ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF YARD LONG BEAN, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.

by

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(2015-11-052)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF YARD LONG BEAN, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF YARD LONG BEAN, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt"** is a record of research work done independently by Ms. Vineetha V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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'If you ate today; thank a farmer'

Dedicated to all farmers

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1. INTRODUCTION

One of the key components of Indian agricultural production is the legumes, among which vegetable cowpea or yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) contributes a major share. Cowpea is popularly known as 'vegetable meat' because of its high protein content. Vegetable cowpea is cultivated extensively for its green long pods. It is a crop of high value which prefers only fewer inputs. The ability to fix nitrogen in the atmosphere through root nodules is an important hallmark of this crop which helps farmers in restoring the soil fertility.

In Kerala, vegetable cowpea is cultivated in an area of 7150 ha out of the total cropped area of 2584007 ha. Among the districts of Kerala, Palakkad ranks first in the area of vegetable cowpea cultivation with 1230 ha. This was followed by Ernakulam district with 1057 ha and Malappuram district having 775 ha. Kasaragod district occupied the last position in vegetable cowpea cultivation with an area of 100 ha (GOK, 2017). The most important constraint that reduces the production and productivity of cowpea is the insect pests. The profuse vegetative growth of yard long bean invites more pests. The insect injury occurring at the most crucial period of growth stage of the crop causes great economic loss.

Among the insect pests, the important and the destructive ones are the aphids, *Aphis craccivora* Koch (Hemiptera: Aphididae); serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae); pod borers such as gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae); spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae); blue butterflies, *Lampides boeticus* (L.) (Lepidoptera: Lycaenidae); pod bugs such as *Riptortus pedestris* (F.) (Hemiptera: Coreidae); *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae); *Clavigralla tomentosicollis* (Stal.) (Hemiptera: Coreidae) and *Nezara viridula* (L.) (Hemiptera: Pentatomidae).

The spotted pod borer, *M. vitrata* is considered as the most devastating pest of yard long bean that causes about 40 per cent yield loss (Yule and Srinivasan, 2013). About 4-6 flowers are consumed by single larvae of *M. vitrata* (Sharma, 1998). It creates web inside flower buds and flowers and feeds by ensconcing on them. Moreover, it bores inside the pods and feed the internal contents. The pod borer, *Lampides boeticus* consume the flower buds and pods by boring and contaminating them which cause heavy yield loss (Ganapathy and Durairaj, 2000).

The attack of pod sucking bug, *C. tomentosicollis* results in desiccation and shrivelling of pods prematurely and formation of half filled pods. During its peak infestation, more than 80 per cent of yield loss occurs (Singh *et al.*, 1990). The cowpea aphid, *A. craccivora* attacks the plant throughout the season. They suck sap by piercing its stylets and inject toxins into the plant tissues. Aphids act as a vector in transmitting viruses which reduces the yield and reduced the market value of the crop (Radha, 2013). Life cycle of aphids is shorter and it posses high rate of reproduction that makes aphid management difficult. Moreover, they are polyphagous in nature (Suresh *et al.*, 2012).

For the management of these pests, different chemical insecticides are available in the market with different modes of action. Lack of technical knowhow in application of chemicals leads to its indiscriminate usage. The inappropriate use of insecticides causes build up of resistance in target species, resurgence of other pest species, devastation of natural enemies, disarray of ecosystem and considerable health impacts (Khade *et al.*, 2014). Taking into perseverance of these issues, some viable environmentally safe alternatives have to be formulated.

The entomopathogenic fungi like *Beauveria bassiana* and *Metarhizium anisopliae* can be included as a peripheral part of integrated pest management in cowpea (Srinivasan *et al.*, 2009). The phenomenal epizootics of *Lecanicillium* *lecanii* made the fungi a far-reaching entomopathogen in managing cowpea aphids (Suresh *et al.*, 2012). Neem and neem products affects the metamorphosis and generative capacity of insects (Dougnon *et al.*, 2013). Spinosad 45 SC exhibits very low toxicity to mammals and no catastrophic effects on exposure for a long time (Gour and Sreedevi, 2012).

Considering all these, there is a requisite for a study and advancement in the area of eco-friendly management of major pests of yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt. With this intention the present study aims to study the efficacy of different microbial agents, neem based and bio rational insecticides against major pests of yard long bean *viz.*, flower and pod borers, pod bugs, cowpea aphid and serpentine leaf miner.

Review of Literature

2. REVIEW OF LITERATURE

Yard long bean or Vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt is one of the common vegetable crops widely used and is a very good source of protein. Cowpea during all its growing stages shows vulnerability to many pests. The important and the destructive ones are the aphids, *Aphis craccivora* Koch (Hemiptera: Aphididae); serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae); pod borers such as gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae); spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae); blue butterflies, *Lampides boeticus* (L.) (Lepidoptera: Lycaenidae); pod bugs such as *Riptortus pedestris* (F.) (Hemiptera: Coreidae); *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae); *Clavigralla tomentosicollis* (Stal.) (Hemiptera: Coreidae) and *Nezara viridula* (L.) (Hemiptera: Pentatomidae).

A literature study was carried out to obtain related reviews regarding the title "Eco-friendly management of major pests of Yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" and the supporting ones are reviewed under following heads.

2.1 EFFICACY OF ENTOMOPATHOGENS, BIORATIONALS, NEEM BASED INSECTICIDE FORMULATIONS ALONG WITH A STANDARD CHECK

2.1.1 Effect of entomopathogens in controlling major pests of vegetable cowpea

According to Gopalakrishnan and Narayanan (1988), *Metarhizium anisopliae* 1.8 x 10^9 spores/ml caused 80-100 per cent larval mortality of *H. armigera* in all larval instars. But no mortality was found in eggs and adults.

According to Bateman *et al.* (1996), the intensity of fungal infection is based on their weight. The vulnerability of attack will be more in young instars than the older ones.

