Impact of biopesticides application on pod borer complex in organically grown field bean ecosystem

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ABSTRACT

The investigation was carried out at the Agriculture Research Station, Balajigapade, Chickaballapura district during *kharif* season 2009. The evaluated biopesticides were NSKE (5%), *Ha*NPV (250 LE/ha), *Bt* (1kg/ha), neem oil (2%), Panchagavya (3%), Clerodendron + Cow urine extract (10%) and sequential spray of *Ha*NPV-*Bt* -NSKE, *Bt*-NSKE-*Ha*NPV and NSKE-*Ha*NPV-*Bt*. FYM (9.5 t ha^{-1}) and bio-digester liquid (6,500 l ha^{-1}) were applied to organic plots. Sequential spray of insecticidal spray (Carbaryl-Endosulfan-Malathion) and recommended dose of FYM (7 t ha^{-1}), fertilizer (25:50:25 kg NPK ha^{-1}) were applied to inorganic plot. Pod borers *viz.*, *Helicoverpa armigera* (Hübner), *Maruca testulalis* Geyer, *Exelastis atomosa* Walshinghan, *Sphenarches caffer* Zeller, *Etiella zinkenella* (Treitschke), *Lampides boeticus* Linnaeus, *Adisura atkinsoni* Moore emerged as serious pests during cropping period. Sequential spray of insecticides carbaryl-endosulfan-malathion applied at 45, 55 and 70 DAG, respectively recorded less insect pests abundance. Among biopesticides, sequential application of NSKE-*Ha*NPV-*Bt* was effective against insect pests. *Ha*NPV was effective against *H. armigera* larvae, but ineffective to other pod borers. Panchagavya and clerodendron + cow urine extract were ineffective in reducing the pod borer incidence. Among biopesticides treated plots, sequential application of NSKE-*Ha*NPV-*Bt* recorded higher grain yield (10.01qha^{-1}) whereas, package of practices followed treatment (inorganic plot) recorded 11.37 qha^{-1} grain.

Key words: *Adisura atkinsoni*, biopesticides, *Etiella zinkenella*, *Exelastis atomosa*, *Helicoverpa armigera*, *Lampides boeticus*, *Maruca testulalis*, *Sphenarches caffer*.

INTRODUCTION

The fieldbean (*Dolichos lablab* L.) is an important pulse-cum-vegetable crop in India. It is cultivated for tender and mature pods, seeds and fodder. The young and immature green pods are cooked as vegetable (Byre Gowda, 2006). It is rich in nutritive value, the protein content of fieldbean is quite high varying from 20 to 28 per cent (Schaaffhausen, 1963). The foliage of the crop provides hay, silage and green manure.

The crop is cultivated in dry tropical parts of Asia, Africa, East and West Indies, South Central America and China. In India, it is being cultivated in Karnataka, Tamil Nadu, Andhra Pradesh, Kerala and Assam. In Karnataka, Dolichos bean is cultivated in 0.77 lakh hectares with an annual production of 0.17 lakh tonnes with productivity rate of 183 kg/ha (Anonymous, 2008). Though the crop is cultivated in almost all regions of Karnataka, it is largely grown as a mixed crop with finger millet and sorghum mainly in many parts of Karnataka. However, it is also grown as pure crop under rainfed as well as irrigated conditions.

In spite of the fact that the area under this crop is increasing in the state, the production is low. One of the most important factors responsible for this is the incidence of various insect pests and diseases. Govindan (1974) recorded as many as 55 species of insects including pod borers and a species of mite feeding on the crop from seedling stage to the harvest of the crop under inorganic condition (Mallikarjunappa, 1989; Rekha, 2005; Thejaswi, 2007 and Mallikarjuna, 2009) and loss to the tune of 80-100 per cent (Katagihallimath and Siddappaji, 1962). Past studies were confined to

inorganic ecosystems. Moreover, no effort seems to have been made on the study of insect faunal abundance and relative abundance in organically maintained Dolichos bean ecosystem. Hence, the present investigation was undertaken.

MATERIAL AND METHODS

The present study was carried out during *Kharif* 2009 at Agricultural Research Station (ARS), Balajigapade, Chickaballapura district, University of Agricultural Sciences (UAS), Bangalore, located in the South- Eastern dry zone of Karnataka state enjoying semiarid climate. It is located at an altitude of 911.66m, latitude of 13° 26′N and longitude of 77° 43′E. The place receives normal annual rainfall of 773mm from Southwest and Northwest monsoons which is distributed well over the season. The maximum and minimum temperature of the locality ranges from 24.5° to 34.5°C and 13.5° to 20.6°C respectively. The soil type is red loamy sand.

The experiment was laid out in randomized complete block design with 10 treatments replicated thrice in 6 x 3.6m plot size and standard check was maintained separately in inorganic field (10 x 10m). the details of the treatments evaluated against insect pests and their impact on the soil fauna were T_{1}- NSKE (5%), T_{2}- *Ha*NPV 250LE/ha., T_{3}- *Bacillus thuringiensis* (*B.t.*) 1 kg/ha, T_{4}- Neem oil (2%), T_{5}- Panchagavya (3%), T_{6}- *Ha*NPV-*B.t.*–NSKE (250LE-1Kg-5%), T_{7}- *B.t.*–NSKE–*Ha*NPV (1Kg-5%-250LE), T_{8}- NSKE–*Ha*NPV-*B.t.* (5%-250LE-1Kg), T_{9}- *Clerodendron* extract + cow urine (10%), T_{10}- Untreated control (water spray) and standard check foliar application of carbaryl 50WP @ 0.5 per cent, endosulfan 35EC @ 0.05 per cent and malathion 50EC @ 0.125 per cent at 45, 55 and 70 days after germination (DAG) respectively. Field bean variety Hebbal Avare-4 (HA-4) treated with rhizobium (75g/ha.) was sown on 17th of August with the spacing of 45cm x 15 cm. The crop was raised as per the recommended package of practices except plant protection measures (Anonymous, 2008).

