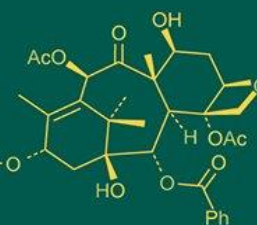
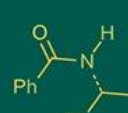
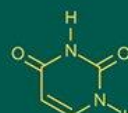
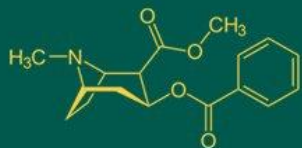


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(6): 1282-1291
www.biochemjournal.com
Received: 18-03-2026
Accepted: 20-04-2026

Gajanand Chhimpia
Department of Entomology,
College of Agriculture, Central
Agricultural University,
Iroisemba, Imphal, Manipur,
India

KI Singh
Department of Entomology,
College of Agriculture, Central
Agricultural University,
Iroisemba, Imphal, Manipur,
India

Nilima Karam
Department of Entomology,
College of Agriculture, Central
Agricultural University,
Iroisemba, Imphal, Manipur,
India

Moirangthem Monalisa Devi
Department of Entomology,
College of Agriculture, Central
Agricultural University,
Iroisemba, Imphal, Manipur,
India

Priyanka Choudhary
Department of Entomology,
College of Agriculture,
Vasantrao Naik Marathwada
Krishi Vidyapeeth, Parbhani,
Maharashtra, India

Subhash Chander
Department of Entomology,
School of Agricultural
Sciences, Nagaland University,
Medziphema, Nagaland, India

Corresponding Author:
Gajanand Chhimpia
Department of Entomology,
College of Agriculture,
Iroisemba, Central
Agricultural University,
Imphal 795004 Manipur, India

Biorational insecticide management of broad bean (*Vicia faba* L.) pests in the Manipur valley: Impact on yield, loss, and economics

Gajanand Chhimpia, KI Singh, Nilima Karam, Moirangthem Monalisa Devi, Priyanka Choudhary and Subhash Chander

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i6p.8891>

Abstract

A field experiment was conducted at the Department of Entomology, CAU, Imphal, during Rabi 2023-24 to evaluate the efficacy of bio-rational insecticides against major insect pests of broad bean. The study included *Beauveria bassiana*, *Bacillus thuringiensis*, *Metarhizium anisopliae*, *Verticillium lecanii*, Azadirachtin (0.03% and 0.1%), Uro insecticide, and Fipronil 5% SC (standard check), arranged in a randomized block design with nine treatments and three replications. Insecticides were applied thrice at 15-day intervals, and observations on aphid population, leaf miner damage, and pod borer infestation were recorded. Among botanical insecticides, Azadirachtin 0.1% EC (Green neem) was most effective against aphids, while *Verticillium lecanii* (Mealikill) showed the best microbial efficacy. *Metarhizium anisopliae* and *Verticillium lecanii* significantly reduced pod borer damage, and Azadirachtin 0.1% EC (Green neem) minimized leaf miner damage. Fipronil 5% SC was the most effective but posed environmental risks. The highest yield (566.71 kg/ha) was recorded with Green neem, increasing yield by 167.79 kg/ha over control. Avoidable loss reduction ranged from 14.52% to 49.12%. The highest cost-benefit ratio (CBR) was 1:22.05 for Fipronil, while among bio-rational insecticides, Green neem had the best CBR (1:11.33). The results suggest that botanical and microbial insecticides are effective eco-friendly alternatives for broad bean pest management, ensuring sustainability and economic viability.

Keywords: Broad bean, Bio-rational management, *Aphis craccivora* (Koch), *Helicoverpa armigera* (Hubner), *Liriomyza* sp

Introduction

Pulses including chickpea, pigeon pea, mung bean, urd bean, lentil, field bean, broad bean, etc. are the most important constituent of Indian diet as they are rich in protein, particularly in the essential amino acid lysine, which is rather deficient in cereals. Therefore, in the vegetarian Indian cuisine, a mixture of cereals and pulses form a balanced diet. Pulses also enhance the sustainability of vulnerable agricultural system as they enrich the soil fertility by fixing atmospheric nitrogen in their roots. Pulses are suitable for mixed cropping or intercropping systems. India is the largest producer, consumer and importer of the pulses in the whole world. It contributes around 33 per cent in production and consumption in the world (Ali, 2007) [4]. Legumes having unique ability to trap atmospheric nitrogen into their root nodules in association with *Rhizobium* and grow well under drastic and delicate ecosystem. Pulse starch is a helpful component for producing products for people with diabetes. The hulls of pulses grains are rich in water- insoluble fibers and polyphenols, which have potent antioxidant properties. On the other hand, the cotyledons of pulse grains have more soluble fibers, slowly digesting resistant starch and oligosaccharides (Singh *et al.* 2017) [30]. Broad bean (*Vicia faba* L.) belongs to the family Fabaceae of the genus *Vicia* which contains chromosome number of $2n = 12, 14$. The plant is an upright annual forage legume with a coarse, hollow, and unbranched stem that can grow to a height of 1.5-2 m. It is an important pulse crop of the world and ranks fourth among the most important leguminous crops of the world. Broad bean is a native of Mediterranean region or South Western Asia (Purseglove, 1974) [26]. In India, it is mainly grown in the North Eastern region as vegetable pulse crop. Broad bean has long been a part of human diet. It can be used directly in two ways, depending on the stage of maturity when very young the whole pod can be cooked in the same manner as pea and when matured seed can be used as dal. In Manipur, the crop is widely grown as a *Rabi* vegetable and harvested at the green pod stage as for using it as vegetable and the overmatured pods are usually kept for seed

purpose. Broad bean is grown widely in the hilly terrains of Manipur. However, productivity of this crop is far below the national average and its potential. Amongst the several abiotic and biotic factors for low productivity of broad bean, the damage caused by insect-pests which attack the crop from seedling to pod maturity stage is considered as one of the major production constraints. Among the different insect-pests of broad bean observed in Manipur, black aphid (*Aphis craccivora* Koch), Gram pod borer (*Helicoverpa armigera* Hubner) and Leaf miner (*Liriomyza* sp.) causes serious damage to the crop (Juliana and Roy, 2012)^[17]. Bean crops are subjected to attacks by various sucking pests, especially aphids, jassids, and thrips. Which causes serious damage, either directly by sucking plant juices or indirectly as vectors of virus diseases (Abdel-Alim, 1994; El-Sarand *et al.*, 2019 and Khodeir *et al.*, 2020)^[1, 10]. The susceptibility of a crop to a pest is greatly influenced by the prevailing climatic conditions and agronomic practices of a region. In order to control the pest economically and effectively, certain studies of the pest such as their seasonal incidence, peak period, extent of damage, the climatic factors that favour the development and multiplication of the pest are necessary. Of these, adjustment of sowing time is one of the most important practices to avoid pest population. By changing or carefully selecting the time when a crop is planted it may be possible to provide asynchrony between the peak period of the pest and susceptible stage of the crop. Generally, in Manipur, synthetic organic pesticides are preferred by the farmers mainly due to their low cost, easy availability and instant suppression of the

pest population. But, indiscriminate use of such persistence insecticides on the other hand leads to development of insecticide resistance, pest resurgence due to killing of natural enemies and secondary pest outbreaks in association with human hazard and environmental pollution. These considerations have prompted the pestologists during the recent years to look for ecofriendly pesticides like botanicals and microbials for insect pest control with minimum adverse effects on the environment.

