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Efficacy of Some Biopesticides against *Helicoverpa Armigera* (Hubner) in Pigeonpea under Natural Condition

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ABSTRACT

The field experiments on efficacy of some biopesticides against *H. armigera* on pigeonpea under field condition was carried out in the experimental field of department of Entomology at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Hyderabad, during 2016-2017 and 2017-2018.These studies revealed Spinosad 45 SC treatment as the most effective against *H. armigera.* Lower larval population of *H. armigera* was observed when crop was treated with consortia of biopesticides which was at par with neem fruit powder followed by HaNPV. The treatment of Spinosad 45 SC was found significantly superior, recording lower pod and seed damage by *H. armigera* (6.82%) followed by consortia (37.95%) and neem fruit powder (39.77%). The highest yield was (1359 kg/ha) recorded in Spinosad 45 SC followed by *Streptomyces* sp.(SAI-25) (762 kg/ha).

Key words: Biopesticides, *H. armigera*, Pigeonpea.

INTRODUCTON

Pigeonpea, (*Cajanus cajan* L.) is an important grain legume and occupies 2nd largest area among the various pulse crops grown in India. It is a staple diet and consumed as green peas as well as dry seeds (Tabo *et al.,*1995). The crop originated from India and moved to Africa about 4,000 years ago. Unlike other grain legumes, pigeonpea production is concentrated in developing countries, particularly in a few South and Southeast Asia and Eastern and Southern African countries. Pigeonpea is the second most important pulse crop of India after chickpea. India is the largest producer and also the largest consumer of pulses in the world. It accounts for 33 per cent of the world areas and 25 per cent share in global production (Srivastava *et al.,* 2010). The *Helicoverpa armigera* (Hubner) was recorded as major pests on this crop by causing more than 51 per cent damage to the crop, whereas, nine insect pests *viz*., *Megalurothrips usitatus* (Bangall), *Empoasca kerri* (Pruthi), *Clavigralla gibbosa* (Spinola), *Riptortus pedestris* (Fb)., *Exelastis atomosa* (May.), *Melanagromyza obtusa* (Mlloch), *Cydia ptychora* (Meyr.), *Maruca testulalis* (Geyer) and *Etiella zinckenella* (Treit) were recorded as moderate pests by inflicting damage between 31 to 50 per cent. As many as ten insect pests were recorded as minor pests on this crop, while ten were recorded as low important (Balikai and Yelshetty, 2008).

A microbial pesticide compatible with commonly used biopesticides pesticide can be used simultaneously or sequentially with it. To harness the benefits of entomopathogenic fungus their compatibility other biopesticides becomes decisive for combined use, while the potential inhibitory effects of insecticides on the entomopathogenic fungus cannot be ignored. The use of incompatible insecticides may inhibit the development and reproduction of these pathogens affecting IPM. If *Beauveria bassiana* has to be incorporated into a pest management programme it is essential to determine the effects of pesticides on it. Management of pod borer complex in pigeonpea relies heavily on insecticides, often to the exclusion of other methods of control. Considerable number of insecticides has been tested and few of them found effective against the pod borers in pigeonpea (Yadav and Dahiya, 2004). Regular and indiscriminate uses of insecticides have induced resistance against several pests besides polluting our much precious environment, coupled with increased cost of cultivation.

Microbial pathogens are considered for eco-friendly management strategy of the pests. Hence, a field trial consisting of different bio-pesticides such as *Beauveria bassiana, Metarrhizium anisopliae Paecilomyces fumosoreseus, Verticillium lecanii* and *Bacillus thuringiensis* var. *kurstaki* microbial products was conducted to evaluate the efficacy against the gram pod borer in pigeonpea. For the management of pod borer bio-pesticides were tested along with control. Among the bio-pesticides, *Beauveria bassiana* @ 1 liter / ha (1×10^{12} spores/ml) was found to be most effective biopesticides as it recorded lowest larval population (Pandey and Das 2016).

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MATERIALS AND METHODS

The field trial was carried out in the experimental field of department of Entomology at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Hyderabad, during 2016-2017 and 2017-2018. The trial was laid out in randomized block design with three replications. Pigeon pea variety ICPL-161 was sown at 120 cm spacing (row to row) having plot size of 20x20m.The trial comprised eight treatments namely, *Streptomyces* sp (5.85×10^7colonies/ml), HaNPV500LE/ha, *Metarhizium anisopliae* (39.2×10^4spores/ml), Neem fruit powder (15-20kg/ha), Consortia (*Streptomyces* sp. (SAI-25) + HaNPV+ *Metarhizium anisopliae* + Neem fruit powder) @ (5.85×10^7colonies/ml + 500LE/ha+39.2×10^4spores/ml+15-20kg/ha), Farmers practice (mostly chemical) Spinosad 45% SC and untreated control. Three sprays per treatment were given at 50% flowering stage and pod formation stage. Observations on larval population of *H. armigera* were recorded on seven plants per plot at 24 hours before spraying (pre treatment) and 3, 7 and 10 days after each spray. At harvest, total number of healthy and borer damaged pods and grain were counted and expressed as per cent damage. The data were the subjected to square root and arcsine transformation values before statistical analysis.