Ekesi *et al*. (1998) reported that *M. anisopliae* was found effective for the management of thrips in cowpea.

Ekesi (1999) reported that *Beauveria bassiana* CPD 9 and *M. anisopliae* CPD 5 at all concentrations cause higher mortality rate of adult bug *Clavigralla tomentosicollis* in cowpea.

To find out the efficacy of entomopathogenic fungi against *A. craccivora*, two strains of *M. anisopliae* CPD 4, 5 and *B. bassiana* CPD 11 were tested *invitro* and the aphids were fed with cowpea foliage. Seven days after treatment, the strains of *M. anisopliae* found superior over the other in having mortality rate of 64-93 per cent and 66-100 per cent respectively. *B. bassiana* CPD 11 showed mortality between 58-91 per cent whereas the control is having mortality of 5 per cent only (Ekesi *et al.,* 2000).

Lingappa and Hegde (2001) reported that entomopathogenic fungi can effectively control sucking pests of cowpea like *C. tomentosicollis, M. sjostedti*, as they are highly susceptible to the action of entomopathogens.

Ekesi *et al*. (2002) evaluated the performance of different entomopathogens against pests of cowpea and concluded that highest ovicidal activity was shown by *B. bassiana* and *M. anisopliae* against the eggs of *C. tomentosicollis* and *M. vitrata.* They also reported that about 80-90 per cent mortality in *M. vitrata* was shown by isolates of *B. bassiana* and *M. anisopliae* under both laboratory and green house conditions; which showed that these bio-pesticides are highly effective against *M. vitrata.*

According to Gundannavar and Lingappa (2003), *B. bassiana* treated plot showed a range of 5 to 52.50 per cent mortality rate in various instars of pod borer larvae, *H. armigera* on five days after treatment (DAT) and it later attained 100 per cent mortality within 10 days.

The shelf life of *B. bassiana* was tested under different conditions of storage *viz.*, deep freeze, refrigerated and under room temperature. The results showed that at room temperature the conidial density is 39.41×10^7 conidia per ml with 90.97 per cent virulence which do not differ when stored up to 90 days. In refrigerated condition a virulence of 92.27 per cent is maintained for 120 days and under deep-freeze condition 86.70 per cent virulence is achieved for 150 days (Puzari *et al.*, 2003).

Mahla *et al.* (2005) conducted a laboratory study to find out the pathogenicity of *M. anisopliae* 1 x 10^8 spores/ml and from the assay, 95 per cent mortality was seen in first instar larvae of *Plutella xylostella* and 86.66 per cent mortality in second and third instar larvae within four days of application.

The effect of different entomopathogens *viz.*, *B. bassiana, Lecanicillium lecanii* and *M. anisopliae* were tested against three aphid species and was found that *L. lecanii* VL-1 isolate of 1×10^7 spores caused maximum mortality of 80.80 per cent in *A. craccivora* (Nirmala *et al.*, 2006).

Laboratory experiment was conducted to find out the efficacy of *M. anisopliae* 1 x 10^8 spores/ml in killing the pod borer, *H. armigera* and found that high virulency was shown in case of first instar larvae with 72.50 per cent mortality (Gundannavar *et al.*, 2007).

Rijal *et al.* (2008) conducted a study to compare the efficiency of *B. bassiana, M. anisopliae, Bt* var. *kurstaki,* HaNPV, Azadirachtin and on chickpea pod borer, *H. armigera* and found that the larval population was less in

B. bassiana strain B3, *M. anisopliae* strain M1 treated plot compared to other treatments.

According to Rosell *et al.* (2008), among different mycoinsecticides, *B. bassiana* is the most prominent one and different strains were marketed in countries like South America, Europe, Russia and China. In United States, *B. bassiana* strain GHA was registered for the control of sucking pests like aphids and thrips.

Arivudainambi and Chandar (2009) reported that control of larvae of *L. boeticus* using *L. lecanii* recorded an increase in yield of more than six quintals per hectare in green gram.

Malarvannan *et al.* (2010) reported that *B. bassiana* when sprayed at higher concentration of 2.7 x 10^7 spores/ml showed significantly greater reduction of pupation in *Spodoptera litura*.

Six different entomopathogenic fungi were tested against adult aphid *A. craccivora* and 100 per cent mortality was shown by *L. lecanii* 10^8 spores/ml followed by *B. bassiana* and *M. anisopliae*. It was also noticed that mortality decreased with decrease in concentration of spores (Saranya *et al.*, 2010).

Soundararajan and Chitra (2011) evaluated the efficacy of *B. bassiana* by applying it as a combination of seed treatment @ 10 g/kg seed + foliar spray @ 5 g/l water and found that the pod damage caused by *M. vitrata* was 6.78 per cent whereas in control the pod damage was 13.33 per cent. Similarly the pod damage caused by *L. boeticus* was 4.66 per cent with control having 6.10 per cent pod damage.

According to Suresh *et al.* (2012), the virulent entomopathogenic fungi *L. lecanii* strain VL-3 when evaluated under field situations at spore concentration of 1×10^7, 1×10^8, 1×10^9 spores/ml showed that the strain VL-3 @ 1×10^9 caused highest percent mortality of about 71.62 in cowpea aphids.

To study the bio - efficacy of *M. anisopliae,* concentrations of conidia ranging from 1×10^3 to 1×10^{11} were sprayed against *A. craccivora*. From the study it was found that five days after treatment (DAT), 1×10^{11} concentrations showed maximum aphid mortality of 83.83 per cent. The second highest mortality rate was shown by 1×10^{10} spore concentration (64.72 per cent) followed by 1×10^9 spore concentration with 52.96 per cent mortality (Dutta *et al.,* 2013).

Among different biorationals and insecticides tested in pigeon pea against the pod bug *Clavigralla gibbosa* during pod formation stage and 15 days after first spray, *L. lecanii* 1×10^{10} spores gave a yield of 0.720 t/ha compared to control having an yield of 0.489 t/ha (Gopali *et al.,* 2013).