Materials and Methods

Site of experiment and soil condition

A field experiment was conducted during the *rabi* season of 2023-2024 at the experimental field, Department of Entomology, College of Agriculture, Iroisemba, Central Agricultural University, Imphal. The experimental site is situated at 24° 81' N latitude, 93° 88' E longitude, and 786 meters above mean sea level, with a clay loam soil type and a pH of 5.5.

Climatic and weather conditions

In general, the climatic condition of Imphal valley is sub-tropical. The meteorological data of temperature, rainfall, relative humidity, sunshine hours and wind velocity for the periods of experimentation viz., from October to February were obtained from meteorological observatory, Imphal West. (Table 1)

Table 1: ANOVA (Analysis of Variance)

Source of variation	d.f.	ss	mss	F calculated	Expectation of MS
Replications	r-1	RSS	RMSS	RMSS/ EMSS	$\sigma_e^2 + g\sigma_r^2$
Treatments	t-1	GSS	GMSS	GMSS/EMSS	$\sigma_e^2 + t\sigma_g^2$
Error	(r-1)(t-1)	ESS	EMSS		σ_e^2
Total	(rt)-1	TSS			

Experimental Design and Treatments

The experiment was conducted using a Randomized Block Design (RBD) with nine treatments, including a control, and was replicated three times. The treatments evaluated were as follows:

S. No.	Treatments
1.	Beauveria bassiana (Green Racer)
2.	Bacillus thuringiensis (Green Lipel)
3.	Metarhizium anisopliae (Green Pacer)
4.	Verticillium lecanii (Green Mealikil)
5.	Azadirachtin 0.03% (Multi neem)
6.	Azadirachtin 0.1% EC (Green neem)
7.	Uro insecticide (cow urine + Vitex trifolia + Artemisia nilagirica)
8.	Fipronil 5% SC (Check)
9.	Control

Crop Management and Data Collection

Broad bean (*Vicia faba* L.) was sown on October 21, 2023, using line sowing at a spacing of 45 cm × 25 cm with a seed rate of 70 kg/ha. Recommended agronomic practices, including tillage, fertilizer application (NPK: 20:50:40 kg/ha), and weeding, were uniformly followed across all plots. Additionally, farmyard manure (10 t/ha) was applied as per recommendations.

Pest incidence and crop damage data were recorded before

treatment and at 3, 7, and 14 days after each application. The following parameters were observed:

Aphid (*Aphis craccivora* Koch) population: Population were recorded from the top 10 cm of the shoot on five randomly selected plants per plot.

Pod borer (*Helicoverpa armigera* Hubner) damage: The percentage of pod damage caused by the pod borer was recorded before treatment and at 3, 7, and 14 days after each application, as well as during the harvesting of fresh pods. Data were collected from ten plants per plot, and pod damage was calculated using the following formula:

$$\text{Per cent pod damage} = \frac{\text{No. of damage pods per plant}}{\text{Total no. of pods per plant}} \times 100$$

Pea leaf miner (*Liriomyza* sp.) damage: The number of healthy and damaged/mined leaflets was recorded from five randomly selected plants per plot. The percentage of mined leaflets was calculated for each observation day using the following formula:

$$\text{Per cent mined leaflets} = \frac{\text{No. of mined leaflets per plant}}{\text{Total no. of leaflets per plant}} \times 100$$

Yield Loss Assessment

The percentage of avoidable yield loss due to treatments was calculated using the formula described by Khosla (1977)^[21]:

$$\text{Percent avoidable loss} = (A - B) / A \times 100$$

Where:

A = Mean yield under the most effective treatment

B = Mean yield under respective treatment

Cost-Benefit Analysis

The cost-benefit ratio (CBR) was computed using the seed yield (kg/ha), market price, and treatment costs. Additional yield over control and net monetary return were determined to calculate the incremental CBR for each treatment.

Statistical Analysis

The mean values obtained from the experiment were subjected to statistical analysis using ANOVA (Analysis of Variance) after appropriate transformations to determine the significance of treatments. (Table 1)

Results and Discussion

Efficacy of biorational insecticides against major insect pests of faba bean

This study assessed the efficacy of various biorational

insecticides and a chemical check (fipronil 5% SC) in managing major insect pests of broad bean under Manipur valley conditions. The results revealed significant differences in pest population reduction and yield improvement across treatments, highlighting the potential of biorational insecticides as effective and sustainable alternatives to chemical pesticides.

The effect of biorational insecticides on aphid (*A. craccivora* Koch) population

This study assessed the efficacy of various biorational insecticides and a check (fipronil 5% SC) in managing major insect pests of broad bean under Manipur valley conditions. The results revealed significant differences in pest population reduction and yield improvement across treatments, the findings indicated that among the biorational treatments, Azadirachtin 0.1% EC (Green Neem) and *Verticillium lecanii* (Green Mealikill) were the most effective. These treatments consistently showed lower aphid populations across all observation periods (1 DBA, 3 DAA, 7 DAA, and 14 DAA), highlighting the potential of biorational insecticides as effective and sustainable alternatives to chemical pesticides. The results are presented in Table 2.

