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Incremental cost benefit ratio of different combination of microbial insecticides for management of lepidopterous defoliating pests of soybean in Manipur

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Abstract
A number of insect pests attack soybean crop which is one of the factor that affect its productivity. Pests control by chemical pesticides requires high production cost resulting in a low profit of soybean farming; therefore, it is less favourable to farmers. The study aims to evaluate the economics of utilizing combination of microbial insecticides for management of lepidopterous defoliating pests of Soybean in Manipur. The research was conducted during the *kharif* season of 2022-23 with recommended soybean variety of Manipur, JS-335 at Agricultural Research Farm, Andro of Central Agricultural University, Imphal, Manipur. Six combination of commercial microbial formulations *viz*., combination of *Beauveria bassiana*, *Metarhizium anisopliae*, *Nomuraea rileyi* and *Bacillus thuringiensis* (*Bt* Commercial) were applied three times at 40, 60 and 80 days after sowing with half of the standard doses of respective microbial formulations. Recommended chemical insecticide Chlorantraniliprole 18.5% SC and untreated control treatment were included as standard check treatments. Upon crop maturity, data on numbers of pods per plant, weight of pods per plant, 100 seed weight and seed yield per plot were recorded. The incremental cost benefit ratio was calculated on the basis of prevailing cost of inputs and grain yield. Among the microbial combination, the highest incremental cost benefit ratio was obtained with treatment combination of fungus and bacteria i.e., *Beauveria bassiana* (500 ml/ha) + *Bt* commercial (500 ml/ha) (1:8.21) and *Nomuraea rileyi* (500 ml/ha) + *Bt* commercial (500 ml/ha) (1:8.14). The lowest ICBR of 1:5.38 was obtained with combination treatment of fungal formulations of *Beauveria bassiana* (500 ml/ha) + *Metarhizium anisopliae* (500 ml/ha).

Keywords: Lepidopterous defoliating pests, Chlorantraniliprole, *Beauveria bassiana*, *Metarhizium anisopliae, Nomuraea rileyi, Bacillus thuringiensis*

Introduction

Soybean (*Glycine max* L. Merril) is the number one oilseed crop in India with approximately 12 million hectares of cultivated land and with average productivity of up to 882 kg/ha (Agrawal *et al*., 2012) [1]. This is a significant increase since its debut in 1970, which not only improves the socio-economic situations of small and marginal farmers, but also contributes to the country's total edible oil requirement (Bhatia *et al*., 2008) [4]. India currently ranks fifth in the world in terms of area and productivity, after the United States, Brazil, Argentina, and China. Soybean is a unique crop that supply protein equal in quality to that of animal sources (Hartman *et al*., 2011) [7]. It is an excellent source of vegetable protein, essential amino acids, polyunsaturated fats, particularly Omega-6 and Omega-5 fatty acids, minerals, crude fibre, and carbohydrates (Chauhan and Joshi, 2005) [5].

Major losses in India in soybean production are due to its susceptibility to about 273 species of insect pests (Singh, 1999) [15]. From germination to harvest, several insects feed on the soybean crop. Defoliators and pod borers are economically important insect pests during the vegetative and post-flowering stages, causing significant yield loss (Singh, 2001) [16]. Karam *et al*. (2014) [8] reported three lepidopterous defoliator pests, *viz*., Bihar hairy caterpillar (BHC), tobacco caterpillar and leaf webber defoliating and destroying soybeans in Manipur.

Various chemical pesticides, in particular, have been mandated for the suppression of soybean lepidopterous pests. As people become more aware of the hazards of chemical insecticides, the use of microbial insecticides in integrated management system is increasing (Kumar *et al*., 2019) [9]. Biological insect pest management with entomopathogenic microorganisms is a desirable and effective strategy that is not only effective against insect pests but also eco-friendly with minimal effect to non-target organisms, livestock and human being which can be used as an alternative to chemical insecticides (Bahadur, 2018) [3]. Pest management can be refined by the combination of microbial formulations, allowing us to use them more successfully and inexpensively under a variety of agro-climatic conditions. Application of more than one microbial pesticide have an additive effect in controlling mixed populations of insect pests. Combination of different microbial formulations takes advantage of the particular strength of each agent minimizing their biological limitations, lowering the dose requirement and improving the speed of kill (Lacey *et al*., 2015) [10].