Statistical analysis

The data was analyzed using computerized statistical software by using Gen-Stat 14th edition software, SPSS 15.0 windows@ and Microsoft Excel.

RESULTS AND DISCUSSION

Efficacy of various biopesticides against gram pod borer, *H. armigera* infesting pigeonpea during 2016-17

Pre- treatment observation indicating the *H. armigera* mean larval population per plant among different treatments were not significant, indicating more or less uniform distribution of the pest. Data presented in Table 1 showed that at 3rd DAFS, the differences in the mean larval population among different treatments were significant. Among the treatments, Spinosad 45 SC @73 g a.i./ha was found to be most effective as it recorded lowest larval population (0.24 larvae / 7 plants) followed by *Streptomyces* sp. @ 5.85 $\times 10^7$colonies/ml (1.24/ 7 plants), neem fruit powder @15-20kg / ha (1.62/ 7 plants). Mahendra *et al.,* (2011) investigated seven different treatments along with untreated check and the efficacy of new insecticides against *H. armigera*. At 7th DAFS the differences in the mean larval population among different treatments were significant. All the biopesticides treatments significantly reduced the larval population as compared to control (2.90 larvae/7 plants). Among the treatments, Spinosad 45 SC was found to be most effective as it recorded lowest larval population (0.76 larvae/7 plants). Dandale *et al.,* (2000) concluded that Spinsosad 48 SC at 75 and 50 g a.i /ha was effective in controlling the infestation of *H. armigera.* This was followed by *Streptomyces* sp. (1.76 larvae/7 plants). At tenth days after first spray also showed similar trends and it showed significant deviation in population of *H. armigera* larvae with respect to treatments. It was ascertained that, among the treatments, Spinosad 45 SC was found to be most effective as it recorded lowest larval population (0.48 larvae/7 plants) followed by *Streptomyces* sp. (3.57 larvae/7 plants). The maximum larval population was recorded in control (5.19 larvae/7 plants). Data presented in Table 1 showed that at 3rd DASS, the differences in the mean larval population of *H. armigera* varying significantly from (0.04 larvae /7 plant) Spinosad 45 SC followed by consortia (1.71 larvae/7 plants). Mahakalkar *et al.,* (2009) reported that application of Spinosad 45 SC @ 50 g a.i./ha registered significantly maximum larval reduction of *H. armigera*. The maximum larval population was recorded in control (2.61 larvae/7 plants). At 7th DASS, the similar trend of decline in the population of *H. armigera* larvae in filed condition, it showed the treatment Spinosad 45 SC evidenced to be with minimum larval population of (0.14 larvae/7 plants) followed by neem fruit powder (1.95 larvae/ 7 plants). The findings were in conformity with Sadawarte and Sarode (1997) who studied the efficacy of neem seed extract, cow dung, cow urine and combinations with and without insecticides to control *H. armigera,* on pigeonpea. Mittal and Ujagir (2005a) reported that the efficacy of Spinosad @ 90 g a. i. /ha the lower number of *H. armigera* larvae in pigeonpea.

The significant difference was noticed by 10th DASS, the lowest population *H. armigera* larvae recorded in treatment Spinosad 45 SC (0.19 larvae/7 plants) followed by neem fruit powder (1.47 larvae/7 plants). The maximum larval population was recorded in control (2.76 larvae/7 plants). Data presented in Table 1 showed that at 3rdDATS, significantly lower population of *H. armigera* in treatment with Spinosad 45 SC (0.04 larvae/7 plants) followed by neem fruit powder (1.00 larvae/7 plants). Present study with Deshmukh *et al.,* (2010) found that spinosad 0.009 per cent found to be the most effective in reducing the *H. armigera* larval population. The highest larval population was recorded in control (3.04 larvae/7 plants). Therefore the present study indicated slower efficacy of bioproducts against *H. armigera*. At 7th DATS the differences in the mean larval population among different treatments were significant. All the biopesticides treatments significantly reduced the larval population as compared to control (2.42 larvae/7 plants). Among the treatments, Spinosad 45 SC was found to be most effective as it recorded lowest larval population (0.04 larvae/7 plants). The significant difference was noticed by 10th DATS, the zero population *H. armigera* larvae recorded in treatment Spinosad 45 SC (0.00 larvae/7 plants) followed by neem fruit powder (1.09 larvae/7 plants). The maximum larval population was recorded in control (2.19 larvae/7 plants).