Table 2: Effect of 1st, 2nd and 3rd round of biorational insecticides on aphid (*Aphis. craccivora* Koch) population

Treatment		Aphid per 10cm terminal shoot/plant														
		1 st Round					2 nd Round					3 rd Round				
		1 DBA	3 DAA	7 DAA	14 DAA	Mean	1 DBA	3DAA	7DAA	14DAA	Mean	1 DBA	3DAA	7DAA	14DA A	Mean
T ₁	<i>Beauveria bassiana</i> (Green racer)	94.00	92.67	88.00	80.00	86.89	80.00 (8.97)	77.33 (8.82)	67.67 (8.26)	61.67 (7.88)	68.89 (8.32)	61.67 (7.88)	59.33 (7.73)	52.33 (7.27)	48.67 (7.01)	53.44 (7.34)
T ₂	<i>Bacillus thuringiensis</i> (Green lipel)	94.67	96.00	92.00	88.33	92.11	88.33 (9.42)	86.00 (9.30)	79.67 (8.95)	73.67 (8.61)	79.78 (8.96)	73.67 (8.61)	72.00 (8.51)	66.33 (8.17)	63.00 (7.97)	67.11 (8.22)
T ₃	<i>Metarhizium anisopliae</i> (Green pacer)	95.00	93.67	89.00	81.00	87.89	81.00 (9.03)	78.00 (8.86)	68.33 (8.30)	62.33 (7.93)	69.56 (8.36)	62.33 (7.93)	60.00 (7.78)	52.67 (7.29)	50.67 (7.15)	54.44 (7.41)
T ₄	<i>Verticillium lecanii</i> (Green mealikill)	95.33	91.33	82.33	72.33	82.00	72.33 (8.53)	68.33 (8.30)	65.00 (8.09)	58.33 (7.67)	63.89 (8.02)	58.33 (7.67)	55.67 (7.49)	49.67 (7.08)	48.00 (6.96)	51.11 (7.18)
T ₅	Azadirachtin 0.03% w/w (Multi neem)	94.67	94.33	91.00	86.67	90.67	86.67 (9.34)	84.00 (9.19)	75.00 (8.69)	69.00 (8.34)	76.00 (8.74)	69.00 (8.34)	67.33 (8.24)	61.00 (7.84)	53.33 (7.34)	60.56 (7.80)
T ₆	Azadirachtin 0.1% EC (Green neem)	95.67	91.33	82.33	72.33	82.00	72.33 (8.53)	68.67 (8.32)	65.33 (8.11)	59.00 (7.71)	64.33 (8.05)	59.00 (7.71)	56.00 (7.52)	47.67 (6.94)	46.67 (6.87)	50.11 (7.11)
T ₇	Uro insecticide	94.00	94.00	92.33	88.33	91.56	88.33 (9.43)	85.67 (9.28)	78.00 (8.86)	72.67 (8.55)	78.78 (8.90)	72.67 (8.55)	71.33 (8.47)	66.33 (8.17)	60.33 (7.80)	66.00 (8.15)
T ₈	Fipronil 5%SC (Check)	96.00	58.00	40.67	30.67	43.11	30.67 (5.58)	21.67 (4.71)	15.33 (3.98)	13.67 (3.76)	16.89 (4.15)	13.67 (3.76)	8.33 (2.97)	6.33 (2.60)	6.00 (2.54)	6.89 (2.71)
T ₉	Control	95.33	100.67	107.00	109.67	105.78	109.67 (10.49)	111.67 (10.59)	112.67 (10.64)	112.67 (10.64)	112.33 (10.62)	112.67 (10.64)	113.67 (10.68)	116.00 (10.79)	113.00 (10.65)	114.22 (10.71)
	S.Em (±)	2.29	1.36	1.54	1.29	0.85	0.07	0.07	0.06	0.09	0.04	0.09	0.07	0.09	0.09	0.06
	CD (P=0.05)	NS	4.09	4.62	3.86	2.54	0.21	0.22	0.18	0.28	0.12	0.28	0.21	0.26	0.28	0.18

DBA- Days Before Application; DAA- Days After Application;

The values in parentheses represent the square root transformed values

NS- Non-significant

These findings are consistent with previous studies that have highlighted the effectiveness of neem-based products and entomopathogenic fungi, such as *Verticillium lecanii*, in managing aphid populations (Golvankar *et al.*, 2019; El-Salam *et al.*, 2012; Dimetry & Hawary, 1995) [13, 9, 8]. As anticipated, the chemical control treatment (Fipronil 5% SC) exhibited the highest efficacy, resulting in the lowest aphid populations throughout the study. The high efficacy of Fipronil 5% SC in aphid management is well-documented, establishing it as a reliable option for chemical control (Meena & Raju, 2014; Manisha & Kumar, 2022) [23, 22]. However, the potential environmental risks and adverse effects on non-target organisms associated with chemical pesticides underscore the

need for integrating biorational alternatives (El-Wakeil & Nabil, 2013) [11].

The effect of biorational insecticides on pod borer (*Helicoverpa armigera* Hubner) damage

Among the biorational treatments, *Bacillus thuringiensis* (Green Lipel), *Verticillium lecanii* (Green Mealikill), and Azadirachtin 0.1% EC (Green Neem) were the most effective in reducing pod borer damage. This study assessed the effectiveness of various biorational treatments alongside a chemical control (Fipronil 5% SC), selected for its neurotoxic action against insects, in managing pod borer damage. The results revealed that among the biorational treatments, *Bacillus*

thuringiensis (Green Lipel), *Verticillium lecanii* (Green Mealikill), and Azadirachtin 0.1% EC (Green Neem) were the most effective (Jagtap *et al.*, 2023) [15]. These treatments consistently resulted in lower pod borer damage across all observation periods (1 DBA, 3 DAA, 7 DAA, and 14 DAA),

with a reduced overall mean percentage of pod borer damage. These treatments consistently exhibited lower pod borer damage across all observation periods, leading to significant yield increases. The results are presented in Table 3.

Table 3: Effect of 1st, 2nd and 3rd round of biorational insecticides on pod borer (*Helicoverpa armigera* Hubner) damage