The effects of entomopathogens *B. bassiana, L. lecanii* and *M. anisopliae* were tested against *A. craccivora* and maximum mortality of 80.80 per cent were recorded in the plot treated with *L. lecanii* VL-1 isolate (Halder *et al*., 2013).

Anitha and Parimala (2014) reported that out of various biorationals tested against *M. vitrata* in pigeon pea, *M. anisopliae* when sprayed gave a yield of 1123 kg/ha with a B: C ratio 2.4 and the percent of pod damage was 8.20 over control having a yield of 791 kg/ha and B: C ratio 1.1 with 16.20 per cent pod damage.

According to Mehinto *et al*. (2014), the pathogenecity due to conidia of *Beauveria bassiana* strain Bb 115 and *Metarhizium anisopliae* strain Ma 29 against *M. vitrata* showed significantly greater mortality rates of first and fifth instar larvae respectively.

Subhasree and Mathew (2014) reported that to manage the pod borer complex of cowpea *Vigna unguiculata*, use of Azadirachtin (0.005 per cent) and other bioagents like *M. anisopliae* 1 per cent, *B. bassiana* 1 per cent, *Bt* 0.2 per cent was found to be effective in reducing the larval population below ETL.

Two strains of *L. lecanii* (V18 and V24) were bioassayed to find out their virulence against different aphid species. Though both the strains were pathogenic to aphid species, their virulence varied according to LC 50 and LT 50 values and the highest virulence was shown by strain V24 against the homologous aphid species. This assay proved that *L. lecanii* is effective for aphids (Alavo, 2015).

Rani *et al*. (2015) reported that a new species from the genus *Lecanicillium* known as *Lecanicillium saksena* isolated from the soil of vellayani proved to be an optimistic isolate for controlling sucking pests. Within 24 hours of application of this isolate, 100 per cent mortality of *A. craccivora* was recorded.

To formulate an IPM strategy for groundnut, different modules were tested among which the lowest sucking pest population were recorded by the module with combination of *L. lecanii* 6 g/l, *B. bassiana* 6 g/l, and SL NPV @ 100 LE/ acre (Biradar and Hegde, 2016).

Various biopesticides were sprayed thrice on pigeon pea during pod formation stage against pod borer, *H. armigera* and the larval count was taken 24 hours before spray and post count after 3, 7, 10 days of each spray. The bio-efficacy of *B. bassiana* was found superior with 5.87 larvae/5 plants which were low when compared to control having 11.21 larvae/5 plants when observed 10 DAT (Pandey and Das, 2016).

Bioassay was conducted using entomopathogenic fungi to test their effect on natural enemies (coccinellid predators like *Chilomenes sexmaculata* and *Micromus timidus*). The results showed that the population of these predators in the treated plot and untreated plot showed no difference whereas these microbial agents infected the sucking pest by direct contact on its cuticle and not by means of ingestion. That is the reason why entomopathogenic fungi are mostly preferred for controlling sucking pests of cowpea. Thereby it helps in maintaining sustainable crop production (Ramanujam *et al.,* 2017). They also reported that different isolates of entomofungal pathogens (1×10^8 cfu/ml spores) were sprayed thrice on cowpea at 30^{th}, 45^{th}, and 60^{th} days after planting for the control of aphids and was found that *L. lecanii* VL-8 has higher efficiency with 78.01 per cent reduction in aphid population followed by *B. bassiana* strain Bb-58 with 77.42 per cent reduction and *M. anisopliae* strain Ma-6 suppressed 76.91 per cent of the aphid population.

2.1.2 Effect of *Bacillus thuringiensis (Bt)* in controlling major pests of vegetable cowpea

According to Horn (1988), for the microbial pesticides to be effective, each spray drop must possess the pathogen and they will degrade easily under sunlight. So they should be diluted in limited range only.

Gill *et al.* (1992) reported that among bacteria, *Bacillus thuringiensis* proved to be the most important microbial pesticide in killing insect pests. In worldwide market, more than 40 number of *Bt* products are available which can be used for controlling mainly lepidopteran caterpillars. Moreover *Bt* products contribute about 1 per cent in the world insecticide market.

According to Lingappa and Hegde (2001), *Bacillus thuringiensis* var. *kurstaki* is a broad spectrum and widely available microbial insecticide that can effectively kill *M. vitrata* and *S. litura.*

Suhas *et al.* (2003) formulated bio intensive and adaptive modules for managing pigeon pea pod borer *H. armigera* by including HaNPV 250 LE/ha, *Bt* @ 1 kg/ha, NSKE 5 per cent as biointensive module. Adaptive module include Profenphos 1 kg ai/ha, NSKE 5 per cent, HaNPV, Alphamethrin 10 EC @ 0.05 kg ai/ha. From this the biointensive method was found cost effective with high B: C ratio of 2.30 which proved that during heavy pest load the bio intensive module has to be adopted.

Subspecies or strains of *B. thuringiensis* are widely used as microbial pesticides for the control of larvae on crop plants. The mode of action of *Bt* is that the protein produced by *Bt* binds to the gut receptor resulting in the starvation of larvae (Rosell *et al.*, 2008).

According to Yadav and Sharma (2010), on evaluating the IPM components against *H. armigera* in chick pea using components like bird perches @ 50/ha, *Bt*-k @ 1 kg/ha, and a chemical, revealed that the IPM block was effective with minimum population of larvae (1.38 larvae/m row length) over farmer's practice (3.27 larvae/m row length). Moreover the incidence of *H. armigera* was reduced to 57.80 per cent in the IPM package with an increase in the grain yield.

Dhaka *et al.* (2011) reported that on spraying *Bt* @ 1500 g/ha the percentage infestation of pods was 13.68 when compared to control with 14.96 per cent infestation 3 days after spray (DAS) and 20.86 per cent of infestation when compared to control having 26.36 per cent 9 DAS in vegetable pea.