In organic plot recommended dose of FYM (7t ha^{-1}) was applied before sowing. The recommended nitrogen (25 kg ha^{-1}) was supplied in split doses *viz*., 50 per cent as a basal dose by FYM (2.5 t ha^{-1}) and remaining 50 per cent (top dress) by bio-digester liquid (6,500 l ha^{-1}) was applied in between rows at peak vegetative stage i.e. 25 DAG. In inorganic plot, recommended dose of FYM (7t ha^{-1}) and recommended dose of fertilizers (25:50:25kg NPK/ha.) was applied before sowing. Inter-cultivation practice, hoeing was carried out by hand weeding on 15DAG. Protective irrigation was given at 8 and 55 DAG due to dry spell. All foliar sprays were imposed using hydraulic high volume sprayer. Imposition of treatments was initiated at 50 per cent flowering stage (45, 55 and 70 DAG). Biopesticides in treatment T6, T7 and T8 were applied in sequence, whereas in T1, T2, T3, T4, T5 and T9, the same were used on 45, 55 and 70 DAG.

Estimation of insect pest population

Kogan and Herzog (1980) sampling methods on soybean was followed to estimate the pod borer complex in fieldbean condition. The larvae (pod borer) were counted in randomly selected one-meter row length (mrl) of crop (border rows not considered). In each sub treatment three samples were taken. Average number of larvae of each species per meter row length was worked out. Pod borer complex incidence was recorded by uprooting ten randomly selected plants during harvesting. Number of pods per plant and number of damaged pods; number of healthy and infested seeds were recorded and expressed as per cent pod damage and seed damage respectively.

Pod damage (%) = Number of damaged pods/ Total No. of pods observed X 100

Seed damage (%) = Number of damaged seeds/ Total number of seeds per pod X 100

The pod yield was recorded on the net plot area basis which was later converted to q/ha.

Preparation of indigenous materials

The materials required for the experimentation were prepared in the laboratory. The procedures adopted for the preparation of various indigenous materials have been described hereunder.

Neem Seed Kernel Extract (NSKE) (5%): Fifty grams of neem seed kernels were crushed into fine powder and then soaked overnight in little quantity of water. The soaked mixture was squeezed

through the muslin cloth and the volume was made up to one litre so as to obtain 5 per cent NSKE. Teepol solution was added at 0.1 per cent as a spreader at the time of spraying.

***Helicoverpa armigera* Nuclear Polyhedrosis Virus (*Ha*NPV) 250LE ha^{-1}:** Readily available *Ha*NPV formulation was procured from Pest Control of India (PCI), Bangalore. One per cent jaggery as a sticker, one per cent teepol as a spreader and 0.1 per cent Robin blue as a UV protectant were added at the time of spraying. The spraying operation was done at evening hrs to protect spores from UV rays.

***Bacillus thuringiensis* (*Bt*):** *Bacillus thuringiensis* product of Directorate of Oilseed Research (DOR), Hyderabad was used @1 kgha^{-1} (1 g/l) for foliar application.

Neem oil (3%): Locally available fresh neem oil was collected from oil mill and used for foliar spray at two per cent concentration. Teepol solution was added at 0.1 per cent as a spreader at the time of spraying.

Preparation of Panchagavya: Cow dung (7kg) and Ghee (1 l) were mixed thoroughly and kept for two days. Similarly, cow urine and water, 10 litres each were mixed thoroughly and kept for six days. Later, above two mixtures were mixed and kept for 15 days. After 15 days, cow milk (3 l), cow curd (2 l), coconut water (3 l), jaggery (3 kg) and ripened banana (a dozen) were added and kept for six days. After six days, panchagavya was filtered through muslin cloth and used for spray at 3 per cent concentration.

***Clerodendron* + Cow urine extract (10%):** Fresh leaves of *Clerodendron* (500g) were collected and washed thoroughly with water. Later the leaves were chapped and ground by adding small quantity of water with the help of a grinder. The extract was filtered and mixed with same proportion of cow urine (500mL). The filtered solution was used for spray at 10 per cent concentration. The data were transformed using arcsine and $\sqrt{x+0.5}$ transformation, wherever necessary and statistically analyzed by adopting analysis of variance (Sundararaj *et al.,* 1972).