Treatment	Per cent pod borer damage/plant														
	1 st Round					2 nd Round					3 rd Round				
	1 DBA	3 DAA	7 DAA	14 DAA	Mean	1 DBA	3 DAA	7 DAA	14 DAA	Mean	1 DBA	3 DAA	7 DAA	14 DAA	Mean
T ₁ <i>Beauveria bassiana</i> (Green racer)	10.93	10.27	8.21	7.06	8.51	7.06	6.00	5.00	4.25	5.08	4.25	4.16	3.57	3.28	3.67
T ₂ <i>Bacillus thuringiensis</i> (Green lipel)	10.81	10.05	7.93	6.58	8.19	6.58	5.39	4.25	3.48	4.37	3.48	3.37	3.03	2.63	3.01
T ₃ <i>Metarhizium anisopliae</i> (Green pacer)	7.90	7.50	6.22	5.41	6.38	5.41	4.76	4.09	3.55	4.13	3.55	3.51	3.22	3.05	3.26
T ₄ <i>Verticillium lecanii</i> (Green mealikill)	8.70	8.22	6.57	5.51	6.77	5.51	4.68	3.97	3.33	3.99	3.33	3.26	3.06	2.81	3.04
T ₅ Azadirachtin 0.03% w/w (Multi neem)	9.78	9.38	7.97	7.01	8.12	7.01	6.51	5.72	4.81	5.68	4.81	5.08	4.82	4.62	4.84
T ₆ Azadirachtin 0.1% EC (Green neem)	9.20	8.64	6.99	5.94	7.19	5.94	6.82	4.27	3.62	4.21	3.62	3.47	3.05	2.59	3.04
T ₇ Uro insecticide	7.87	7.55	6.64	5.97	6.72	5.97	5.55	4.82	4.33	4.90	4.33	4.30	4.28	4.04	4.21
T ₈ Fipronil 5%SC (Check)	10.40	6.24	4.36	4.27	4.96	4.27	3.20	2.56	2.35	2.70	2.35	1.88	1.69	1.60	1.72
T ₉ Control	7.96	8.43	9.69	11.02	9.71	11.02	11.47	12.72	14.24	12.81	14.24	14.02	13.59	15.22	14.28
S.Em (±)	0.78	0.64	0.56	0.46	0.26	0.46	0.52	0.38	0.48	0.31	0.48	0.39	0.35	0.33	0.23
CD (P=0.05)	NS	1.93	1.69	1.37	0.79	1.37	1.55	1.14	1.45	0.92	1.45	1.18	1.06	0.99	0.70

DBA- Days Before Application; DAA- Days After Application;

NS- Non-significant

Table 4: Effect of 1st, 2nd and 3rd round of biorational insecticides on leaf miner (*Liriomyza* sp.) damage

Treatment	Per cent leaf minor damage/plant														
	1 st Round					2 nd Round					3 rd Round				
	1 DBA	3 DAA	7 DAA	14 DAA	Mean	1 DBA	3 DAA	7 DAA	14 DAA	Mean	1 DBA	3 DAA	7 DAA	14 DAA	Mean
T ₁ <i>Beauveria bassiana</i> (Green racer)	7.98	7.18	6.67	6.01	6.62	6.01	5.88	5.52	5.35	5.58	5.35	5.18	4.86	4.61	4.88
T ₂ <i>Bacillus thuringiensis</i> (Green lipel)	6.38	6.44	6.31	6.23	6.33	6.23	6.16	5.91	5.79	5.95	5.79	5.67	5.44	5.22	5.44
T ₃ <i>Metarhizium anisopliae</i> (Green pacer)	6.07	6.00	5.94	5.88	5.94	5.88	5.93	5.69	5.54	5.72	5.54	5.42	5.14	4.93	5.16
T ₄ <i>Verticillium lecanii</i> (Green mealikil)	6.80	6.59	6.39	6.26	6.41	6.26	6.13	5.88	5.76	5.92	5.76	5.64	5.41	5.13	5.39
T ₅ Azadirachtin 0.03% w/w (Multi neem)	7.42	6.67	6.33	6.14	6.38	6.14	5.83	5.42	5.25	5.50	5.25	5.04	4.53	4.21	4.59
T ₆ Azadirachtin 0.1% EC (Green neem)	8.40	6.72	5.91	5.61	6.08	5.61	5.04	4.48	4.21	4.58	4.21	3.99	3.39	3.05	3.48
T ₇ Uro insecticide	5.60	5.88	5.82	6.11	5.94	6.11	6.17	6.10	5.97	6.08	5.97	5.91	5.73	5.38	5.68
T ₈ Fipronil 5%SC (Check)	7.90	5.53	4.14	3.56	4.41	3.56	2.84	2.69	2.44	2.66	2.44	2.28	2.16	1.83	2.09
T ₉ Control	5.25	6.03	7.23	7.59	6.95	7.59	7.96	8.11	8.35	8.14	8.35	8.51	8.76	8.95	8.74
S.Em (±)	0.96	0.28	0.27	0.27	0.16	0.27	0.36	0.36	0.34	0.16	0.34	0.25	0.24	0.29	0.16
CD (P=0.05)	NS	0.83	0.82	0.80	0.47	0.80	1.08	1.08	1.01	0.47	1.01	0.76	0.72	0.87	0.49

DBA- Days Before Application; DAA- Days After Application;

NS- Non-significant

These findings are consistent with previous studies demonstrating the effectiveness of entomopathogenic fungi and neem-based products in reducing pod borer damage (Rijal, 2008; Abedi *et al.*, 2014; Choudhary *et al.*, 2017) [29, 2, 9]. Among all treatments, the chemical control (Fipronil 5% SC) exhibited the highest efficacy, resulting in the lowest percentage of pod borer damage throughout the study. The effectiveness of Fipronil 5% SC in reducing pod borer damage is well-documented, establishing it as a reliable option for chemical control (Adsure and Mohite, 2015; Manisha and Kumar, 2022; Patil and Yadav, 2023) [3, 22, 25]. However, the potential environmental risks and adverse effects on non-target organisms associated with chemical pesticides highlight the necessity of integrating biorational alternatives (Isman, 2006;

El-Wakeil and Nabil, 2013; Faria and Wraight, 2007) [14, 11, 12].

These findings highlight the importance of integrating biorational treatments into pest management strategies to reduce reliance on chemical pesticides, thereby promoting the sustainability of agricultural practices.

The effect of biorational insecticides on leaf miner (*Liriomyza* sp.) damage

Among the botanical treatments, Azadirachtin 0.1% EC (Green Neem), and among the microbial treatments, *Metarhizium anisopliae* (Green Pacer) emerged as promising alternatives, consistently exhibiting low leaf miner damage across all observation periods. Fipronil 5% SC was the most effective treatment in reducing leaf miner damage, followed by

Azadirachtin 0.1% EC (Green Neem) and *Metarhizium anisopliae* (Green Pacer). These treatments consistently exhibited lower leaf miner damage across all observation periods, highlighting their potential as effective management

tools. The findings from three rounds of biorational insecticide applications on leaf miner (*Liriomyza sp.*) damage demonstrated the effectiveness of various treatments in reducing pest infestation (Table 5)

Table 5: Avoidable loss and Incremental cost: benefit ratio of the different treatment against major insect pests of broad bean (*Vicia faba* L.)