Though the efficacy of various microbial insecticides has been studied extensively, there are a few report on yield from crops treated with combination of microbial insecticides, as well as little information on the cost benefit analysis for the biopesticides when compared to conventional insecticide. For their potential to be realised, it is vital to comprehend their economic viability. The purpose of this study was to investigate the economics of utilizing combination of microbial insecticides to manage lepidopterous foliage pests of soybean in Manipur condition.

Material and Methods

A field experiment was conducted during the *kharif* season of 2022-23 with recommended soybean variety of Manipur, JS-335 at Agricultural Research Farm, Andro of Central Agricultural University, Imphal which is located at 24° 25´ N latitude and 93° 56´ E longitude with an elevation of 790 metres above msl. Spacing between plants and rows were maintained as 10 cm and 45 cm, respectively and the crop was raised with standard agronomic practices. The experiment was laid out in Randomized Block Design with eight treatments in three replications to compare the efficacy of microbial combinations against major lepidopterous defoliating pests of soybean under Manipur conditions *viz*. bihar hairy caterpillar, bean leaf webber and tobacco caterpillar. Six consortia of commercial microbial formulations *viz*., combination of *Beauveria bassiana*, *Metarhizium anisopliae*, *Nomuraea rileyi* and *Bacillus thuringiensis* (*Bt* Commercial) were tested along with standard chemical check Chlorantraniliprole 18.5% SC and untreated control treatment. In combination treatment, half of the standard doses of respective microbial formulations were applied as treatment combinations. Spray frequencies using knapsack sprayer were scheduled three times at 40, 60 and 80 days after sowing for all the treatments. The details of the treatment are presented in Table 1.

Table 1: Treatment details

Treatment		Dose
T1	*Beauveria bassiana* + *Metarhizium anisopliae*	500ml/ha + 500ml/ha
T2	*Nomuraea rileyi* + *Bacillus thuringiensis*	500ml/ha + 500ml/ha
T3	*Nomuraea rileyi* + *Metarhizium anisopliae*	500ml/ha + 500ml/ha
T4	*Beauveria bassiana* + *Nomuraea rileyi*	500ml/ha + 500ml/ha
T5	*Beauveria bassiana* + *Bacillus thuringiensis*	500ml/ha + 500ml/ha
T6	*Metarhizium anisopliae* + *Bacillus thuringiensis*	500ml/ha + 500ml/ha
T7	Chlorantraniliprole 18.5% SC (standard chemical check)	100 ml/ha
T8	Untreated Control	No treatment

Yield and yield attributing characters *viz*., numbers of pods per plant, weight of pods per plant (g), 100 seed weight (g) and seed yield per plot (kg) were recorded from sample plants at the time of harvest. The seed yield per plot for each treatment was computed in kg/ha before analysis using formula as

$$\text{Seed yield (kg/ha)} = \frac{\text{Yield per plot in kg}}{\text{Plot size in sq.m}} \times 10000$$

Various parameters used for working out the incremental cost benefit ratio are given below.

Additional yield (kg/ha): The increased in yield over control in individual treatment (i.e., additional yield) was determined by the following formula

Additional yield = T – C

Where, T = Yield in respective treatment
C = Yield in untreated control treatment

Gross monetary return (Rs/ha): It was obtained by multiplying the additional yield over control with prevailing minimum local market price of soybean seed.

Cost of treatments (Rs/ha): The total cost of treatment was calculated as per the prevailing market price of insecticides per ha with labour charges. Two mandays were considered sufficient for spraying in a day over one hectare crop at prevalent local rate of labour per day.

Net additional return (Rs/ha): Net monetary return of a treatment was worked out by deducting the total cost of plant protection from gross monetary return (Nemade *et al.* 2017) [12].

Incremental Cost benefit ratio: It was worked out as a ratio of net profit to the cost of plant protection of treatment which exhibits the economic viability of the treatment. It is calculated separately for each treatment by dividing the net monetary return by total cost of treatment following formulae suggested by Ojha (2017) [13].

$$\text{Incremental Cost Benefit Ratio} = \frac{\text{Net Profit}}{\text{Total cost of Plant Protection Treatment}}$$

Results and Discussion

The data in respect of yield and yield attributing factors of soybean after management of soybean lepidopterous defoliating pests by different combination of microbial insecticides during *kharif* 2022-2013 and benefit incurred is presented in Table 2.