RESULTS

Pest incidence

***Helicoverpa armigera*:** Mean larval population of *H. armigera* was varied from 15.83-20.26 per

Table 1. Effect of foliar application of biopesticides on the incidence of *Helicoverpa armigera*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	15.83	14.88	12.44	10.30	9.90	9.86	7.72	7.78	8.18	10.76^{b}
T2	20.26	13.44	11.69	10.86	8.13	7.40	7.75	6.87	5.48	10.21^{b}
T3	17.80	14.14	12.35	10.89	10.76	9.13	8.54	6.08	6.56	10.69^{b}
T4	19.46	12.72	15.17	13.46	11.53	11.15	7.06	9.42	8.99	12.10^{c}
T5	16.20	15.65	16.53	16.17	15.18	15.30	14.80	10.55	11.86	14.69^{d}
T6	20.23	13.50	13.06	9.48	9.90	7.33	9.17	8.70	7.04)	10.93^{c}
T7	20.26	14.91	13.10	10.04	9.86	8.22	7.80	6.47	7.33	10.88^{b}
T8	17.83	14.12	12.40	10.83	9.04	7.46	8.38	6.67	5.24	10.22^{b}
T9	18.63	17.75	17.20	16.13	15.56	16.03	15.78	12.66	16.10	16.20^{e}
Untreated control	19.43	21.97	20.66	23.19	21.56	22.54	22.22	18.79	17.80	20.90^{f}
Standard check	20.26	9.95	9.67	6.00	2.63	2.46	3.49	3.02	3.28	6.75^{a}
Mean	18.74^{d}	14.82^{c}	13.89^{c}	11.7^{b}	11.9^{b}	10.3^{a}	9.45^{a}	9.49^{a}	9.45^{a}	
									SEM	CD@5%
Treatments									0.06	0.17
Days									0.05	0.15
Interaction									0.18	0.52

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

Table 2. Effect of foliar application of biopesticides on the incidence of *Etiella zinckenella*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	2.28	2.10	1.71	1.49	1.37	0.98	1.60	0.35	1.34	1.33 ^{ab}
T2	1.83	2.10	2.16	2.22	2.01	1.91	1.40	1.32	1.78	1.76 ^{bcd}
T3	2.69	1.67	1.87	1.49	1.37	1.00	1.04	0.86	0.41	1.47 ^{ab}
T4	2.10	1.82	1.87	1.49	1.45	1.35	1.40	0.84	0.39	1.41 ^{ab}
T5	2.30	2.48	2.57	2.23	2.18	1.92	2.46	1.31	1.58	2.11 ^{cd}
T6	2.30	2.16	2.18	1.47	1.61	1.28	1.40	1.60	0.41	1.60 ^{bc}
T7	2.27	2.09	1.94	2.15	0.41	1.04	1.49	1.63	2.11	1.68 ^{bcd}
T8	2.04	1.36	1.84	1.50	1.12	1.99	1.07	1.26	0.93	1.46 ^{ab}
T9	2.75	2.03	2.58	2.98	2.74	2.33	2.47	0.91	1.21	2.22 ^{d}
Untreated control	2.30	3.28	2.97	3.37	3.22	2.97	3.52	1.75	2.81	2.91 ^{c}
Standard check	1.35	1.23	0.70	0.74	0.64	0.92	1.05	0.87	0.00	0.98 ^{a}
Mean	2.11 ^{d}	2.06 ^{d}	2.06 ^{c}	1.86 ^{bcd}	1.79 ^{bcd}	1.56 ^{bcd}	1.56 ^{bc}	1.43 ^{ab}	1.05 ^{a}	
									SEM	CD@5%
Treatments									0.07	0.19
Days									0.06	0.18
Interaction									0.21	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

meter at 44DAG. The carbaryl sprayed plot recorded the lowest number of larvae on 3 days after foliar application which differed significantly from all other treatments. However rest of the treatments recorded significantly lower population compared to untreated check. Among the biopesticides, the plot treated with neem oil recorded the lowest population, which significantly differed from T9 and T10. Further it was on par with T2, T6 and standard check (Table I).

The highest population was recorded in untreated check at 3DAS of 45DAG. The foliar application of carbaryl significantly suppressed the *H. armigera* at 7DAS which significantly differed from all other treatments. However, among biopesticides, *Ha*NPV sprayed plot recorded least number of larvae/m at 7 days after first spray. The dead cadavers of larvae were also observed which hanged from top of inflorescence.

Table 3. Effect of foliar application of biopesticides on the incidence of *Exelastis atomosa*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	2.28	1.74	1.39	1.60	1.34	1.51	1.60	0.98	0.87	1.48 ^{b}
T2	3.62	2.44	2.43	2.39	2.34	2.16	2.01	1.81	1.51	2.30 ^{cd}
T3	2.24	2.09	1.78	1.99	1.67	1.13	1.60	1.05	1.31	1.65 ^{b}
T4	3.65	1.74	1.83	1.59	1.32	1.89	1.21	1.31	1.29	1.76 ^{b}
T5	3.21	2.19	2.59	3.15	2.34	2.65	2.44	1.99	2.40	2.55 ^{d}
T6	2.25	2.21	2.64	2.10	1.67	1.52	1.60	1.60	1.30	1.87 ^{bc}
T7	3.22	2.01	1.75	1.67	1.19	1.39	1.72	1.74	1.89	1.84 ^{bc}
T8	3.65	1.31	1.58	2.09	1.67	1.77	1.90	1.60	1.29	1.87 ^{bc}
T9	2.69	2.79	2.73	3.18	2.68	2.65	3.09	1.99	2.13	2.66 ^{d}
Untreated control	3.65	3.85	4.42	3.58	4.01	3.03	4.00	4.22	3.46	3.80 ^{e}
Standard check	2.25	0.41	1.36	0.79	0.66	0.76	1.39	0.32	0.41	0.93 ^{a}
Mean	2.97 ^{c}	2.28 ^{b}	2.11 ^{ab}	1.95 ^{ab}	1.94 ^{ab}	1.86 ^{ab}	1.85 ^{ab}	1.84 ^{a}	1.77 ^{a}	
									SEM	CD@5%
Treatments									0.06	0.18
Days									0.05	0.16
Interaction									0.19	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