Treatment	Dose/ha.	Yield (Kg/ha)	Increased yield over control (kg/ha)	Avoidable loss (%)	Gross monetary return (Rs.) *	Cost of treatment (Rs.) **	Net additional return (Rs. ha ⁻¹)	Incremental Cost: benefit ratio
T ₁ <i>Beauveria bassiana</i>	5ml/ltr	503.75	104.83	35.75	41932.00	9342.00	32590.00	1:3.49
T ₂ <i>Bacillus thuringiensis</i>	5ml/ltr	522.26	123.34	33.39	49336.00	9342.00	39994.00	1:4.28
T ₃ <i>Metarhizium anisopliae</i>	5ml/ltr	500.05	101.13	36.22	40452.00	9342.00	31110.00	1:3.33
T ₄ <i>Verticillium lecanii</i>	5ml/ltr	514.86	115.94	34.33	46376.00	9342.00	37034.00	1:3.96
T ₅ Azadirachtin 0.03% w/w	5ml/ltr	470.41	71.49	40.00	28596.00	9342.00	19254.00	1:2.06
T ₆ Azadirachtin 0.1% EC	2ml/ltr	566.71	167.79	27.72	67116.00	5445.00	61671.00	1:11.33
T ₇ Uro insecticide	10ml/ltr	466.70	67.78	40.48	27112.00	4044.00	23068.00	1:5.70
T ₈ Fipronil 5%SC	2ml/ltr	784.06	385.14	0.00	154056.00	6684.00	147372.00	1:22.05
T ₉ Control	-	398.92	-	49.12	-	-	-	-
SEm	-	9.68	-	-	-	-	-	-
CD @5%	-	29.03	-	-	-	-	-	-

Minimum sale price of broad bean seeds was Rs. 400/kg. \Cost of botanical, microbial and chemical insecticide+ Labour charges (2 Mandays/spray treatment+ Hiring of sprayer for three times (2 pump per spray). (Hiring charge of spray pump 50/pump). Labour charge=424/per person

The present findings agree with those of Kale *et al.* (2022) [18] and Aynalem *et al.* (2022) [5]. Similarly, these results align with previous studies, such as El-Wakeil and Nabil (2013) [11], who emphasized the importance of integrating biorational treatments to mitigate the environmental and non-target impacts of chemical pesticides. Furthermore, the effectiveness of Azadirachtin is consistent with the findings of Khorshidi *et al.* (2017) [20] and Ravsaheb (2013) [28]. The consistent performance of Fipronil 5% SC across multiple application rounds further reinforces its reliability as a chemical control option (Ravsaheb, 2013) [28].

Yield and Economic Returns

This study assessed the effects of various biorational and chemical insecticides on crop yield, avoidable losses, and economic returns. The findings revealed significant differences in yield and economic benefits among the treatments. The recorded yield data, presented in Table 5 and Figure 4 ranged from 398.92 kg ha⁻¹ to 784.06 kg ha⁻¹. The highest – mean yield of 784.06 kg ha⁻¹ was recorded in plots treated with Fipronil 5% SC, which – yielded 385.14 kg ha⁻¹ more than the untreated control. Among the biorational insecticides, – including botanical and microbial treatments, Azadirachtin 0.1% EC (Green Neem) achieved the highest yield (566.71 kg ha⁻¹), with an increase of 167.79 kg ha⁻¹ over the control, – followed by *Bacillus thuringiensis* (Green Lipel) at 522.26 kg ha⁻¹, corresponding to a yield – increase of 123.34 kg ha⁻¹ over the control. The maximum avoidable yield loss due to insect – pests in the untreated control plots was estimated at 49.12%, based on the highest attainable yield recorded with Fipronil 5% SC (784.06 kg ha⁻¹), which was also highly effective in – suppressing major crop pests. The application of insecticides

significantly reduced the mean avoidable yield loss, ranging from 27.72% to 40.48% across different insecticidal treatments, with the lowest loss observed in Azadirachtin 0.1% EC (Green Neem), followed by *Bacillus thuringiensis* (Green Lipel), while the highest avoidable loss was recorded in plots treated with Uro insecticide.

The net profit from insecticidal treatments ranged from Rs. 19,254.0 (Multi Neem) to Rs. 1,47,372.0 (Fipronil 5% SC), with the incremental cost-benefit ratio (ICBR) varying between 1:2.06 and 1:22.05. Among the biorational insecticides, Azadirachtin 0.1% EC (Green Neem) was the most effective and economically viable treatment for managing broad bean pests, achieving an ICBR of 1:11.33. The findings of this study demonstrate that both biorational and chemical insecticides have a significant influence on broad bean yield, avoidable losses, and economic returns.

The present findings align with the results of Radhika and Reddy (2018). Among the biorational insecticides, Azadirachtin 0.1% EC (Green Neem) achieved the highest yield (566.71 kg ha⁻¹), recording a yield increase of 167.79 kg ha⁻¹ over the control, followed by *Bacillus thuringiensis* (Green Lipel), consistent with the findings of Ojha *et al.* (2019) [24] and Chouhan *et al.* (2023) [7]. The maximum avoidable yield loss due to insect pests in the untreated control plots was 49.12%, emphasizing the critical role of pest management in broad bean (*Vicia faba* L.) cultivation (Jagtap *et al.*, 2020) [16]. The net profit from insecticidal treatments varied significantly, with Fipronil 5% SC yielding the highest return (Rs. 1,47,372.00), while Azadirachtin 0.1% EC (Green Neem) emerged as the most effective and economically viable biorational option (Meena *et al.*, 2022) [23].