Effect of different combination of microbial pesticides on weight of 100 numbers of soybean seed

The weight of 100 number of seeds per plot did not differ significantly with different treatments ranging from 12.30g to 13.37g. It is evident from the data that different treatments had a non-significant effect on 100 seed weight. However, weight of soybean seeds due to microbial combination treatment as well as chemical insecticide were comparatively higher than untreated control (12.30 g).

Effect of combination of microbial pesticides on numbers of pods per plant

The number of pods per plant was found to be significantly influenced by the treatments as insect pests attack was reduced due to the treatments. During *kharif* 2022, number of pods per plant was significantly higher with combination treatment of microbial pesticides as well as chemical insecticide as compared to untreated control. Treatment with Chlorantraniliprole 18.5% SC recorded higher number of pods per plant (74.93 pods per plant) which was statistically similar in result with all the combination treatment of microbial pesticides with *Beauveria bassiana* + *Bt* and *Nomuraea rileyi* + *Bt* giving higher number of pods per plant of 73.47 and 73.07 respectively.

Effect of combination of microbial pesticides on weight of pods per plant

Weight of pods per plant is an important yield attributing character that influences the final seed yield. More number of seeds per pod results in more number of total seeds per plant. Due to the different treatments, weight of pods per plant were higher than the untreated control. Treatment with chemical check insecticide Chlorantraniliprole 18.5% SC resulted in highest weight of pods of 33.47 g per plant which was statistically at par with microbial combination of *Nomuraea rileyi* + *Bt* recording weight of pods as 31.23 g per plant followed by *Beauveria bassiana* + *Bt* recording weight of pods as 30.99 g per plant. The microbial combination of only fungal formulations was inferior statistically to the combination treatment of fungus and bacterial formulations.

Effect of combination of microbial pesticides on seed yield of soybean

The results revealed that the all treatments exhibited positively significant effect on the yield of soybean and higher seed yield of soybean was obtained due to combination of microbial pesticides. The chemical treatment of Chlorantraniliprole 18.5% SC gave the highest yield of 3000.01 kg/ha but was statistically at par with treatment combination of *Beauveria bassiana* + *Bt* (2796.31 kg/ha) and *Nomuraea rileyi* + *Bt* (2790.14 kg/ha). These two combination of microbial pesticides were however similar in efficacy with other treatment combinations of *Metarhizium anisopliae* + *Bt* recording 2645.07 kg/ha, *Nomuraea rileyi* + *Metarhizium anisopliae* recording 2608.04 kg/ha, *Beauveria bassiana* + *Nomuraea rileyi* recording 2554.02 kg/ha and *Beauveria bassiana* + *Metarhizium anisopliae* recording 2550.94 kg/ha which were significantly superior over untreated control. It can be observed that combination of fungal microbial formulation with bacterial pesticide are more effective in giving higher yield than combination of only fungal pesticides. On the other hand minimum seed yield was recorded in untreated control yielding 1996.92 kg/ha. Harish *et al.*, (2009) [6] obtained highest grain yield with the treatment, *Bacillus thuringiensis* against lepidopteran defoliator infesting soybean which is slightly similar to the findings of the experiment that revealed that combination of fungal formulations with *Bacillus thuringiensis* gave maximum yield of soybean. Seed yield was found to be positive and significantly associated with number of pods per plant, weight of pods per plant, 100 seed weight which is in total agreement with that stated by Yachna *et al*., (2018) [17].

Economics of using combination of microbial pesticides against defoliating pests of soybean in Manipur

Cost: benefit ratio is an indicator of the relative economic performance of the treatments (Aziz *et al*., 2012) [2]. A ratio of more than one indicates the economic viability of the treatment compared with control treatment. During *kharif* 2022, economics of different treatments indicated that the maximum gross returns over untreated control was obtained from chemical Chlorantraniliprole 18.5% SC with Rs. 90278.18/ha closely followed by combination of *Beauveria bassiana* + *Bt* commercial (Rs. 71944.76/ha) and *Nomuraea rileyi* + *Bt* commercial (Rs. 71389.20/ha). Considering the net profit realized from different treatments, data indicated that the maximum net returns of Rs. 80.666.18/ha was obtained from Chlorantraniliprole 18.5% SC module followed by combination of *Beauveria bassiana* + *Bt* commercial (Rs. 64132.76/ha) and *Nomuraea rileyi* + *Bt* commercial (Rs. 63577.20/ha).