Table 4. Effect of foliar application of biopesticides on the incidence of *Muruca testulalis*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	1.85	1.37	1.50	1.83	1.47	0.72	1.20	0.41	0.91	1.24 ^{ab}
T2	2.61	2.41	2.25	2.63	2.25	1.81	1.75	1.45	1.52	1.99 ^{cd}
T3	2.20	1.83	1.71	1.87	1.16	1.08	0.87	0.79	0.72	1.36 ^{b}
T4	2.24	1.70	1.90	2.72	1.09	1.43	1.60	0.79	0.87	1.67 ^{bcd}
T5	3.37	2.28	3.09	3.39	1.86	2.17	2.15	1. 21	1.29	2.31 ^{def}
T6	1.79	1.88	2.41	1.99	1.45	1.14	1.09	1.41	1.75	1.65 ^{bc}
T7	2.20	2.06	1.36	1.77	0.79	1.31	1.46	1.51	1.82	1.63 ^{bc}
T8	2.25	0.79	1.06	1.80	1.83	1.72	1.53	1.25	1.45	1.52 ^{bc}
T9	2.65	1.80	2.25	2.62	2.27	2.18	2.16	1.82	1.99	2.26 ^{ef}
Untreated control	2.40	2.67	3.76	3.44	2.26	3.33	3.27	1.72	2.01	2.75 ^{f}
Standard check	1.52	0.69	0.75	1.36	0.35	0.72	1.13	0.37	0.00	0.77 ^{a}
Mean	2.41 ^{d}	2.09 ^{cd}	1.93 ^{cd}	1.92 ^{bc}	1.78 ^{abc}	1.61 ^{abc}	1.45 ^{ab}	1.23 ^{a}	1.26 ^{a}	
									SEM	CD@5%
Treatments									0.07	0.20
Days									0.06	0.18
Interaction									0.22	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

The plot that received endosulfan spray recorded significantly least larval population compared to rest of treatments at 7DAS. The highest larval population was noticed in untreated control. Significantly, lower population was recorded in T6 (7.33/m) and was on par in larval population with *Ha*NPV, T8, T7, T3 and T1. At 70DAG, significantly least larval population was noticed in malathion sprayed plot on 7DAS. Among the biopesticides, T4 registered significantly lower larval population and was on par with T2, T3, T6 and T7.

Cumulative treatment effect on *H. armigera* larval population was noticed among the treatments. The plots applied with insecticide sprays recorded least

Table 5. Effect of foliar application of biopesticides on the incidence of *Sphenarches caffer*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	2.99	0.97	1.23	2.38	0.41	1.00	1.10	0.63	0.72	1.27 ^{ab}
T2	2.99	2.72	2.04	2.08	1.35	1.96	1.63	1.70	1.69	1.83 ^{cd}
T3	3.82	2.04	1.66	1.63	1.01	0.40	0.73	0.69	0.65	1.45 ^{abc}
T4	2.10	1.29	1.60	2.71	1.24	1.30	1.35	0.99	1.02	1.51 ^{bcd}
T5	3.86	2.02	2.03	2.72	1.42	1.94	2.07	1.31	1.41	2.09 ^{d}
T6	3.37	2.38	2.06	1.99	1.34	1.32	1.10	1.05	0.99	1.73 ^{bcd}
T7	2.96	2.41	1.36	2.04	0.98	1.24	1.30	1.31	1.30	1.65 ^{bcd}
T8	2.55	1.71	1.36	1.66	1.69	1.94	1.06	1.03	0.82	1.42 ^{abcd}
T9	2.99	1.62	2.37	2.61	1.36	2.07	1.38	0.98	1.03	1.82 ^{cd}
Untreated control	3.41	4.07	4.12	3.40	2.91	2.47	2.44	2.36	2.10	3.03 ^{e}
Standard check	3.44	0.72	0.43	0.35	0.34	0.33	0.65	0.36	0.00	0.98 ^{a}
Mean	3.13 ^{e}	2.32 ^{d}	1.89 ^{cd}	1.62 ^{bc}	1.57 ^{bc}	1.35 ^{ab}	1.28 ^{ab}	1.11 ^{a}	1.11 ^{a}	
									SEM	CD@5%
Treatments									0.07	0.21
Days									0.07	0.19
Interaction									0.23	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

Table 6. Effect of foliar application of bio-pesticides on the incidence of *Lampides boeticus*

Treatment	Larvae (#/m)									Mean
	45DAG			55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	2.20	1.39	1.66	2.06	1.35	0.75	2.04	0.85	0.76	1.47 [bc]
T2	1.90	1.69	1.68	1.64	1.71	1.97	1.84	1.83	1.48	1.72 [bc]
T3	2.92	2.14	1.64	1.39	1.05	1.11	1.65	1.14	0.72	1.53 [bc]
T4	2.25	1.23	1.69	1.06	1.33	1.11	1.23	1.15	1.10	1.46 [bc]
T5	2.04	1.44	1.75	2.03	1.58	1.56	1.60	1.49	1.52	1.63 [bc]
T6	2.07	1.85	1.28	2.06	1.66	1.03	1.11	2.61	1.15	1.43 [b]
T7	2.20	1.27	1.37	1.66	1.35	0.77	1.50	1.40	1.21	1.45 [b]
T8	1.50	1.27	1.66	1.68	1.23	1.48	1.24	1.10	0.81	1.60 [bc]
T9	2.05	1.27	1.85	2.10	2.03	1.91	1.86	0.82	1.88	1.75 [bc]
Untreated control	2.20	2.40	2.10	2.48	2.69	2.72	2.58	2.61	2.06	2.11 [c]
Standard check	1.15	0.69	1.26	1.24	0.67	0.42	0.42	0.38	0.39	0.77 [a]
Mean	1.88	1.68	1.72	1.61	1.54	1.46	1.39	1.34	1.23	
									SEM	CD@5%
Treatments									0.07	0.21
Days									0.07	NS
Interaction									0.23	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