Gram pod borer, *H. armigera* during 2017-18

Pre- treatment observation in the *H. armigera* mean larval population per plant among different treatments were not significant, indicating less distribution of the pest in the

Table 1: Efficacy of various biopesticides against gram pod borer, *H. armigera* infesting pigeonpea during 2016-17.

Treatments	Dose	Mean number of larvae/7 plants											
	g a.i./ha or spores/ml	DBFS	3DAFS	7DAFS	10 DAFS	DBSS	3 DASS	7 DASS	10 DASS	DBTS	3 DATS	7 DATS	10 DATS
Streptomyces sp.	5.85×10^7 colonies/ml	1.00	1.24	1.76	3.57	2.76	2.76	2.85	2.66	2.28	1.85	1.47	1.47
		(1.21)	(1.30)^{ab}	(1.50)^{ab}	(2.00)^{b}	(1.80)^{bc}	(1.81)^{b}	(1.82)^{b}	(1.78)^{d}	(1.67)^{c}	(1.53)^{c}	(1.40)^{bc}	(1.40)^{bc}
HaNPV	500 LE/ha	1.10	2.43	2.42	3.62	3.28	2.33	2.47	2.23	1.85	1.33	2.38	1.90
		(1.24)	(1.67)^{b}	(1.71)^{b}	(2.03)^{b}	(1.94)^{bc}	(1.68)^{b}	(1.72)^{b}	(1.65)^{cd}	(1.53)^{bc}	(1.35)^{bc}	(1.68)^{d}	(1.55)^{cd}
Metarhizium	39.2×10^4 spores/ml	1.00	2.33	3.04	5.14	3.71	2.09	2.80	2.85	2.19	1.95	2.19	2.04
anisopliae		(1.22)	(1.67)^{b}	(1.88)^{b}	(2.37)^{b}	(2.05)^{bc}	(1.61)^{b}	(1.82)^{b}	(2.83)^{d}	(1.64)^{c}	(1.56)^{c}	(1.62)^{bc}	(1.60)^{cd}
Neem fruit powder	15-20kg/ha	1.38	1.62	2.47	3.81	2.57	2.23	1.95	1.47	1.52	1.00	1.19	1.09
		(1.37)	(1.45)^{b}	(1.70)^{b}	(2.05)^{b}	(1.75)^{b}	(1.65)^{b}	(1.57)^{b}	(1.40)^{b}	(1.42)^{b}	(1.21)^{b}	(1.28)^{b}	(1.26)^{b}
Consortia	(Sr.no 1 to 4)	1.19	2.24	2.57	3.67	2.76	1.71	2.09	1.71	2.04	1.28	1.52	1.09
		(1.28)	(1.65)^{b}	(1.74)^{b}	(2.03)^{b}	(1.79)^{bc}	(1.47)^{b}	(1.61)^{b}	(1.47)^{bc}	(1.60)^{bc}	(1.34)^{bc}	(1.41)^{bc}	(1.26)^{b}
Spinosad	73 g a.i./ha	1.33	0.24	0.76	0.48	0.90	0.04	0.14	0.19	0.14	0.04	0.04	0.00
		(1.31)	(0.85)^{a}	(1.11)^{a}	(0.99)^{a}	(1.18)^{a}	(0.74)^{a}	(0.80)^{a}	(0.83)^{a}	(0.80)^{a}	(0.74)^{a}	(0.74)^{a}	(0.71)^{a}
Control		0.80	2.0	2.90	5.19	4.33	2.61	2.38	2.76	3.66	3.04	2.42	2.19
		(1.14)	(1.59)^{b}	(1.83)^{b}	(2.39)^{b}	(2.19)^{c}	(1.74)^{b}	(1.69)^{b}	(1.80)^{d}	(2.04)^{d}	(1.88)^{d}	(1.71)^{d}	(1.64)^{d}
SE±m		0.15	0.15	0.13	0.12	0.11	0.12	0.08	0.07	0.04	0.06	0.12	0.06
CD at 5%		NS	0.48	0.42	0.39	0.37	0.38	0.27	0.24	0.15	0.2	0.39	0.2

Figures in parentheses are square root transformed values, NS- Non significant.

The values denoted by a common letter are showing significant difference from each other as per DMRT.