Considering the prevailing cost of inputs, highest incremental cost benefit ratio per hectare was registered with Chlorantraniliprole 18.5% SC @ 100ml/ha (1:8.39). Among the combination of microbial pesticides, treatment *Beauveria bassiana* (500ml/ha) + *Bt* commercial (500ml/ha) recorded maximum ICBR of 1:8.21. The present results collaborate with that of Panwar *et.al*. (2020) [14] who found maximum net profit with chemical check followed by *B. bassiana* (1:4.26) when tested against leaf eating caterpillars of soybean. The results are also in agreement with the findings of Mandal *et al*., (2003) [11] who reported that the highest B:C ratio with the application of *B. thuringiensis*. The remaining five treatment combination recorded ICBR as follows *Nomuraea rileyi* (500 ml/ha) + *Bt* commercial (500ml/ha) (1:8.14), *Metarhizium anisopliae* (500ml/ha) + *Bt* commercial (500 ml/ha) (1:6.47), *Nomuraea rileyi* (500 ml/ha) + *Metarhizium anisopliae* (500 ml/ha) (1:6.04), *Beauveria bassiana* (500 ml/ha) + *Nomuraea rileyi* (500 ml/ha) (1:5.42) and *Beauveria bassiana* (500 ml/ha) + *Metarhizium anisopliae* (500 ml/ha) (1:5.38).

Table 2: Harvest data, yield, net additional return and incremental cost: benefit ratio in different treatments

	Treatments	No. of pods/ plant	Wt. of pods/ plant (g)	100 seed weight (g)	Yield (kg/ha)	Additional yield (kg/ha)	Gross additional return (Rs.)*	Cost (Rs.)**	Net additional return (Rs.)	Incremental Cost: Benefit	Rank
T1	*Beauveria bassiana* (500 ml/ha) + *Metarhizium anisopliae* (500ml/ha)	68.07	27.70	12.73	2550.94	554.01	49861.33	7812.00	42049.33	1:5.38	VII
T2	*Nomuraea rileyi* (500 ml/ha) + *Bt* (500ml/ha)	73.07	31.23	13.11	2790.14	793.21	71389.20	7812.00	63577.20	1:8.14	III
T3	*Nomuraea rileyi* (500 ml/ha) + *Metarhizium anisopliae* (50 0ml/ha)	67.80	27.61	13.06	2608.04	611.11	55000.24	7812.00	47188.24	1:6.04	V
T4	*Beauveria bassiana* (500 ml/ha)	68.27	28.67	12.87	2554.02	557.10	50139.11	7812.00	42327.11	1:5.42	VI

	+ *Nomuraea rileyi* (500 ml/ha)										
T5	*Beauveria bassiana* (500 ml/ha) + *Bt* (500 ml/ha)	73.47	31.20	13.23	2796.31	799.39	71944.76	7812.00	64132.76	1:8.21	II
T6	*Metarhizium anisopliae* (500ml/ha)) + *Bt* (500 ml/ha)	68.27	30.99	13.12	2645.07	648.15	58333.59	7812.00	50521.59	1:6.47	IV
T7	Chlorantraniliprole 20% SC (100 ml/ha)	74.93	33.47	13.37	3000.01	1003.09	90278.18	9612.00	80666.18	1:8.39	I
T8	Untreated control	58.07	20.76	12.30	1996.92	-	-	-	-	-	VIII
	S.E(d)±	4.53	2.52	-	139.05	-	-	-	-	-	
	CD @ 5%	9.72	5.40	NS	298.24	-	-	-	-	-	

* Sale price of soybean seeds (var. JS – 335) was Rs. 90/kg **Includes cost of microbial formulations and chemical insecticide and labour charges (2 mandays/spray treatment)

Conclusion

Chemical check Chlorantraniliprole 18.5% SC @ 100ml/ha gave the highest incremental cost benefit ratio per hectare of 1:8.39. Among the microbial combination, the highest incremental cost benefit ratio was obtained with treatment combination of fungus and bacteria i.e., *Beauveria bassiana* (500ml/ha) + *Bt* commercial (500ml/ha) (1:8.21) and *Nomuraea rileyi* (500 ml/ha) + *Bt* commercial (500 ml/ha) (1:8.14). Considering the hazards of chemical insecticide which can pollute the ecosystem, utilization of combination of microbial insecticides shall be the most effective against soybean defoliating pests as well as economical under Manipur conditions.

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