population (6.75/m), which was significantly less compared to rest of treatments (Table 6). Foliar application of *Ha*NPV was next best to suppress *H. armigera* which recorded significantly the lowest population over rest of the treatments, except T8, T1, T3, T8, T7 and T6. However, T4, T5 and T9 were superior to one another individually and all these were recorded significantly lower population than untreated control. Initial highest mean larval population was recorded at 44DAG, which was significantly higher in number than all other days interval. Least larval number was recorded at 7 days after third spray of 70DAG, but it was on par with 3DAS, 1DBS of 70DAG and 7DAS of 55DAG, followed by 1DBS of 55DAG and 3DAS of 55DAG. The general population was in decreasing trend among the days after treatment.

***Etiella zinkenella*:** The highest mean population of *E. zinkenella* was recorded at 1day before first spray. Initial population was significantly lower in chemical treated plot. The plot sprayed with carbaryl documented the lowest number of larvae which was the least compared to other treatments at 7DAS, However the larval population among the treatments was on par with untreated check. Lower number of larvae was observed in T1 among the biopesticides sprayed plots. The highest mean population was recorded in untreated check at days after first spray (Table 2). The mean population of larvae was less in plots treated with biopesticides after 55 days that recorded less population compared to 7 days after first spray. *E. zinkenella* larval population varied from 0.98 (NSKE 5%) to 2.97 (untreated control). However no difference was noticed among the treatments.

Seven days after 3rd spray; it was found that there was further reduction in larval population. The plot treated with insecticide was free from *E. zinkenella* larvae. The larval population varied from 0.39 (neem oil 2%) to 2.81 (untreated control) larvae/m. However, there was no difference in larval population among the treatments. The varied cumulative effect was noticed among the treatments, standard check recorded least mean population, which was significantly lower compared to other treatments. But it was on par with NSKE 5% in reducing *E. zinkenella* larvae. *Bt*, neem oil and NSKE+*Ha*NPV+ *Bt*. Rest of treatments also exhibited toxicity to *E. zinkenella* compared to untreated control. Among days interval, significantly higher larvae number was recorded at a day before first spray and this was on par with 3 and 7DAS at 45DAG. Further, the larval population reduction was observed during rest of the period.

Table 7. Effect of foliar application of bio-pesticides on the incidence of *Adisura atkinsoni*

Treatment	Larvae (#/m)						Mean
	55DAG			70DAG			
	1DBS	3DAS	7DAS	1DBS	3DAS	7DAS	
T1	2.86	1.23	1.75	1.12	0.97	1.03	1.55 ^{abc}
T2	3.21	2.83	2.48	1.46	1.69	1.59	2.13 ^{cdef}
T3	3.18	1.70	1.17	1.41	1.03	1.02	1.71 ^{abc}
T4	2.86	1.60	1.50	2.46	1.34	1.02	1.80 ^{bc}
T5	2.85	2.40	2.46	2.57	1.71	2.39	2.39 ^{def}
T6	2.85	2.11	1.90	1.51	1.01	1.02	1.73 ^{bcd}
T7	2.82	1.42	1.98	1.92	1.71	1.37	1.87 ^{bcde}
T8	2.13	1.41	1.53	1.51	0.98	0.67	1.37 ^{ab}
T9	3.21	2.46	2.77	2.58	2.37	2.11	2.58 ^{ef}
Untreated control	3.51	2.46	3.17	2.98	3.35	2.72	2.68 ^{f}
Standard check	2.86	0.15	1.14	1.37	0.65	0.76	1.13 ^{a}
Mean	2.68 ^{d}	2.24 ^{cd}	1.86 ^{bc}	1.76 ^{abc}	1.59 ^{ab}	1.30 ^{a}	
						SEM	CD@5%
Treatments						0.08	0.23
Days						0.06	0.17
Interaction						0.20	NS

DBS- Day Before Spray; DAS- Days After Spray; DAG- Days After Germination; Means followed by same letter in the column/row do not differ significantly by DMRT (P=0.05)

***Exelastis atomosa*:** Initial higher mean number of *E. atomosa* larvae was recorded on before first spray and no difference in population was observed among the treatments (Table III). Among the biopesticides sprayed plots, NSKE 5% (T1) recorded the lowest population and the maximum population was observed in untreated control at 7 days after first spray. However, all the treatments were on par in larval population. On the other hand, the lowest and highest larval population was recorded in *Bt* applied plot and untreated control respectively. But all the treatments were on par with one another. Similarly, third foliar application of biopesticides on 70DAG also resulted in the lowest number of larvae in NSKE treatment, but there was a significant difference in pest population among the treatments. However all other treatments registered lower populations when compared to untreated check. Cumulative effect in the mean reduction of larvae was seen in insecticides treated plots, which significantly superior in managing pest. Three foliar application of NSKE 5%, significantly reduced the *E. atomosa* larvae more than rest of treatments except *Bt*, Neem oil, T6, T7, T8.