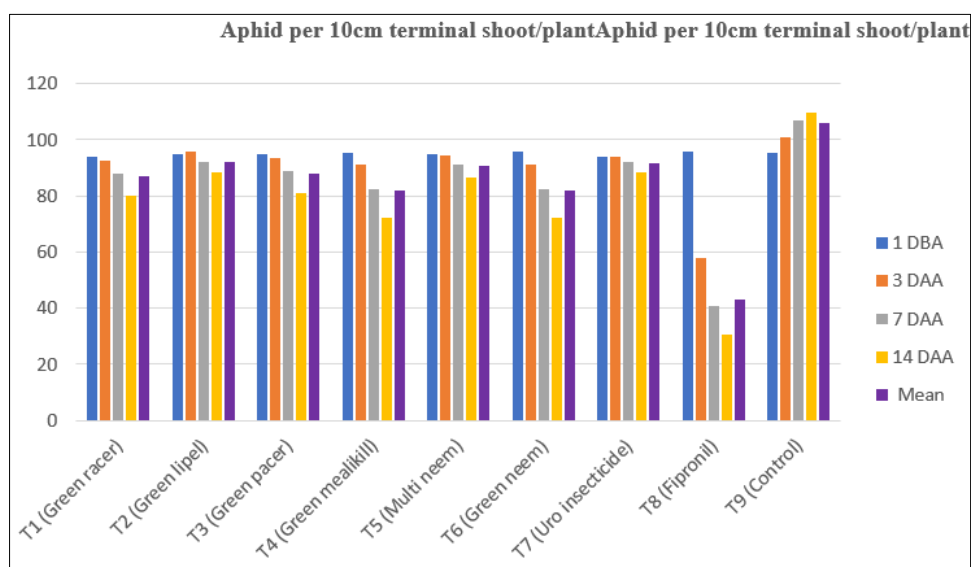


Fig 1(a): Effect of 1st round of biorational insecticides on aphid population

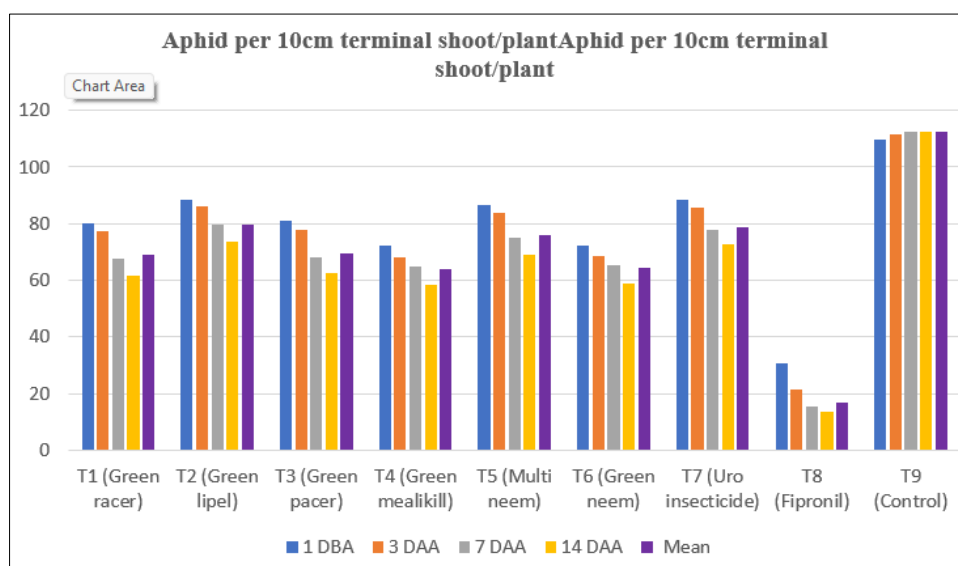


Fig 1(b): Effect of 2nd round of biorational insecticides on aphid population

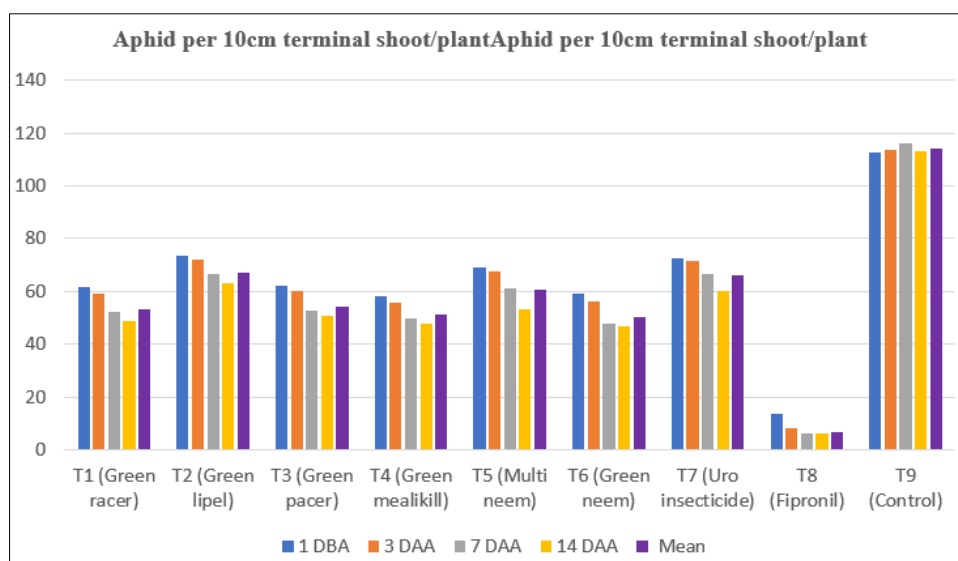


Fig 1(c): Effect of 3rd round of biorational insecticides on aphid population

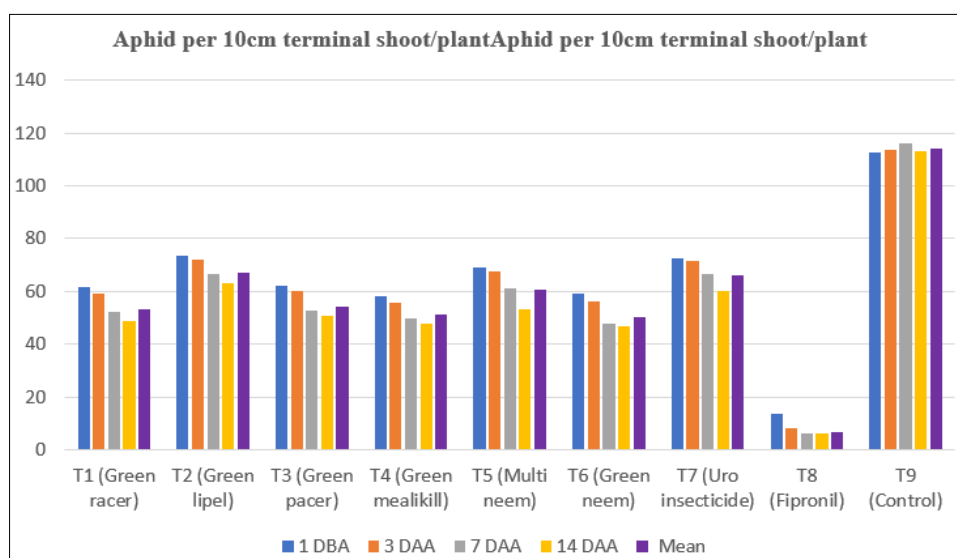


Fig 2(a): Effect of 1st round of biorational insecticides on pod borer (*Helicoverpa armigera* Hubner) damage