DBFS= Day before first spray, **DAFS**= Day after first spray, **DBSS**=Day before second spray, **DASS**= Days after second spray, **DBTS**= Day before third spray, **DATS**= Day after third spray. **Consortia** (Combination of *Streptomyces* sp + HaNPV + *Metarhizium anisopliae* + Neem fruit powder).

experimental field. Data presented in Table 2 showed that at 3rd DAFS, the differences in the mean larval population among different treatments were significant. Among the treatments, *M. anisopliae* (0.14 larvae/7 plant) and consortia (0.14 larvae/7 plants) was found to be most effective as it recorded lowest larval population followed by Spinosad 45 SC (0.19 larvae/7 plants). The maximum larval population was recorded in control (0.38 larvae/7 plants). At 7th DAFS the differences in the mean larval population among different treatments were significant. Raghuraman *et al.* (2008) have mentioned that determined the bioefficacy of neem based formulations were significantly effective in reducing the larval population of *H. armigera* and increased the yield of chickpea. All the biopesticides treatments significantly reduced the larval population as compared to control (0.33 larvae/7 plants). Among the treatments, Spinosad 45 SC was found to be most effective as it recorded zero larval population (0.00 larvae/7 plants) followed by HaNPV (0.04 larvae/7 plants) (Table 2). At 10th DAFS also showed similar trends and it showed in significant variation in population of *H. armigera* larvae with respect to treatments. It was ascertained that, among the treatments, HaNPV was found to be most effective as it recorded lowest larval population (0.04 larvae/7 plants) followed by Spinosad 45 SC (0.05 larvae/7 plants). The maximum larval population was recorded in control (0.24 larvae/7 plants) (Table 2). Data presented in Table 2 showed that at 3DASS, the differences in the mean larval population of *H. armigera* varying significantly from (0.05 larvae/7 plant) Spinosad 45 SC followed by HaNPV (0.24 larvae/7 plants). The maximum larval population was recorded in control (0.57 larvae/7 plants). At 7th DASS, the similar trend of decline in the population of *H. armigera* larvae in filed condition, it was showed the treatment Spinosad 45 SC evidenced to be with minimum larval population of (0.43 larvae/7 plants) followed by consortia (0.48 larvae/7 plants). The maximum larval population was recorded in control (1.05 larvae/7 plants). (Table 2).The significant difference was noticed at 10th DASS, the lowest population *H. armigera* larvae recorded in treatment neem fruit powder (0.43 larvae/7 plants) followed by Spinosad 45 SC (0.48 larvae/7 plants).The maximum larval population was recorded in control (1.29 larvae/7 plants) (Table 2). Data presented in Table 2 showed that at 3DATS, showed significant variation were observed among treatment at 3DATS, the lowest population *H. armigera* larvae recorded in Spinosad 45 SC (0.05 larvae/7 plants) followed by consortia (0.24 larvae/7 plants) (T5). At 7th DATS, showed the minimum larval population of *H. armigera* with Spinosad 45 SC (0.19 larvae/7 plants) followed by HaNPV (0.29 larvae / 7 plants) (Table 2). The significant difference was noticed by 10th DATS, the lowest population of *H. armigera* larvae recorded in treatment Spinosad 45 SC (0.10 larvae/7 plants) followed by *M. anisopliae* (0.19 larvae/7 plants) and consortia (0.29 larvae/7 plants) (T5). The least effective treatment was HaNPV (0.29 larvae/7 plants) (T2) but was significantly superior to control. The maximum larval population was recorded in control (1.52 larvae/7 plants) (Table 2). Similarly earlier finding with Pandey and Das (2016) among the bio-pesticides, *B. bassiana* @ 1 liter/ha (1x10^{12} spores/ml) was found to be most effective bio-pesticide as it recorded lowest larval population (6.68 larvae/5 plants).

Pooled mean gram pod borer, *H. armigera* during 2016 and 2017

Pre-treatment of spraying in all 7 treatments showed uniform distribution of larval population of *H. armigera* recorded with *M. anisopliae* (0.53 larvae/7 plants) which was statistically at par with *Streptomyces* sp. and maximum recorded with Spinosad 45 SC (0.71 larvae/7 plants) in comparison with control (0.43 larvae/7 plant) (Table 3). Malik *et al.* (1993) found that *B. bassiana* gave effective control from seventh days of application. At 3DAFS, the pooled mean of larvae of *H. armigera* population showed significant differences among treatments, with minimum of Spinosad 45 SC (0.22 larvae/7 plants) followed by *Streptomyces* sp. (0.77 larvae/ 7 plants) and maximum population recorded with HaNPV (1.31 larvae/7 plants) in comparison with control (1.22 larvae/ 7 plants) (Table 3). The collective mean of *H. armigera* larvae at 7 DAFS, it showed a statistically highly significant difference among population of all treatments. It was recorded lowest *H. armigera* larval population in Spinosad 45 SC (0.38 larvae/7 plants), followed by *Streptomyces* sp. (0.93 larvae/7 plants). At 10th DAFS, the pooled mean of both the season, showed significant variation in population of larvae among treatments. It was ascertained that, the lowest *H. armigera* larvae in Spinosad 45 SC (0.27 larvae/7 plants), this was followed by consortia (1.88 larvae/7 plants) (Table 3). Tamboli and Lolage (2008) also concluded that treatments Spinosad @ 90 g a.i./ha as the most effective against *H. armigera* in pigeonpea by recording 0.29 larva / plant and was at par with flubendiamide @ 50 g. a.i. /ha. Similarly, for second spray, two years pooled data were presented in Table 3 At 3 DASS revealed that the lowest (0.05 larvae/7 plants) larval population when crop was treated with Spinosad 45 SC followed by consortia (1.05 larvae/7 plants). Srinivasan and Durairaj (2007) also reported lowest *Helicoverpa* larval population with Spinosad 45 SC (73 g a.i./ha) treated plots, followed by indoxacarb 14.5 SC and maximum population in the untreated control. Maximum larval population was recorded in control (1.59 larvae/7 plants). At 7th DASS, the pooled two years data it showed a similar trend of gradual decline in the population of *H. armigera* larvae in field condition, with data showed that the lowest population was recorded in Spinosad 45 SC (0.29 larvae/7 plants), followed by consortia (1.29 larvae/7 plants). Significant difference among treatments was noticed by 10th DASS, the pooled mean of the lowest population *H. armigera* larvae recorded in Spinosad 45 SC (0.34 larvae/7 plants) followed by neem fruit powder (1.36 larvae/7 plants) (Table 3). Pooled results of two year on third spray, 3DATS showed that the lowest (0.05 larvae/7 plants) larval population when crop was treated with Spinosad 45 SC