***Maruca testulalis*:** The highest mean population of *M. testulalis* was recorded a day before first spray. Initial population was significantly lower in chemical treated plot. The plot sprayed with carbaryl documented the lowest number of larvae at 7days after first spray which was the least compared to other treatments. However, the larval population among the treatments was on par with untreated check. Lower number of larvae was observed in T8 (Table 4).

M. testulalis larval population varied from 0.72 (NSKE 5%) to 3.33/m (untreated control), however no difference was noticed among the treatments. Further reduction in larval population was noticed seven days after 3rd spray. The plot treated with insecticide was free from *M. testulalis* larvae. The larval population varied from 0.72 (*Bt*) to 2.01 (untreated control) larvae/m. However, there was no difference in larval population among the treatments.

Diverse cumulative effect was seen among treatments. Standard check recorded least mean population, which was significantly lower compared to other treatments except NSKE 5%. Rest of the treatments also exhibited toxicity to *M. testulalis* compared to untreated control. However, clerodendron + cow urine sprayed plot accounted

Table 8. Effect of biopesticides of different origin and insecticides on pod borer incidence and crop yield

Treatments	% Termite damage	% pod damage	% seed damage	100 seed weight (g)	Yield (qha^{-1})	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BC ratio
NSKE (5%)	20.24	23.97^{c}	17.90^{c}	21.15^{ab}	9.01^{cd}	12,833.12	27,030	14,196.88	1:2.11
***Ha*NPV250LE/ha.**	17.41	39.96^{e}	24.99^{d}	20.96^{abc}	7.05^{e}	13,053.12	21,150	8,096.88	1:1.62
***Bt* 1 kg/ha**	17.96	31.62^{d}	21.76^{c}	21.02^{abc}	8.47^{d}	13,853.12	25,410	11,556.88	1:1.83
Neem oil (2%)	19.45	31.37^{d}	20.41^{c}	21.05^{ab}	8.78^{d}	13,013.12	26,340	13,326.88	1:2.02
Panchagavya (3%)	15.88	47.87^{f}	35.73^{e}	20.67^{bcd}	6.16^{ef}	13,353.12	18,480	4,926.88	1:1.38
***Ha*NPV - *Bt* – NSKE(250LE-1Kg-5%)**	20.25	23.82^{c}	18.30^{c}	21.07^{ab}	9.22^{bcd}	13,228.12	27,660	14,431.88	1:2.09
***Bt* – NSKE – *Ha*NPV (1Kg-5%-250LE)**	18.83	23.37^{c}	18.07^{c}	21.14^{ab}	9.78^{bc}	13,228.12	29,340	16,111.88	1:2.22
NSKE – *Ha*NPV – *Bt* (5%-250LE-1Kg)	16.55	15.96^{b}	13.62^{b}	21.19^{ab}	10.01^{b}	13,228.12	30,030	16,801.88	1:2.27
***Clerodendron* extract + Cow urine (10%)**	19.10	55.24^{g}	40.32^{ef}	20.47^{cd}	5.98^{f}	12,422.12	17,940	5,517.88	1:1.44
Untreated control	21.66	55.59^{g}	42.50^{f}	20.34^{d}	5.51^{f}	12,153.12	16,530	4,476.88	1:1.36
Standard check	23.43	8.70^{a}	7.40^{a}	21.25^{a}	11.37^{a}	13,427.78	34,110	20,682.22	1:2.54
SEM±	6.90	0.55	0.95	0.18	0.33				
CD@5%	NS	1.64	2.82	0.55	0.98				

Means followed by same letter in the column do not differ significantly by DMRT (P=0.05)

on par with untreated control. Significantly higher larval population was recorded at a day before first spray and was on par with 3 and 7 days after first spray. Further, reduction in the larval population was observed during rest of period.

***Sphenarches caffer*:** Initial higher larval population of *S. caffer* was recorded at a day before first spray and no difference in population was observed among the treatments. Among the biopesticides sprayed plots, NSKE 5% recorded the lowest population and the maximum population was observed in untreated control 7 days after first spray. However, all the treatments were on par in larval population. On the other hand, the lowest and the highest larval population was recorded in *Bt* applied plot and untreated control respectively. But all the treatments were in line with larval population (Table 5).

Similarly, third foliar application of biopesticides on 70DAG also resulted reduction of larval population. The lowest number of larvae was recorded in *Bt* treatment, but there was no significant difference in pest population among the treatments. However all biopesticides treatments registered lower populations compared to untreated check. Cumulative effect in the reduction of larvae was seen in insecticides treated plots and it exhibited significantly superior to other treatments in reducing the *S. caffer* larvae. Foliar application of NSKE 5% thrice more significantly reduced *S. caffer* larvae than rest of treatments except sequential spray of NSKE-*Ha*NPV-*Bt* and *Bt*.

***Lampides boeticus*:** Mean larval population of *L. boeticus* before imposition of treatments varied from 1.15 to 2.92 per row meter. However, no difference in population among the treatments was observed. Among the biopesticides treated plots, the lowest and the highest larval population were recorded in NSKE 5% and untreated control respectively. But all the treatments were on par with each other at 7days after second spray (Table 6). Third foliar application of biopesticides of different origin and malathion to respective treatments resulted in least number of larvae in malathion applied plot and maximum in untreated check. Sequential application of carbaryl-endosulfan-malathion recorded significantly least population compared to other treatments. Among biopesticides sequential application of HaNPV-Bt-NSKE recorded lower number of larvae. However, all treatments recorded significantly lower population compared to untreated control. The lowest larval population was found at 7 days after third spray however there was no significant variation in different day's interval.