The *Bt* formulations Biolep 0.5 per cent, Bioasp 0.5 per cent, neem formulations *viz.,* NSKE 5 per cent, Nimbecidine 2 per cent, Neem oil 2 per cent and three chemicals *viz.,* Endosulfan 0.07 per cent, Monocrotophos 0.04 per cent and Endosulfan 0.025 per cent were sprayed on chick pea during pod forming stage against *H. armigera* and results showed that along with chemicals, Biolep 0.5 per cent was found superior in controlling pod borer with reduction in larval population from 4.5 larvae/plant to 2 larvae/plant followed by NSKE 5 per cent (Agrawal and Ram, 2013).

Spraying of *B. thuringiensis* var. *kurstaki* 1.5 per cent during flowering time and during pod formation and a second spray 20 days after first spray reduced the pod damage to 2.45 per cent compared to control having 4.62 per cent pod damage caused by *L. boeticus* in pigeon pea (Singh *et al*., 2013).

According to Yule and Srinivasan (2013), the mean pod damage caused by *M. vitrata* in *B. thuringiensis* subsp. *kurstaki* treated plot was 25.73 per cent and in *B. thuringiensis* subsp. *aizawai* treated plot was 25.53 per cent where as in the control, the pod damage was 40.06 per cent. Thus *M. vitrata* showed more susceptibility towards *B. thuringiensis* subsp. *kurstaki* and *B. thuringiensis* subsp. *aizawai,* and these becomes an important component in the integrated pest management strategy in cowpea.

Anitha and Parimala (2014) reported that on testing the performances of different biorationals against *M. vitrata, Bt* formulation (Dipel) recorded highest yield (1235 kg/ha) with 5.1 per cent of pod damage compared to control (791 kg/ha) showing 16.2 per cent pod damage in pigeon pea when it was applied thrice on the crop during 50 per cent flowering, full flowering and pod initiation stage.

Application of *B. thuringiensis* (0.2 per cent) for controlling pod borer complex in cowpea, *V. unguiculata* recorded a higher yield in terms of pod weight (Subhasree and Mathew, 2014).

Amizadeh *et al*. (2015) conducted an experiment in culture medium to find out the effect of chemicals on the colonisation of *B. thuringiensis* var *kurstaki* and it was found that no chemicals tested had reduced colonisation in *Bt*.

In order to find out the economics involved in using pesticides and bio-agents for controlling *H. armigera,* Gupta *et al*. (2016) conducted an experiment with treatments *viz.,* HaNPV, *Bt* var. *kurstaki*, NSKE 5 per cent, and a chemical combination on chick pea. They were sprayed two times when the pest level crossed ETL. Studies revealed that *Bt* showed a B: C ratio of 1: 2.7 followed by HaNPV with B: C ratio 1: 2.4 proving that these bioagents are less economical.

The *Bt* strain NBAII-*Bt*G4, 2 per cent (liquid formulation) was found to be effective against spotted pod borer, *M. vitrata* and gram pod borer, *H. armigera* in pigeon pea with less pod damage of 5.30 per cent which was on par with the chemical treatment chlorpyriphos with 5.07 per cent pod damage. Similarly *B. bassiana* PDBC-BT1 at 2 per cent also showed equal effect with respect to the superior ones revealed that bio-pesticide use should be encouraged (Kumar *et al.*, 2016).

2.1.3 Effect of Spinosad in controlling major pests of vegetable cowpea

According to Khalid *et al.* (2000), in a laboratory study conducted to know the ovicidal effect of newer insecticides against *S. litura*, Indoxacarb recorded maximum mortality rate of 86.66 per cent which was followed by Spinosad with 77.33 per cent mortality.

Dey and Somchoudhury (2001) reported that Spinosad 48 SC at the rate of 15-25 g a.i/ha was found to be more promising for the control of most of the lepidopteran caterpillars and moreover it doesnot adversely affect the parasitoids.

Mittal and Ujagir (2005) compared the efficacy of different insecticides against gram pod borer, *H. armigera* in pigeon pea and concluded that Spinosad at 90 g a.i/ha and 45 g a.i/ha were the effective insecticides.

Singh and Verma (2006) evaluated the efficiency of Novaluron along with some newer insecticides like Emamectin Benzoate and Spinosad against *H. armigera* in chickpea and arrived at the conclusion that all the three molecules found superior showing lowest pod damage and higher grain yield.

Rao *et al*. (2007) reported that application of Spinosad and Indoxacarb showed a drastic reduction in the population of *M. vitrata* by about more than 70 per cent in pigeon pea within two days after application.

According to Durairaj and Sreenivasan (2007), Spinosad 45 SC (73 g a.i/ha) when sprayed against *H. armigera* recorded minimum population of 2/plant on comparison with the control having maximum population of 6.7/plant.

According to Tamboli and Lolage (2008), Spinosad proved to be the most promising insecticide in controlling the larvae of *H. armigera* in pigeon pea recording 0.29 larvae/plant with 5.62 per cent pod damage which was very low compared to the control followed by Flubendiamide 20 WDG 50 g a.i/ha and Novaluron 10 EC 75 g a.i/ha.

Sunitha *et al.* (2008) reported that among different pesticides tested for controlling *M. vitrata*, higher efficacy was shown by Spinosad and Indoxacarb whereas moderate effect was shown by *M. anisopliae* and *Bt*.

Kumar and Shivaraju (2009) reported that Spinosad (Tracer) 45 SC @ 84.375 g ai/ha reduced the population of *H. armigera* from 8.98 larva/10 plants to 3.3 larva/10 plants after two sprays. Also the percentage pod damage calculated after spraying Spinosad was 16.26 per cent where as in control, it was 39 per cent.

According to Mallikarjuna *et al*. (2009), for the control of pod borers of field bean, *Lablab purpureus,* twelve different treatments were applied and among them Spinosad 45 SC @ 0.2 ml/l recorded high yield of 13.69 q/ha compared to the untreated plot with a yield of 3.17 q/ha.