Table 2: Efficacy of various biopesticides against gram pod borer, *H. armigera* infesting pigeonpea during 2017-18.

Treatments	Dose	Mean number of larvae/7 plants											
	g a.i./ha or spores/ml	DBFS	3 DAFS	7 DAFS	10 DAFS	DBSS	3 DASS	7 DASS	10 DASS	DBTS	3 DATS	7 DATS	10 DATS
Streptomyces sp.	5.85×10^{7} colonies/ml	0.10	0.29	0.09	0.28	0.19	0.34	0.76	0.76	0.76	0.34	0.48	0.43
		(0.77)	(0.88)	$(0.77)^{a}$	(0.88)	$(0.82)^{ab}$	$(0.91)^{bc}$	$(1.12)^{ab}$	$(1.12)^{ab}$	$(1.12)^{b}$	$(0.91)^{ab}$	$(0.98)^{ab}$	$(0.96)^{a}$
HaNPV	500 LE/ha	0.10	0.19	0.04	0.04	0.05	0.24	0.52	0.66	0.71	0.53	0.29	0.38
		(0.77)	(0.82)	$(0.74)^{a}$	(074)	$(0.74)^{a}$	$(0.86)^{ab}$	$(1.01)^{a}$	$(1.08)^{ab}$	$(1.10)^{b}$	$(1.00)^{b}$	$(0.88)^{a}$	$(0.93)^{a}$
Metarhizium	39.2×10^{4} spores/ml	0.05	0.14	0.19	0.24	0.09	0.24	0.66	0.76	0.76	0.43	0.57	0.19
anisopliae		(0.74)	(0.80)	$(0.83)^{ab}$	(0.85)	$(0.77)^{a}$	$(0.86)^{ab}$	$(1.08)^{ab}$	$(1.12)^{b}$	$(1.12)^{b}$	$(0.96)^{b}$	$(1.02)^{ab}$	$(0.82)^{a}$
Neem fruit powder	15-20 kg/ha	0.24	0.19	0.19	0.10	0.09	0.43	0.76	0.43	0.76	0.43	0.81	0.57
		(0.86)	(0.82)	$(0.83)^{ab}$	(0.77)	$(0.77)^{a}$	$(0.96)^{bc}$	$(1.12)^{ab}$	$(0.96)^{ab}$	$(1.12)^{b}$	$(0.96)^{b}$	$(1.14)^{b}$	$(1.03)^{a}$
Consortia	(Sr.no 1 to 4)	0.00	0.14	0.19	0.09	0.19	0.38	0.48	0.62	0.67	0.24	0.48	0.29
		(0.71)	(0.80)	$(0.83)^{ab}$	(0.77)	$(0.83)^{ab}$	$(0.93)^{bc}$	$(0.99)^{a}$	$(1.05)^{ab}$	$(1.07)^{b}$	$(0.85)^{ab}$	$(0.99)^{ab}$	$(0.88)^{a}$
Spinosad	73 g a.i./ha	0.09	0.19	0.00	0.05	0.05	0.05	0.43	0.48	0.29	0.05	0.19	0.10
		(0.77)	(0.82)	$(0.71)^{a}$	(0.74)	$(0.74)^{a}$	$(0.74)^{a}$	$(0.96)^{a}$	$(0.98)^{a}$	$(0.88)^{a}$	$(1.74)^{a}$	$(0.83)^{a}$	$(0.77)^{a}$
Control	Control	0.05	0.38	0.33	0.24	0.38	0.57	1.05	1.29	1.38	1.09	1.43	1.52
		(0.74)	(0.94)	$(0.91)^{b}$	(0.86)	$(0.94)^{b}$	$(1.03)^{c}$	$(1.24)^{b}$	$(1.33)^{b}$	$(1.37)^{c}$	$(1.26)^{c}$	$(1.39)^{c}$	$(1.41)^{b}$
SE±m		0.07	0.09	0.06	0.09	0.06	0.09	0.11	0.14	0.14	0.1	0.14	0.17
		NS	NS	0.17	NS	0.2	0.27	0.33	0.43	0.43	0.31	0.44	0.53

Figures in parentheses are square root transformed values, NS- Non significant.