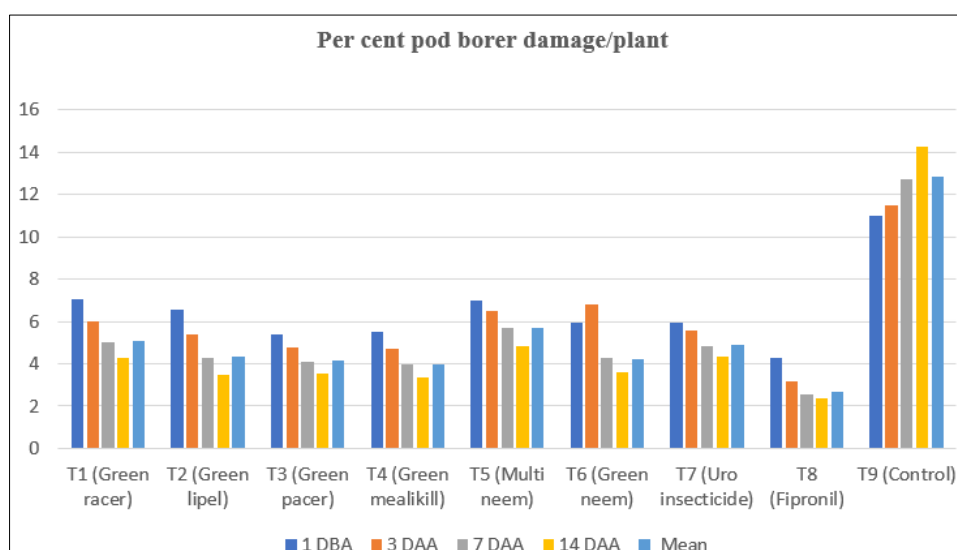


Fig 2(b): Effect of 2nd round of biorational insecticides on pod borer (*Helicoverpa armigera* Hubner) damage

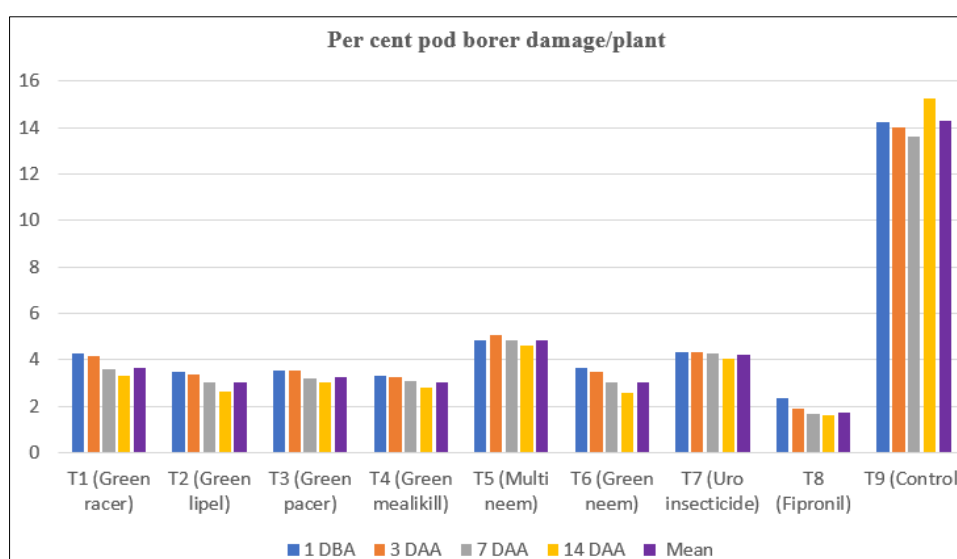


Fig 2(c): Effect of 3rd round of biorational insecticides on pod borer (*Helicoverpa armigera* Hubner) damage

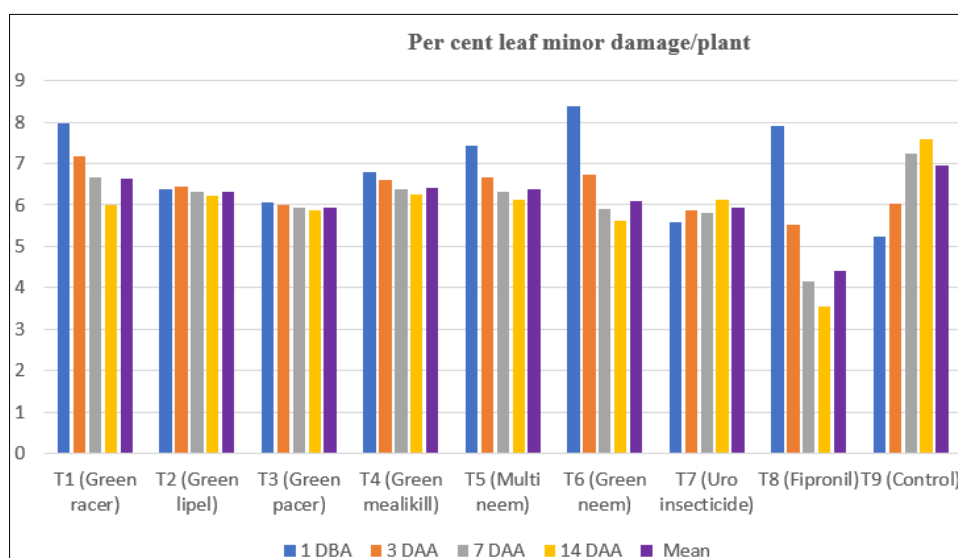


Fig 3(a): Effect of 1st round of biorational insecticides on leaf miner (*Liriomyza* sp.) damage

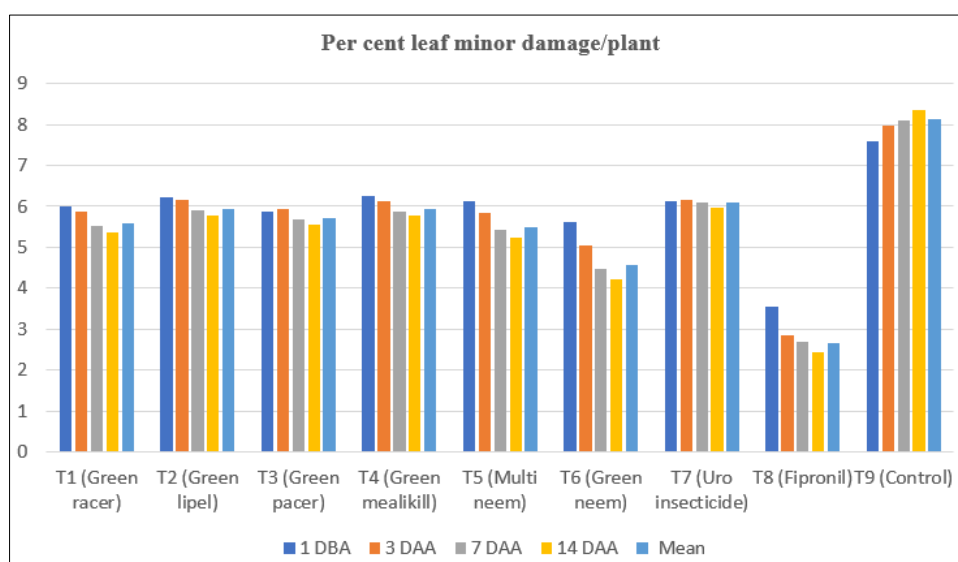


Fig 3(b): Effect of 2nd round of biorational insecticides on leaf miner (*Liriomyza* sp.) damage