Ankali *et al*. (2011) reported that Spinosin after seven days of application caused 100 per cent mortality of *M. vitrata,* whereas 70 per cent mortality was shown by *Bacillus thuringiensis* and NSKE.

According to Dhaka *et al.* (2011), the percentage infestation of pods three days after second spray of Spinosad @ 500 ml/ha in pigeon pea was 12.60 per cent whereas in control the percentage infestation of pods was 23.05 per cent The observation taken nine days after second spray showed that the infestation reduced to 11.94 per cent in the treatment plot and increased to 26.36 per cent in the control.

Sreekanth and Seshamahalakshmi (2012) conducted a study to assess the toxic effect of biopesticides and insecticides on *H. armigera* and *M. vitrata* in pigeon pea, Spinosad 45 SC @ 73g ai/ha sprayed plot showed 4.47 per cent damage to the inflorescence and 17.38 per cent pod damage which was very low compared to the control plot with 24.79 per cent inflorescence damage and 45.84 per cent pod damage. Moreover Spinosad treated plot gave the highest grain yield of 831 kg/ha over control having 407.4 kg/ha.

Spinosad @ 0.1 ml/l when sprayed against pod bug *C. gibbosa* during the tender pod stage and 15 days after first spray in pigeon pea resulted in 30.69 per cent pod damage whereas in the control, pod damage was 40.56 per cent. Similarly the Spinosad sprayed plot gave a better grain yield of 0.787 t/ha compared to control having 0.489 t/ha (Gopali *et al.*, 2013).

Narasimhamurthy and Ram (2013) reported that Spinosad 45 SC was effective against pod bug, *C. gibbosa* in pigeon pea and there was reduction of 89.85 per cent in population which was on par with Indoxacarb 14.5 SC with 89.26 per cent population reduction.

Radha (2013) reported that Spinosad @ 2.5 per cent caused 89 per cent mortality of *A. craccivora* in cowpea when compared to control having mortality of only 5 per cent. Spinosad also reduced the percentage of adult emergence in aphids.

Anitha and Parimala (2014) reported that Spinosad 45 SC when sprayed against *M. vitrata* in pigeon pea, gave the least pod damage of 5.10 per cent with higher yield (1237 kg/ha) compared to control having 16.20 per cent pod damage and yield of 791 kg/ha.

Umbarkar and Parsana (2014) reported that among different insecticides, Spinosad 0.009 per cent showed highest mortality percentage of *M. vitrata* when it was sprayed during 50 per cent flowering stage and a second spray 15 days after first spray in green gram.

According to Yadav and Singh (2014), insect count taken on 3^{rd}, 7^{th} and 10^{th} day after first spray of insecticides showed that after 3^{rd} day of spray the population of larvae (*M. testulalis*) were low in Spinosad 45 SC sprayed plot.

The reduction of pod borer larvae of *H. armigera* in chick pea from 9.29 to 2.7 after first spray of Spinosad 45 SC @ 84.37g ai/ha and again reduced to 2.10 after second spray showed that Spinosad is effective against *H. armigera* (Adsure and Mohite, 2015).

Sreekanth *et al*. (2015) reported that inflorescence damage caused by *M. vitrata* in Spinosad treated plot of pigeon pea was only 6.21 per cent while in the control plot it was 31.18 per cent. Also Spinosad treated plot gave the highest grain yield.

Application of Spinosad 45 SC @ 150 ml/ha showed the highest reduction of larval population in *Spodoptera exigua* (97.90 per cent) compared to control and 91.8 per cent population reduction in *H. armigera* along with a greater seed yield of 1200 g/ha where as the control plot yields only 561 g/ha (Suneelkumar and Sarada, 2015).

Sreelakshmi and Paul (2016) reported that under laboratory conditions Spinosad showed 100 per cent mortality of pod borer *M. vitrata* even at 12 hours after treatment.

According to Biradar and Hegde (2016), the control of leaf miner was found effective by spraying of Spinosad 45 SC @ 0.25 ml/l.

Bioefficacy of eight newer insecticides were evaluated against plume moth, *Exelastes atomosa* in pigeon pea and found that least pod damage of 5.06 per cent was recorded by Spinosad 45 SC @ 73 g a.i/ha with 11.40 per cent pod damage in the control. Also Spinosad recorded the least grain damage of 1.56 per cent when compared to control having 5.46 per cent (Nithish *et al.*, 2017).

2.1.4 Effect of Neem oil in controlling major pests of vegetable cowpea

Neem oil emulsifiable concentrate exhibited very high degree of insecticidal activity with greater reduction in the population of the third instar larvae of *M. vitrata* in cowpea (Jackai and Oyediran, 1991).

Extract of dried neem leaves 20 per cent by weight can be used for controlling leaf feeding caterpillars and 35 per cent by weight was needed for the control of *M. vitrata* and thrips in pulses (Jackai and Oyediran, 1991).

The efficacy of insecticides and botanicals on green gram aphid *A. craccivora* were tested and found that TNAU Neem oil (3 per cent) can effectively control the aphids recording drastic reduction in their population. It also contributed a higher yield of 7.4 q/ha (Chandrasekharan and Balasubramanian, 2002).

Opareke *et al.* (2005) evaluated the efficiency of neem along with other leaf extract mixtures against *M. vitrata* and *C. tomentosicollis* in cowpea and found that the maximum mortality of *M. vitrata* was shown by Neem + Lemon grass mixture and the number of *C. tomentosicollis* was highly reduced by spraying Neem + African curry leaf.

Neem oil which is produced by cold- pressing of seeds is very effective against sucking and soft bodied insects and also used in controlling phyto-pathogens. The bioactivity of neem oil is contributed by disulfides present in the oil (Isman, 2006).

Rajnish *et al.* (2006) reported that neem based formulations *viz.*, NSKE 3 per cent, Achook 0.3 per cent, Neemgold 0.3 per cent and Nimbecidine 0.3 per cent were found to have comparable effect as that of the chemical insecticide dimethoate.