The values denoted by a common letter are showing significant difference from each other as per DMRT.

DBFS= Day before first spray, **DAFS**= Day after first spray, **DBSS**=Day before second spray, **DASS**= Days after second spray, **DBTS**= Day before third spray, **DATS**= Day after third spray. **Consortia** (Combination of *Streptomyces* sp + HaNPV + *Metarhizium anisopliae* + Neem fruit powder).

Table 3: Pooled efficacy of various biopesticides against gram pod borer, *H. armigera* in pigeonpea during 2016 and 2017.

Treatments	Dose g a.i./ha or spores/ ml	Pooled Mean number of larvae/7 plants									
			First spray			Second spray			Third spray		
		DBFS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS
Streptomyces sp.	5.85×10^{7} colonies/ml	0.55	0.77	0.93	1.93	1.55	1.81	1.71	1.10	0.98	0.95
		(0.99)	$(1.09)^{b}$	$(1.14)^{ab}$	$(1.44)^{b}$	$(1.36)^{b}$	$(1.47)^{b}$	$(1.45)^{b}$	$(1.22)^{bc}$	$(1.19)^{b}$	$(1.18)^{b}$
HaNPV	500 LE/ha	0.60	1.31	1.23	1.70	1.29	1.50	1.45	0.93	1.34	1.14
		(1.01)	$(1.25)^{b}$	$(1.23)^{b}$	$(1.39)^{b}$	$(1.27)^{b}$	$(1.37)^{b}$	$(1.37)^{b}$	$(1.18)^{bc}$	$(1.28)^{b}$	$(1.24)^{b}$
Metarhizium anisopliae	39.2×10^{4} spores/ml	0.53	1.24	1.62	2.69	1.17	1.73	1.81	1.19	1.38	1.12
		(0.98)	$(1.24)^{b}$	$(1.36)^{b}$	$(1.61)^{b}$	$(1.24)^{b}$	$(1.45)^{b}$	$(1.98)^{b}$	$(1.26)^{c}$	$(1.32)^{b}$	$(1.21)^{b}$
Neem fruit powder	15-20 kg/ha	0.81	0.91	1.33	1.96	1.33	1.36	0.95	0.72	1.00	0.83
		(1.12)	$(1.14)^{b}$	$(1.27)^{b}$	$(1.41)^{b}$	$(1.31)^{b}$	$(1.35)^{b}$	$(1.18)^{ab}$	$(1.09)^{b}$	$(1.21)^{b}$	$(1.15)^{b}$
Consortia	(Sr.no 1 to 4)	0.60	1.19	1.38	1.88	1.05	1.29	1.17	0.76	1.00	0.69
		(1.00)	$(1.23)^{b}$	$(1.29)^{b}$	$(1.40)^{b}$	$(1.20)^{b}$	$(1.30)^{b}$	$(1.26)^{b}$	$(1.10)^{b}$	$(1.20)^{b}$	$(1.07)^{b}$
Spinosad	73 g a.i./ha	0.71	0.22	0.38	0.27	0.05	0.29	0.34	0.05	0.12	0.05
		(1.04)	$(0.84)^{a}$	$(0.91)^{a}$	$(0.87)^{a}$	$(0.74)^{a}$	$(0.88)^{a}$	$(0.91)^{a}$	$(1.24)^{a}$	$(0.79)^{a}$	$(0.74)^{a}$
Control	Control	0.43	1.22	1.62	2.72	1.59	1.71	2.03	2.05	1.93	1.86
		(0.94)	$(1.27)^{b}$	$(1.37)^{b}$	$(1.63)^{b}$	$(1.39)^{b}$	$(1.47)^{b}$	$(1.57)^{c}$	$(1.57)^{d}$	$(1.55)^{c}$	$(1.53)^{c}$
SE±m		0.09	0.10	0.08	0.08	0.07	0.06	0.05	0.04	0.08	0.05
CD at 5%		NS	0.31	0.28	0.27	0.22	0.19	0.18	0.13	0.25	0.17

Figures in parentheses are square root transformed values, NS- Non significant.

The values denoted by a common letter are showing significant difference from each other as per DMRT.

