly superior over untreated control. The treatment of *Beauveria bassiana* 10 g/L (0.48 larvae/plant) was significantly superior over all other treatments; however, it was at par with *Metarhizium anisopliae* 10 g/L (0.57 larvae/plant), EPN 10 g/L (0.68 larvae/plant), *Beauveria bassiana* 8 g/L (0.78 larvae/plant) and *Metarhizium anisopliae* 8 g/L (0.85 larvae/plant). The highest numbers of survival of *Spodoptera frugiperda* population was found in untreated control (1.58 larvae/plant).

At ten days after second spray the treatment of *Beauveria bassiana* 10 g/L (0.35 larvae/plant) was superior over all other treatment. The next followed treatments were *Metarhizium anisopliae* (0.40 larvae/plant) and EPN (0.50 larvae/plant). The treatment of *Beauveria bassiana* 8 g/L (0.57 larvae/plant) and *Metarhizium anisopliae* 8 g/L (0.62 larvae/plant) were also at par.

At fifteen days after spray, there was slight increase in mean larval population in all treatments. Among all the treatments the *Beauveria bassiana* 10 g/L (0.47 larvae/plant) was the best treatment and on par with *Metarhizium anisopliae* 10 g/L and EPN 10 g/L. The maximum larval population of FAW was observed in untreated control (1.55 larvae/plant). The mean larval population per plant was ranged from 0.43 to 1.58.

The reduction in fall armyworm population in different treatments was in the order of *B. bassiana* followed by *M. anisopliae* and EPN. The maximum reduction in larval population over untreated control was found in *B. bassiana* 10 g/L (72.79%), followed by *M. anisopliae* 10 g/L (67.73%), EPN 10 g/L (62.03%), *B. bassiana* 8 g/L (57.60%) and *M. anisopliae* 8 g/L (53.17%).

Table 3: Efficacy of biopesticides against fall armyworm under field conditions (Second Spray)

Sr. No.	Treatments	Dose g/L	Mean No. of survival					Reduction over control (%)
			Pre count	Second spray				
				5 DAS	10 DAS	15 DAS	Mean	
1.	*Metarhizium anisopliae*	6	1.47 (1.40)*	0.98 (1.21)	0.78 (1.13)	0.97 (1.21)	0.91 (1.18)	42.41
2.	*Metarhizium anisopliae*	8	1.30 (1.34)	0.85 (1.16)	0.62 (1.05)	0.77 (1.12)	0.74 (1.11)	53.17
3.	*Metarhizium anisopliae*	10	1.07 (1.25)	0.57 (1.03)	0.40 (0.95)	0.58 (1.04)	0.51 (1.00)	67.73
4.	*Beauveria bassiana*	6	1.53 (1.42)	1.03 (1.24)	0.78 (1.13)	0.98 (1.21)	0.93 (1.19)	41.14
5.	*Beauveria bassiana*	8	1.25 (1.32)	0.78 (1.13)	0.57 (1.03)	0.68 (1.08)	0.67 (1.08)	57.60
6.	*Beauveria bassiana*	10	0.87 (1.16)	0.48 (0.99)	0.35 (0.92)	0.47 (0.98)	0.43 (0.96)	72.79
7.	EPN	5	1.58 (1.44)	1.08 (1.25)	0.87 (1.17)	1.05 (1.24)	1.00 (1.22)	36.71
8.	EPN	7	1.40 (1.38)	0.93 (1.19)	0.75 (1.11)	0.92 (1.18)	0.86 (1.16)	45.57
9.	EPN	10	1.17 (1.29)	0.68 (1.09)	0.50 (1.00)	0.62 (1.05)	0.60 (1.04)	62.03
10.	Control	0	2.10 (1.61)	1.58 (1.44)	1.62 (1.45)	1.55 (1.43)	1.58 (1.44)	-
	SE±		0.063	0.061	0.061	0.067	-	-
	CD at 5%		0.19	0.18	0.18	0.20	-	-
	CV%		8.02	9.12	9.69	10.15	-	-

DAS- Days after spraying * Figures in the parentheses are √x+0.5 transformed values.

3. Third Spray

Data pertaining to the survival population of *S. frugiperdaon* maize one DBS and 5, 10 and 15 days after third spray was given in Table No. 4

Observations recorded at five days after spray showed that all the treatments were significantly superior over untreated control. The treatment of *Beauveria bassiana* 10 g/L (0.18 larvae/plant) was found effective and superior over all other treatments. However, this treatment was at par with *Metarhizium anisopliae* 10 g/L (0.23 larvae/plant), EPN 10 g/L (0.28 larvae/plant). The treatment *Beauveria bassiana* 8 g/L (0.33 larvae/plant) and *Metarhizium anisopliae* 8 g/L

(0.40 larvae/plant) were also at par. The treatment of EPN 5 g/L (0.62 larvae/plant) was found less effective among all the treatments. However, the highest population of fall armyworm was noticed (1.22 larvae/plant) in untreated control plant.