Satyavir and Yadava (2006) reported that the locally formulated crude neem oil caused high per cent mortality of *H. armigera.*

Singh and Yadav (2006) evaluated the efficacy of different formulations of neem and it was found that 85.88 per cent increase in yield was shown by nimbecidine treated plot. The second highest yield of 64.63 per cent was shown by the plot treated with neem based formulation, Achook.

Ahmed *et al.* (2009) reported that insect pests of cowpea can be controlled effectively at the pod formation stage using the extracts from neem, garlic, ginger than any other plant extracts. These are lethal to pests like *M. vitrata, C. tomentosicollis* and *Megalurothrips sjostedti* as these extracts act as repellants on plants.

According to Arivudainambi and Chandar (2009), neem oil was found more effective than NSKE in controlling the larval population of blue butterfly, *Lampides boeticus.*

According to Byrappa *et al.* (2009), neem oil 2 per cent is very effective in controlling pod borer complex in legumes.

Spraying neem oil @ 30-40 ml per litre water along with a suitable emulsifier such as liquid soap 1ml can control sucking pests like aphids, whiteflies and stem borers in black gram (Gupta and Pathak, 2009). They also reported that during kharif season, in black gram the efficacy of neem products, insecticides and their combinations were tested and the incidence of pod borer, whitefly and yellow mosaic came down with the use of admixture NSKE 3 per cent with dimethoate 0.03 per cent and dimethoate 0.03 per cent with neem oil 0.5 per cent.

Egho and Emosairue (2010) reported that calendar spray of NSKE 5 per cent at 10 days intervals (CA. S10) and monitored spray (MOS) by which insects were monitored before chemical application proved to be better and beneficial than calendar spray at intervals of seven days (CA. S7).

According to Ganapathy *et al.* (2010), spraying of neem oil 3 per cent 35 days after sowing (DAS) found to be effective against leaf miner, *L. trifolii* by recording 29.7 per cent mean leaf damage compared to control having 43 per cent mean leaf damage.

To evaluate various IPM measures against *H. armigera* in the chick pea, various combination of treatments were considered and from the pooled data it was found out that the lowest pod damage of 9.08 per cent was recorded from the combination NSKE 5 per cent @ 2.5 L/ha, HaNPV 250 LE/ha, *Bt* @ 2 kg/ha. Also the yield was high in the above module with 13.07 quintal/ha compared to other modules (Jadhav *et al.,* 2010).

According to Degri and Sodangi (2013), application of neem seed oil four times had significantly reduced the population of the pod sucking bugs

N. viridula, C. tomentosicollis, R. pedestris and the flower beetle *Mylabris* sp. in cowpea.

According to Singh *et al*. (2013) two sprays of the biopesticide NSKE 5 per cent, first during flowering stage followed by 20 days after first spray showed that the percentage of pod damage caused by the larvae of blue butterfly in pigeon pea was 1.28 per cent compared to control 3.34 per cent.

Among different biorationals tested against *M. vitrata* in pigeon pea, neem oil 5 per cent when applied during 50 per cent flowering, full flowering and at pod initiation stage recorded less pod damage of 8.6 per cent with better yield of 1101 kg/ha and B: C ratio 2.5 over the untreated plot having 16.2 per cent pod damage, yield of 791 kg/ha and B: C ratio 1.1 respectively (Anitha and Parimala, 2014).

According to Khade *et al*. (2014), the application of neem oil 1 per cent recorded 64.84 per cent nymphal reduction and *L. lecanii* (2×10^9 cfu/ml) recorded 54.35 per cent reduction of nymphal population of aphids in cowpea, *Vigna sinensis*.

Rai *et al*. (2014) reported that the leaf miner attacking cowpea can be managed by spraying NSKE 5 per cent 10 days after germination.

Umbarkar and Parsana (2014) reported that the percentage of pod damage caused by *M. vitrata* on application of NSKE 5 per cent were 26.32 per cent whereas in control it was 32.89 per cent, which showed that NSKE 5 per cent can effectively control pod borer in green gram.

2.1.5 Effect of Azadirachtin in controlling major pests of vegetable cowpea

According to Das *et al.* (2000), in the evaluation of various botanicals and biopesticides in controlling pod borer *H. armigera* in pigeon pea, Azadirachtin 1500 ppm retained its efficiency upto 72 hours after spray.

According to Dhaliwal and Arora (2004), neem based formulations should be sprayed at the time of egg hatching in insects so that the insects could be controlled at the initial stage itself. Also the effectiveness of neem products could be increased if they were sprayed along with other selective insecticides.

In certain crops, Azadirachtin shows systemic action which increases its efficiency greatly and also the field persistence. Also Azadirachtin is non- toxic to all mammals. Azadirachtin showed a half- life period of 20 hours when applied to plants (Isman, 2006).

The neem formulations like Azadirachtin (Neemix) 4.5 EC @ 23g a.i/ha and neem oil emulsion 1 per cent were evaluated to find out their efficacy in controlling *Aphis glycine*. Azadirachtin could be able to increase the nymphal mortality by 80 per cent and neem oil increased the mortality rate by 77 per cent (Kraiss and Cullen, 2008).

Mehta *et al.* (2010) reported that Neemazal when sprayed three times on cowpea at 20 ppm concentration showed greater reduction in larval population (71.29 per cent) of *H. armigera* and higher fruit yield was recorded.

According to Krishna *et al.* (2011), Neemazal F (0.1 per cent) was found to be significantly superior in controlling *M. vitrata* by recording highest grain yield of 11 q/ha.

The effect of NSKE 5 per cent and Azadirachtin 0.001 per cent was comparable to that of Endosulfan with respect to the mortality of *M. vitrata* where

NSKE treated plot recorded 83-85 per cent mortality followed by Azadirachtin (82.84 per cent) and Endosulfan treated plot recorded mortality of 87.89 per cent (Kanhere *et al*., 2012).