DBFS= Day before first spray, **DAS**= Day after spray, **Consortia** (Combination of *Streptomyces* sp + HaNPV + *Metarhizium anisopliae* + Neem fruit powder).

followed by neem fruit powder (0.72 larvae/7 plants) and consortia (1.29 larvae/ 7 plants), the maximum population was observed in T3 in comparison with control (2.05 larvae/ 7 plants) (Table 3). At 7th DATS, the pooled two years data indicated a similar trend of gradual decline in the population of *H. armigera* larvae in field condition, with data showed that the lowest population was recorded in Spinosad 45 SC (0.12 larvae/7 plants), followed by *Streptomyces* sp. (0.98 larvae/7 plants). The maximum population was recorded in control (1.93 larvae / 7 plants) (Table 3). Nahar *et al.,*(2004) showed similar result with *M. anisopliae* and *B. bassiana* preparations less effective against *H. armigera*. At 10th DATS the pooled mean of both years, showed significant deviation in population of larvae among different treatments. It was ascertained that, the lowest *H. armigera* larvae in Spinosad 45 SC (0.05 larvae/7 plants) this was followed by consortia (0.69 larvae/7 plants) (Table 3). Revathi *et al.,* (2011) support the present finding of entomopathogenic fungi *M. anisopliae* against third instar larvae of *H. armigera* at 1×10^7 conidia/ml. It revealed that individual treatment resulting in 50-70 per cent larval mortality of *H. armigera*.

Efficacy of biopesticides on pigeonpea pod and grain damage by *H. armigera* (Years 2016 and 2017)

The percentage pod damage due to *H. armigera* in different treatments recorded during the year 2016 significantly reduced the pod damage by gram pod borer as compared to control (63.00%). Among the treatments, Spinosad 45 SC was found to be most effective as it recorded lowest pod damage (11.30%) followed by treatments consortia (57.30%) (Table 4). Narasimhamurthy and Keval (2012a) studies on the highest pod damage in pigeonpea on the treatment *B. bassiana* @1.5 kg/ha (39.4% and 39.8%) followed by NSKE 5% with 32.9 per cent and 31.2 per cent compared to least damage in case of Spinosad 16.3 per cent and 17 per cent in two successive years 2009-10 and 2010-2011. The percentage grain damage due to *H. armigera* in different treatments recorded during the year 2016 revealed that Spinosad 45 SC gave significantly lowest grain damage (8.30%) followed by consortia (19.30%) (Table 4). The percentage pod damage due to *H. armigera* in different treatments recorded during the year 2017 significantly reduced the pod damage by gram pod borer as compared to control (44.17%). Among the treatments, Spinosad 45 SC was found to be most effective as it recorded lowest pod damage (2.80%) followed by treatments consortia (18.53%) (Table 4). The percentage grain damage due to *H. armigera* in different treatments recorded during the year 2017 revealed Spinosad 45 SC gave significantly lowest grain damage (2.60%) followed by consortia (6.52%) (Table 4). The pooled data in the year of 2016 and 2017 (Table 4) revealed that the difference in pod damage among the biopesticides treatments was significant over control. The treatment of Spinosad 45 SC was found significantly superior, recording lower pod damage (6.82%). This was followed by consortia (T5) (37.95%). Untreated control plot recorded the highest pod damage (53.56%). In case of grain damage Spinosad 45 SC found most effective, recorded lowest grain damage (5.47%) This was followed by consortia (12.90%). Maximum grain damage was recorded in control (27.35%). Sarode *et al.,* (1995b) confirmed that two

Table 4: Pod and grain damage (%) caused by gram pod borer *H. armigera* in different spray schedules during 2016 and 2017.

Treatments	Dose g a.i./ha or spores/ml	Pooled per cent pod and grain damage					
		Pod damage (%)			Grain damage (%)		
		2016	2017	Pooled	2016	2017	Pooled
Streptomyces sp.	5.85×10^7 colonies/ml	65.00 (53.72)^b	21.87 (27.88)^b	43.51 (41.27)^b	28.70 (32.39)^b	8.65 (17.10)^b	18.65 (25.58)^b
HaNPV	500 LE/ha	62.00 (51.94)^b	22.00 (27.97)^b	42.01 (40.40)^b	24.31 (29.53)^b	10.18 (18.61)^b	17.34 (24.61)^b
Metarhizium anisopliae	39.2×10^4 spores/ml	66.30 (54.51)^b	27.03 (31.33)^b	46.71 (43.11)^b	27.00 (31.30)^b	9.87 (18.31)^b	18.42 (25.42)^b
Neem fruit powder	15-20 kg/ha	60.30 (50.94)^b	19.13 (25.94)^b	39.77 (39.09)^b	21.31 (27.48)^b	8.28 (16.73)^b	14.70 (22.54)^b
Consortia	(Sr.no 1 to 4)	57.30 (49.19)^b	18.53 (25.50)^b	37.95 (38.02)^b	19.30 (26.06)^b	6.52 (14.80)^b	12.90 (21.05)^b
Spinosad	73 g *a.i.*/ha	11.30 (19.64)^a	2.80 (9.63)^a	6.82 (15.14)^a	8.30 (16.07)^a	2.60 (9.29)^a	5.47 (13.52)^a
Control	Control	63.00 (52.53)^b	44.17 (41.65)^c	53.56 (47.04)^c	37.70 (37.87)^c	17.03 (24.37)^b	27.35 (31.53)^b
SE±m		3.7	1.95	0.20	4.03	0.35	0.25
CD at 5%		11.5	6.0	0.65	12.4	1.09	0.78

Figures in parentheses arc sin transformed values.