At ten DAS, the mean number of survival population of fall armyworm ranged from 0.13 to 0.92 larvae per plant. The treatment of *Beauveria bassiana* 10 g/L (0.13 larvae/plant) was found effective and superior over all other treatments. However, this treatment was at par with *Metarhizium anisopliae* 10 g/L (0.20 larvae/plant), EPN 10 g/L (0.22 larvae/plant). The treatment of EPN was also at par with *Beauveria bassiana* 8 g/L (0.30 larvae/plant) and *Metarhizium anisopliae* 8 g/L (0.30 larvae/plant). The treatment of EPN 5 g/L (0.52 larvae/plant) was found less effective among all the treatments. However, the highest population of fall armyworm was noticed (0.92 larvae/plant) in untreated control plant.

At fifteen DAS, the mean number of survival population ranged from 0.07 to 0.68 larvae/plant. The highest survival population was recorded in untreated control plot (0.68 larvae/plant). Again treatment with *Beauveria bassiana* 10 g/L (0.07 larvae/plant) emerged as best over all other treatments; however, this was at par with *Metarhizium anisopliae* 10 g/L, EPN 10 g/L, *Beauveria bassiana* 8 g/L and *Metarhizium anisopliae* 8 g/L; where 0.08, 0.13, 0.22 and 0.18 larvae per plant were recorded, respectively.

Table 4: Efficacy of biopesticides against fall armyworm under field conditions (Third Spray)

Sr. No.	Treatments	Dose g/L	Mean No. of survival					Reduction over control (%)
			Pre Count	Third spray				
				5 DAS	10 DAS	15 DAS	Mean	
1	*Metarhizium anisopliae*	6	0.97 (1.21)*	0.52 (1.01)	0.48 (0.99)	0.52 (1.00)	0.50 (1.00)	46.81
2	*Metarhizium anisopliae*	8	0.77 (1.12)	0.40 (0.94)	0.30 (0.89)	0.18 (0.83)	0.29 (0.88)	69.15
3	*Metarhizium anisopliae*	10	0.58 (1.04)	0.23 (0.86)	0.20 (0.84)	0.08 (0.76)	0.17 (0.82)	81.92
4	*Beauveria bassiana*	6	0.98 (1.21)	0.55 (1.02)	0.50 (1.00)	0.35 (0.92)	0.46 (0.98)	51.07
5	*Beauveria bassiana*	8	0.68 (1.08)	0.33 (0.91)	0.30 (0.89)	0.22 (0.85)	0.28 (0.88)	70.22
6	*Beauveria bassiana*	10	0.47 (0.98)	0.18 (0.83)	0.13 (0.80)	0.07 (0.75)	0.12 (0.79)	87.24
7	EPN	5	1.05 (1.24)	0.62 (1.05)	0.52 (1.01)	0.52 (1.00)	0.55 (1.02)	41.49
8	EPN	7	0.92 (1.18)	0.45 (0.97)	0.45 (0.97)	0.48 (0.99)	0.46 (0.97)	51.07
9	EPN	10	0.62 (1.05)	0.28 (0.88)	0.22 (0.85)	0.13 (0.80)	0.21 (0.84)	77.66
10	Control	0	1.55 (1.43)	1.22 (1.31)	0.92 (1.18)	0.68 (1.08)	0.94 (1.19)	-
	SE±		0.067	0.045	0.049	0.044	-	-
	CD at 5%		0.20	0.14	0.15	0.13	-	-
	CV%		10.15	8.09	9.19	8.61	-	-

DAS- Days after spraying *Figures in the parentheses are √x+0.5 transformed values.

In the current study, all the treatments proved their superiority over untreated control. The mean data associated with the efficacy of different treatments against fall armyworm showed that *Beauveria bassiana* 10 g/L was the most effective treatment over untreated control.

The maximum reduction in larval population over untreated control was observed in *Beauveria bassiana* 10 g/L (87.24%), followed by *Metarhizium anisopliae* 10 g/L (81.92%), EPN 10 g/L (77.66%), *Beauveria bassiana* 8 g/L (70.22%) and *Metarhizium anisopliae* 8 g/L (69.15%).

The results of the present study are substantially in conformity with the findings of Ramanujam *et al.* (2020) [8] resulted 70 and 76% reduction of FAW infestation by *Metarhizium anisopliae* and *Beauveria bassiana*. Field trial with *M. rileyi* against fall armyworm showed 58 to 62% reduction of pest (Mallapur *et al.* 2018).