According to Singh *et al*. (2013), larval population of *L. boeticus* were reduced by 2 sprays of Nimbecidine 1 per cent one at flowering time and second at pod formation stage.

Rai *et al*. (2014) reported that *M. vitrata* can be controlled effectively by giving a need based spray of Azadirachtin 0.005 per cent or NSKE 4 per cent.

2.1.6 Effect of Malathion in controlling major pests of vegetable cowpea

Six different insecticides were tested to find out their efficacy in controlling pod borer complex of cowpea *Vigna unguiculata* among which the Malathion @ 1.2 l/ha showed a reduction in pod damage by 42.8 per cent whereas the control plot showed pod damage of 90.66 per cent. Also in malathion sprayed plot the population of *M. vitrata* per five plant was 5.33 which was low compared to the control having larval population 10.60 (Jagginavar *et al.,* 1991).

Vikram *et al.* (2000) reported that among different IPM modules tested, the module comprising combination of insecticides and biopesticides was proved to be significantly dominant in controlling *H. armigera* in chickpea and thereby increased the production.

Lal (2008) reported that the sucking pests of mung bean can be controlled by spraying Malathion 50 EC, 950 ml or Rogor 30 EC, 625 ml or Metasystox 25 EC, 625 ml in 200 litre water.

Spraying of Malathion 0.1 per cent or Quinalphos 0.05 per cent is very effective against the pea aphid, *Aphis craccivora* (KAU, 2011).

Byrappa *et al.* (2012) reported that Malathion 50 EC @ 0.125 per cent when sprayed on 45, 55, 70 days after germination (DAG) of dolichos bean, significantly lowered the larval population of *L. boeticus* seven days after third spray.

According to Rai *et al.* (2014), Solenopsis mealy bug (*Phenacoccus solenopsis*) a polyphagous pest attacking cotton now became a threat to majority of the vegetable crops and can be controlled effectively by spraying Malathion 50 EC @ 2ml/l. They also reported that the incidence of Hadda beetle, *Henosepilachna vigintioctopunctata* found to be attacking on cowpea severely in many parts of the country and a need based spray of Malathion @1 kg ai/ha was recommended for its control and also opinioned that the attack of *Sphenarches caffer* (Zeller) was controlled by spraying of Malathion @ 2 ml/l.

According to Reghunath *et al.* (2014), the extract taken from 20g garlic when mixed with Malthion 50 EC 4 ml/l of water and sprayed on to cowpea, *Vigna unguiculata* found significantly superior in controlling the pod bugs.

Malathion 50 EC 2 ml/L of water or Quinalphos 25 EC 1.25 ml/l of water can be used for controlling cowpea aphid, *Aphis craccivora* (KAU, 2016).

Materials and Methods

2. MATERIALS AND METHODS

A study was carried out on "Eco-friendly management of major pests of yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" at College of Agriculture, Padannakkad during Kharif and Rabi season in the year 2016. The main objective of the work was 'to study the efficacy of different microbial agents, neem based and bio-rational insecticides against major pests of yard long bean, *viz*., cowpea aphid, serpentine leaf miner, flower and pod borers, and pod bugs'.

3.1 LOCATION OF THE EXPERIMENT

The research work was carried out in the Instructional Farm of College of Agriculture, Padannakkad during kharif season from May to August 2016 and rabi season from September to December 2016.

3.2 EXPERIMENT MATERIAL

The Yard long bean or vegetable cowpea variety Lola released by KAU was selected for conducting the study.

3.3 DETAILS OF THE EXPERIMENT

The experiment was laid out in Randomized Block Design with 9 treatments and three replications. The following were the treatments used.

Treatments		
T_1	*Beauveria bassiana* (liquid formulation)	10^7spores/ml of water
T_2	*Metarhizium anisopliae* (liquid formulation)	10^7spores/ml of water
T_3	*Lecanicillium lecanii* (liquid formulation)	10^7spores/ml of water
T_4	*Bt* formulation 2×10^8 cfu/ml	1 ml/l of water

T_5	Neem based insecticide (Azadirachtin 1%)	5 ml/l of water
T_6	Neem oil emulsion 5%	50ml/l of water
T_7	Spinosad 45 SC	0.4 ml/l of water
T_8	Malathion 50 EC – Standard check	2ml/l of water
T_9	Absolute control	

All the treatments except fungal entomopathogens were sprayed by diluting the recommended dose in one litre water and the control plot was treated with water. The treatments were imposed at fortnightly intervals just after the initial attack of pest was seen. Observations were recorded at weekly intervals corresponding to standard weeks.

3.4 PREPARATION OF ENTOMOPATHOGENIC FUNGAL AGENTS FOR SPRAYING AGAINST MAJOR PESTS OF YARD LONG BEAN

3.4.1 Maintaining the pure culture of entomopathogenic fungi

The pure culture of entomopathogenic fungi *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii* needed for the conduct of the research work were brought from National Bureau of Agricultural Insect Resources (NBAIR), Bangalore. The cultures were transferred to Potato Dextrose Agar medium (PDA) by sub culturing the pure cultures under laboratory conditions. All the three fungal entomopathogens were sub cultured periodically to PDA slants and stored under refrigerated conditions for future use.

3.4.1.1 Preparation of Potato Dextrose Agar Medium (Saxena *et al.*, 2012)

Potato Dextrose Agar is the most widely used medium for cultivating and storing fungi as it induces better sporulation. PDA also helps in maintaining the stock cultures.