The values denoted by a common letter are showing significant difference from each other as per DMRT.

Consortia (Combination of *Streptomyces* sp + HaNPV + *Metarhizium anisopliae*+Neem fruit powder).

Table 5: Effect of various biopesticides on grain yield of pigeonpea.

Treatments	Dose	Grain yield kg/ha			Pooled increase in yield
	g a.i./ha or spores/ml	2016	2017	Pooled	over control (%)
Streptomyces sp.	5.85×10^7 colonies/ml	345	1179	762	30.92
HaNPV	500 LE/ha	402	945	674	15.80
Metarhizium anisopliae	39.2×10^4 spores/ml	383	1085	734	26.11
Neem fruit powder	15-20 kg/ha	473	1006	740	27.14
Consortia	(Sr.no 1 to 4)	383	1097	740	27.14
Spinosad	73 g a.i./ha	1194	1524	1359	133.50
Control	Control	348	816	582	0.00
SE±m		70.7	77.1	1.01	
CD at 5%		217.7	237.6	3.13	

applications of 5% NSKE as the most effective treatment resulting in the lowest pod damage and highest seed yield of 0.95q/ha. Present study agrees with observation of Yogesh and Kumar (2014) was evaluated biopesticides and insecticides against *H. armigera*. Minimum pod damage (18.89% and 18.83%) was observed in treatment NPV 250 LE + imidacloprid 17.8 SL in both the years. Chandra and Singh (2014) showed that the grain damage was ranged from 10.29 to 36.7% plot treated with Spinosad 45 SC @ 73 g a.i./ha was most effective with lowest pod damage (0.00%) followed by flubendiamide 20 WG (0.60%).

Efficacy of biopesticides on pigeonpea grain yield

During 2016 all the treatments registered significantly higher grain yields compared to the control. The highest grain yield was recorded in Spinosad 45 SC (T6) treated plots (1194 kg/ha) which was significantly superior to the rest of the treatments, followed by neem fruit powder (473 kg/ha) and HaNPV (402 kg/ha). The lowest yield was obtained in untreated control plot (348 kg/ha) and they differed significantly from each other. Grain yield of the year 2017 the data on healthy pod yield presented in Table 5. Haldar *et al.,* (2006) showed that Spinosad 45 SC at 73 g a.i./ha sprayed twice against major insect pests of pigeonpea at 15 days interval gave the maximum protection an highest grain yield of 840 kg/ha, followed by novaluron 10 EC (75 g). Similar finding conform with Ajagol *et al.* (2014) showed that IPM modules for management of pod borer complex in pigeonpea. The study concluded that pesticide based IPM module comprising Spinosad 45 SC proved to be cost effective by recording highest grain yield (2819 kg/ha). Shinde *et al.* (2013) revealed that the efficacy of microbials against *H. armigera* in chickpea and found that the HaNPV was most effective biopesticide which registered 16.78 q yield/ha.The highest grain yield was recorded in Spinosad 45 SC treated plots (1524 kg/ha) followed by *Streptomyces* sp. (1179 kg/ha) and consortia (1097 kg/ha). Lowest yield was obtained in untreated control plot (816 kg/ha). Two years (2016 and 2017) pooled data were presented in Table 5 revealed that the treatment of Spinosad 45 SC recorded the highest yield (1359 kg/ha) this was followed by *Streptomyces* sp. (762 kg/ha). The lowest yield was obtained in untreated control (582 kg/ha) (Table 5). Taggar and Singh (2015) showed that Spinosad 45 SC recorded the highest grain yield (711.93 kg/ha) which was followed by the commercial Bt formulation (1.5 kg/ha) and a combination of Bt and *B. bassiana* (3.0 g/liter). Gowda *et al.* (2003) reported highest (741 kg /ha) grain yield from the plots treated with Spinosad 45 SC @ 90 a.i./ha.

Increase in yield over control

The pooled data on yield increase over untreated control due to pod borer management in pigeonpea presented in Table 5. Among the different treatments, highest increase in yield over control was recorded in Spinosad 45 SC (133.50%), this was followed by *Streptomyces* sp.(30.92%). Whereas, it was minimum (15.80%) in the treatment of HaNPV (T2). Thus, yield increase over control ranged from 26.1 to 27.1 per cent.

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