***Adisura atkinsoni*:** *Adisura atkinsoni* larvae were noticed on 54 DAG (3.51/m) and no difference in larval population was registered among the treatments. Among the biopesticides sprayed plots, Bt recorded the lowest population and the maximum population was observed in untreated control at 7 days after second spray. However all treatments were on par in larval population (Table 7). Sequential spray of NSKE-*Ha*NPV-*Bt* also resulted in lowest number of larvae, but there was no significant difference in pest population among the treatments. However all other treatments were registered lower populations compared to untreated check. The significant lower larval population was seen in insecticides treated plot compared to rest of treatments. However, it was on par with sequential spray of NSKE-*Ha*NPV-*Bt*, NSKE 5% and *Bt*. Larval population in T5 and T9 recorded less number of *A. atkinsoni* but on par with untreated control. Least larval population was found at 7 days after third spray which was significantly different with rest of the days except a day before and 3 days after third spray.

Pod borer incidence and crop yield

Significantly lower pod damage was observed in insecticide treated plot compared to rest of treatments (Table 8). Among the biopesticides treated plots, foliar application of NSKE-*Ha*NPV-*Bt* recorded significantly lower pod damage compare to remaining treatments. Rest of the treatments recorded >23% of pod damage but these results were significantly lower compared to untreated control. Insecticide sprayed plot recorded significantly lower seed damage than rest of the treatments. Among the biopesticides treated plots, T8 recorded significantly lower seed damage. Foliar application of biopesticides of different origin and chemical insecticides resulted in significant difference in 100 seed weight. Significantly higher seed weight was recorded in chemically treated plot, which was on par with rest of treatments except T5, T9 and untreated control.

Termites incidence was also seen on the stubbles of the crop after harvest. The plant damage varied from 15.88 (T5) 23.43% (standard check). However there was no significant difference among the treatments (Table 8). Significantly higher seed yield was obtained in the plot which received sequential spray of *Ha*NPV-*Bt*-NSKE, than rest of the treatments except chemical treated plot.

Cost economics of different treatments: Insecticides sprayed plot registered higher net returns (Rs. 34,110/ha) followed by NSKE-*Ha*NPV-*Bt* (Rs. 30,030/ha). Consequently insecticides (1:2.54) treated plot recorded higher BC ratio (Table 8) followed by NSKE-*Ha*NPV-*Bt* (1:2.27), T7 (1:2.22), T6 (1:2.09), T1 (1:2.10), T4 (1:2.02), T3 (1:1.83) and T2 (1:1.62).

DISCUSSION

In the present study seven pod borers were found to feed on the flower buds, opened flowers, tender and mature pods by boring inside the pods, except *H. armigera.* While feeding on pods, the posterior part of caterpillar remained outside. The pod borers incidence appeared with a mean number of *H. armigera*, E. zinckenella, *E. atomosa, M. testulalis*, *S. caffer*, *L. boeticus* and *A. atkinsoni.*

Against all these pod borers, carbaryl-endosulfan-malathion sprayed plots recorded significantly less number of larvae/m. Among the biopesticides treated plots NSKE 5% was effective in reducing the larval number per meter followed by *Bt* against all pod borers. But, *Ha*NPV was found more effective in suppressing the *H. armigera* than rest of treatments. Neem oil was the next best to NSKE 5% in bringing down the *E. zinckenella* population. Sequential spray of NSKE-*Ha*NPV-*Bt* found effective in reducing the larval population of *A. atkinsoni*. All the sprayed plots recorded were significantly lower in *L. boeticus* larvae, which were next best to insecticides treated plots.

The present findings are in line with Govindarajan and Reghupathy (1973) who noticed significant reduction of pod borers infestation in endosulfan 0.05% sprayed plot. Similar results were noticed by Mallikarjunappa (1989) who observed three sprays of endosulfan at fortnightly intervals commencing from 50% flowering. Surulivelu *et al*. (1978) also reported minimum pod borers infestation when sprayed with endosulfan at 0.07%. Similar findings were noticed by Deware and Dhanorkar (1981) against *H. armigera* and *E. atomosa* in pigeon pea. 2 sprays of endosulfan and NSKE were found to

result in 60.22% reduction in mean pod borer infestation in the plot sprayed with endosulfan (2mL/L) followed by NSKE 5% (42.14%). But there is no literature available on sequential spray of carbaryl-endosulfan-malathion in any other crop.

In the present investigation, *Ha*NPV found effective in bringing down the *H. armigera* larvae. These findings are in close agreement with Padmanaban and Arora (2002) who reported 3 sprays at weekly interval of *Ha*NPV 375 $LEha^{-1}$ recorded significantly lower larval population of 0.83/ten plants, also reported which is as best as carbaryl 50WP. The slight variation in the reduction of pod borer population might be abiotic factors, change in locality. Mishra *et al.* (1984) and Jayaraj *et al*. (1987) opined 5 sprays of 250LE *Ha*NPV at weekly intervals gave satisfactory results. Similar results were noticed by Dhamdhare and Khaire (1986); Pawar and Thombre (1992), Jagadeesh Babu *et al.* (1992) and Gopali (1998).

In Contrary to the present findings of *Ha*NPV efficacy, Abdally *et al.* (1987) found no significant reduction of *H. armigera* on chickpea when sprayed alone. However, Cherry *et al.* (2000) recorded *Ha*NPV proved effective in controlling *H. armigera* over endosulfan. This controversy might be due to variation in the climatic factors and biotic factors. In the present study *Ha*NPV was found ineffective in controlling other pod borers except *H. armigera* due to their specificity. Converse to this Surulivelu *et al.* (1978) found *Ha*NPV found effective against *A. atkinsoni* on field bean.