Lotfy and Moustafa (2021) [10] reported that *Metarhizium anisopliae* and *Beauveria bassiana* showed 77.74 and 76.51% reduction of *E. insulana*, respectively. Pandey and Das (2016) [11] found the *Beauveria bassiana* was most effective treatment to control gram pod borer on pigeon pea.

Fite *et al.* (2020) [12] found that *B. bassiana* and *M. anisopliae* were most effective against 3rd instar of *H. armigera* and *B. bassiana* is effective in reducing larval infestation in chick pea.

Cumulative effect of biopesticides against fall armyworm in field condition

Data pertaining to damage of *S. frugiperda* on maize after first, second and third spray was presented in Table No. 5

The treatment with *Beauveria bassiana* 10 g/L was the most effective over other treatments having 70.13 percent reduction in larval population. The highest yield was observed in treatment *B. bassiana* 10 g/L 41.13 q/ha. It was followed by *Metarhizium anisopliae* 10 g/L, EPN 10 g/L, *B. bassiana* 8 g/L and *M. anisopliae* 8 g/L in which 64.94, 60.39, 55.85 and 53.25 percent reduction in larval population were observed, respectively.

The treatment with EPN 5 g/L recorded 35.72 percent reduction in larval population over control with yield 26.20 percent.

Table 5: Cumulative effect of biopesticides against fall armyworm in field conditions

Sr. No.	Treatments	Dose g/L	Pre Count	Mean of First Spray	Mean of Second Spray	Mean of Third Spray	Mean	Reduction Over Control (%)	Yield (q/ha)
1	*Metarhizium anisopliae*	6	1.78 (1.51)*	1.37 (1.36)	0.91 (1.18)	0.50 (1.00)	0.92 (1.18)	40.26	28.12
2	*Metarhizium anisopliae*	8	1.77 (1.50)	1.14 (1.28)	0.74 (1.11)	0.29 (0.88)	0.72 (1.09)	53.25	31.85
3	*Metarhizium anisopliae*	10	1.87 (1.54)	0.95 (1.20)	0.51 (1.00)	0.17 (0.82)	0.54 (1.00)	64.94	38.90
4	*Beauveria bassiana*	6	1.72 (1.49)	1.41 (1.38)	0.93 (1.19)	0.46 (0.98)	0.93 (1.18)	39.62	26.27
5	*Beauveria bassiana*	8	1.78 (1.51)	1.10 (1.26)	0.67 (1.08)	0.28 (0.88)	0.68 (1.07)	55.85	33.90
6	*Beauveria bassiana*	10	1.82 (1.52)	0.85 (1.16)	0.43 (0.96)	0.12 (0.79)	0.46 (0.97)	70.13	41.13
7	EPN	5	1.73 (1.49)	1.44 (1.39)	1.00 (1.22)	0.55 (1.02)	0.99 (1.21)	35.72	26.20
8	EPN	7	1.77 (1.50)	1.34 (1.35)	0.86 (1.16)	0.46 (0.97)	0.88 (1.16)	42.86	30.63
9	EPN	10	1.67 (1.47)	1.02 (1.23)	0.60 (1.04)	0.21 (0.84)	0.61 (1.03)	60.39	36.13
10	Control		2.15 (1.63)	2.11 (1.61)	1.58 (1.44)	0.94 (1.19)	1.54 (1.41)	-	20.8
	SE±		0.057	0.061	0.063	0.046	0.056		0.19
	CD at 5%		NS	0.18	0.18	0.14	0.16	-	0.59
	CV%		6.57	8.11	9.65	8.63	8.79	-	6.12

*Figures in the parentheses are √x+0.5 transformed values.

Conclusion

In the present study, *Beauveria bassiana* 10 g/L found most effective for control of the fall armyworm at 5, 10 and 15 days after first, second and third spray. It was followed by *Metarhizium anisopliae* 10 g/L and EPN 10 g/L which were next in order after B. bassiana 10 g/L. It was followed by B. bassiana 8 g/L and M. anisopliae 8 g/L in field condition.

Acknowledgement

It gives me great pleasure to express my deep sense of gratitude and sincere thanks to my research guide Dr. A. S. Bagde, Asst. Professor of Agricultural Entomology, RCSM College of Agriculture, Kolhapur. Also my special thanks to my committee members, I owe to them for their constant inspiration and well-versed advice and keen criticism, prompt suggestions regarding research problem, constant encouragement and sympathetic attitude throughout the course of investigation and the completion of thesis.

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