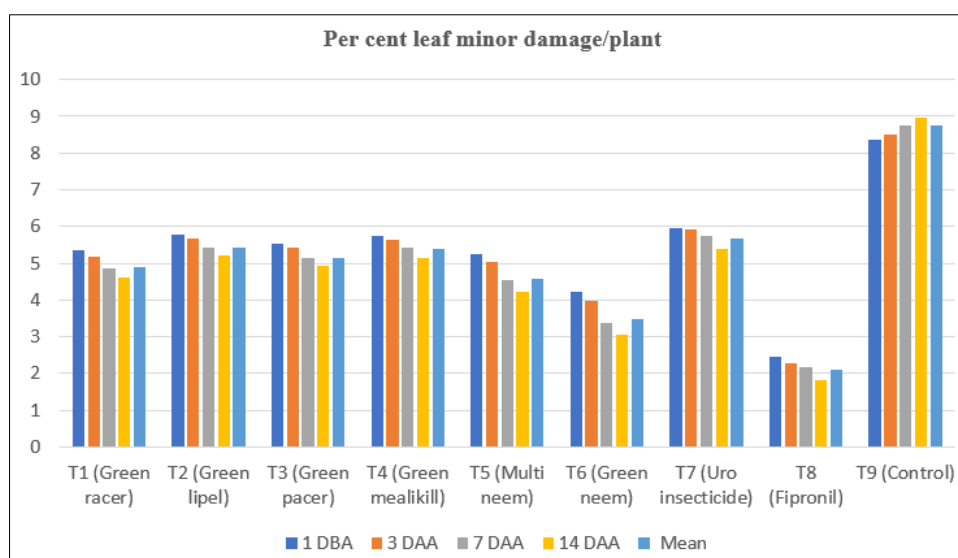


Fig 3(c): Effect of 3rd round of biorational insecticides on leaf miner (*Liriomyza* sp.) damage

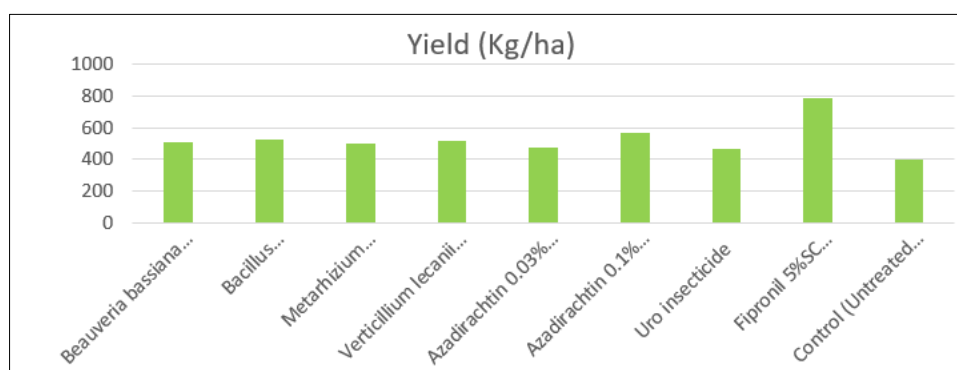


Fig 4: Effect of different biorational insecticides on yield (kg ha^{-1})

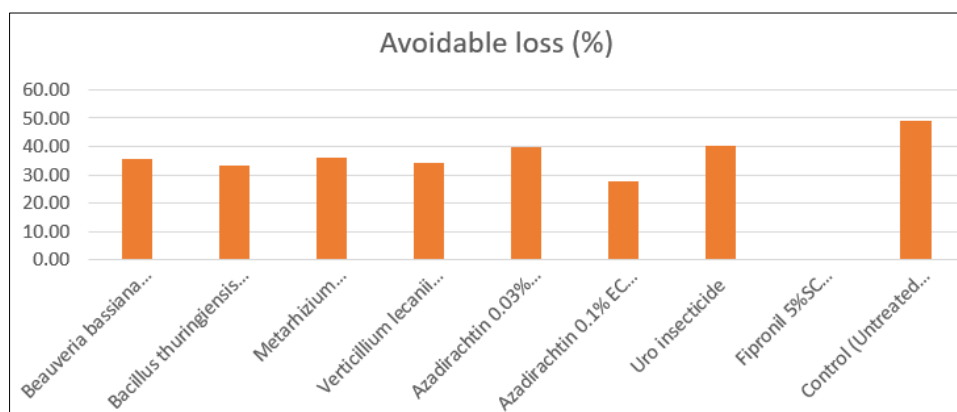


Fig 5: Avoidable loss percentage across different biorational treatments

Conclusion

The present study concludes that the tested biorational insecticides, including Azadirachtin 0.1% EC (Green Neem), *Beauveria bassiana* (Green Racer), *Bacillus thuringiensis* (Green Lipel), *Metarhizium anisopliae* (Green Pacer), *Verticillium lecanii* (Green Mealikill), Azadirachtin 0.03% w/w (Multi Neem), and Uro insecticides, were effective against all major insect pests of broad bean. These botanical and microbial formulations serve as viable alternatives to chemical insecticides and hold significant potential for eco-friendly pest management due to their efficacy against target pests. The study's findings have important implications for the development of sustainable and environmentally responsible pest management strategies in broad bean cultivation.

Future Perspectives and Research Priorities

Further research is required on this topic, as the present findings are based on a single season's field data. To comprehensively assess the potential of these biorational insecticides, future studies should explore their integration with other IPM practices, evaluate their environmental impact, investigate resistance mechanisms in target insect pests, assess their effects on natural enemies, and examine their efficacy under diverse environmental conditions. Such research will contribute to optimizing pest management strategies and promoting sustainable agricultural production.

Acknowledgements

I sincerely express my gratitude to Dr. Kh. Ibohal Singh, Professor, Department of Entomology, College of Agriculture, Iroisemba, Central Agricultural University, Imphal, for his unwavering support and invaluable guidance throughout this work. I also extend my heartfelt appreciation to Dr. Nilima

Karam, Junior Entomologist (PI, AICRP-Soybean) at the same institution, for her insightful suggestions, which have significantly contributed to this study.

Financial Support

No funding has been accessed

Conflict of Interest

There are no conflicts of interest to declare, ensuring the objectivity and integrity of this research.

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