The present findings on NSKE 5% are in close association with studies of Rekha (2005) and Mallikarjuna (2009). They reported 2 sprays of NSKE 5% were found efficient in controlling the pod borers of field bean. Dong and Zhao (1996) opined that azadirachtin has repellent, antifeedent, stomach and contact poison and growth inhibitor effects on many insects, whereas Kareem *et al.* (1988) noticed application of NSKE 5% against pest complex of mung bean, recorded superior to monocrotophos. As observed in the present studies on *Bt*, Surulivelu *et al.* (1978) also noticed six sprays at weekly intervals starting from the flowering stage gave promising results in reduction of lablab pod borers.

Bt formulations can be effectively used in management of lepidopteran insects. Contrary to the present findings, Thippaiah (1997) noticed *Bt* formulations were not as much effective when sprayed on soybean in Bangalore. This may be due to change in the formulation, weather parameters and change in crop. Many authors opined that combination sprays were more effective in managing insects than alone. Neem oil 2% found effective in controlling the pod borer complex incidence. The present observations are in close similarity with the findings of Satya Vir and Yadav (2006) who detailed locally formulated crude neem oil concurred higher mortality of *H. armigera*, whereas Ramachandra Rao *et al.* (1990) opined neem oil 3% has high repellency activity against *S. litura*. Similar results were stated by Prabu (2009) who found neem oil effective against several insect pests.

During the present study, panchagavya recorded meager control of pod borers and found on par with untreated control, which has repellant and antifeedent action when sprayed. There are disparate findings to the efficacy of panchagavya on pod borer. Rekha (2005) and Mallikarjuna (2009) opined 2 sprays at 3% concentration gave satisfactory results against pod borer complex on fieldbean. Similar findings are reported in mungbean (Shivaraju, 2009). This gap may be due to change in the contents, method of preparation etc. However, present study shows panchagavya is ineffective in controlling pod borer complex. It might be due to weather parameters, change in variety etc.

Clerodendron+cow urine extract were also found inefficient in reducing the pod borer complex, which has repellant and antifeedent activity, whereas Ramakrishna (2007) noticed leaf extracts of *Clerodendron inermi* along with other plant extracts were found effective in managing pests. But many authors opined mixed extracts along with *C. inermi* were found effective in reducing insect pest population. However no literature is traceable in the efficacy of *Clerodendron*+ cow urine extract on field bean borers as well as on other crops. Significant reduction of *A. atkinsoni* and *L. boeticus* was recorded in sequential sprays of biopesticides. However, no literature is in support

of the sequential sprays of *Ha*NPV-*Bt*-NSKE; *Bt*-NSKE-*Ha*NPV and NSKE-*Ha*NPV-*Bt* of present study. However all these sprays were effective in minimizing the pod borer incidence.

Significantly higher 100 seed weight was noticed in insecticide treated plot. NSKE-*Ha*NPV-*Bt* treatment recorded next best to insecticides. The significantly lower pod and seed damage of 8.70 and 7.40 respectively registered in carbaryl-endosulfan-malathion treated plot and consequently resulted in higher yield of 11.37 q/ha. The next best treatment to follow was sequential application of NSKE-*Ha*NPV-*Bt* in which the pod and seed damage were 15.96 and 13.62 per cent, respectively and further this treatment recorded 10.01 q/ha of seed yield. The next best treatments were T7, T6, NSKE 5%, neem oil 2% which recorded <32 and <20.41 per cent of pod and seed damage respectively, which consequently gave yield of 9.78, 9.22, 9.01 and 8.78q/ha respectively. Panchagavya at 3% was inline with untreated control in yield. Untreated control encountered higher pod damage and seed damage, which lead to lower yield. The present findings are in agreement with those of Mallikarjunappa (1989) and Mallikarjuna (2009, 2009a) where they recorded pod damage up to fifty and seed damage of 46.86 % in untreated control.

Rekha (2005) observed less pod and seed damage with higher yield when NSKE + cow urine, GE + cow urine and NSKE were applied. Mallikarjuna (2009) reordered less pod damage in endosulfan treated plot. However, in the present study it was observed sequential spraying of carbaryl-endosulfan-malathion effectively reduced the pod damage, where he also observed 21.09, 29.33 and 20.64, 28.22 per cent pod and seed damage in NSKE 5% and panchagavya 3%, respectively. The present findings are in line with NSKE 5% on seed damage but latter treatment recorded higher pod damage. In contrast to present results of *Ha*NPV, Mishra *et al*. (1984) noticed lower pod damage and highest grain yield in single spray of either insecticide or NPV, whereas five sprays of *Ha*NPV @ 250 LE ha^{-1} at weekly interval gave satisfactory control of pests and resulted in increase of grain yield. This may be due to occurrence of more pod borers on field bean compared to chickpea.

Among biopesticides, sequential spray of NSKE-*Ha*NPV-*Bt* recorded high BC ratio of followed by T7. However, insecticides sprayed plot registered 1:2.54 BC ratio, which is superior to rest of the treatments. Consequently a higher net return was observed in insecticides sprayed plot. Present findings are not closely similar to any others, because the crop was raised for seed purpose, sold at the rate of Rs. 30/kg. However, main aim of organic farming is to increase the soil fertility and sustainability by lessening the harmful effects on soil fauna.

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