The composition of PDA include

Potato	: 200g
Dextrose	: 20g
Agar	: 20g
Water (distilled)	: 1 Litre

200g potato were cut into pieces and boiled in 500ml distilled water for about 20 minutes until the potatoes get cooked well. The contents were strained using a muslin cloth and the filtrate was collected. To the filtrate 20g dextrose was added. Agar (20g) was melted in some known quantity of distilled water by boiling and was added to the above filtrate. Distilled water was added to make the volume of the extract to 1 Litre. The mixture was then distributed equally in conical flasks and kept for sterilization in autoclave at 121^0 C for 20 minutes under 15 psi. After sterilization, the medium was poured in petri plates under laminar airflow chamber to avoid contamination. The fungal hyphae from the mother culture were transferred aseptically on to petri plates having PDA to obtain new culture for mass multiplication. The petri dishes were sealed and incubated at room temperature of 25 ± 1^0 C. Complete sporulation was seen 2 weeks after inoculation. The fungal discs cut from the media plates were transferred into PDA slants to maintain pure culture.

3.4.1.2 Beauveria bassiana (White muscardine fungus)

The media preparation and maintenance of culture were done as described in 3.4.1.1. Complete sporulation was seen two weeks after inoculation. The culture can be identified by the formation of white mycelia mat with white coating above the mat (Plate 1. a).

3.4.1.3 Metarhizium anisopliae (Green muscardine fungus)

The media and fungal culture was prepared as mentioned in 3.4.1.1. By 10-14 days complete sporulation occurred and green coloured sporulating colonies were found on white mycelia mat (Plate 1. b).

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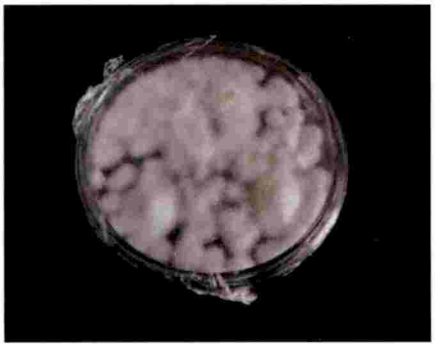
Plate 1. Primary culture of entomopathogenic fungi

(a) Beauveria bassiana

(b) Metarhizium anisopliae



(c) Lecanicillium lecanii

3.4.1.4 Lecanicillium lecanii (White halo fungus)

The fungus were cultured in PDA medium as described in 3.4.1.1 and white cottony mycelial growth were seen 10-14 days after inoculation (Plate 1. c).

3.4.1.5 Mass multiplication of Beauveria bassiana (Dhingra and Sinclair, 1993)

Mass multiplication of entomopathogenic fungi was done under laboratory conditions in Potato Dextrose Broth (PDB). The composition of PDB include

Potato	- 200g
Dextrose	- 20g
Water (distilled)	- 1 Litre

200g of potato were sliced and boiled in 500ml distilled water for about 20 minutes until the potato was cooked well. Using a muslin cloth the contents were strained and to the collected filtrate 20g dextrose was added. The filtrate was then made up to 1 litre by adding distilled water. 300ml of the prepared broth was then transferred to glucose bottles of 500ml capacity. Mouth of the bottles were plugged with cotton and sterilized in autoclave at 15psi under 121^0 C for 20 minutes.

Discs were cut from the sub cultured fungal plates and transferred to the bottles containing PDB. The mouth of the bottles were plugged with cotton and allowed to incubate under room temperature of 25 ± 1^0 C for 14 days. Complete sporulation could be seen by 10-14 days and white mycelia mat got occupied completely over the PDB showing a white bloom appearance (Plate 2. a). The mycelia mat along with little amount of broth was grinded thoroughly using a pestle and mortar. The density of spore suspension was then determined using a haemocytometer.

3.4.1.6 Mass multiplication of Metarhizium anisopliae

Mass multiplication of *M. anisopliae* was done in PDB with the procedure as described in 3.4.1.5. Complete sporulation could be seen by 10-14 days and the mycelia mat was occupied with greenish spores (Plate 2. b). The mycelia mat along with little amount of broth was grinded thoroughly using a pestle and mortar. The density of spore suspension was then determined using a haemocytometer.

3.4.1.7 Mass multiplication of Lecanicillium lecanii

The procedure used for mass multiplication of *L. lecanii* was same as described in 3.4.1.5. The white halo fungal mycelia mat covered completely over the broth by two weeks (Plate 2. c). The fungal mat was grinded with a pestle and mortar and the density of spore suspension was then determined using a haemocytometer.

3.4.2 Determining the density of spore suspension (Aneja, 1993)

The fungal spores of *B. bassiana, M. anisopliae* and *L. lecanii* in liquid suspension were assayed using Neubauer haemocytometer (Plate 3.). The fungal suspension from the PDB of *B. bassiana, M. anisopliae* and *L. lecanii* was filtered using muslin cloth to remove the mycelium and spore suspension was prepared separately. Using a micropipette 50µl of each of the suspension was pipetted into the engraved grid of the counting chamber. Cover slip were placed carefully over the slide and observed under compound microscope in 40X magnification. The spores were counted and average number of spores was taken. The spore density was calculated using the formula,

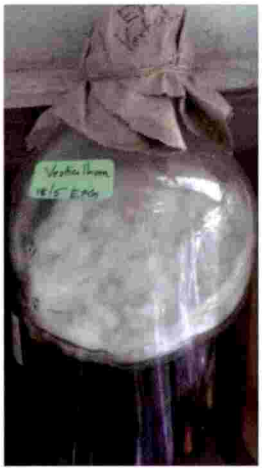
$$\textbf{Spores/ml} = \textbf{(n)} \times 4 \times 10^6$$

Where n = the average spore count per square counted

Plate 2. Mass multiplication of entomopathogenic fungi

(a) Beauveria bassiana

(b) *Metarhizium anisopliae*



(c) Lecanicillium lecanii

After determining the density of spore suspension, 2 per cent of each of the fungal entomopathogens of 1 x 10^7spores/ml of water were sprayed on to the crop at fortnightly intervals. The commercial formulation of *Bt* 2 x 10^8 cfu/ml (BT CARE) was purchased from Biopharmacy, Krishibhavan, Nileshwar. The other treatments *viz.*, Azadirachtin 1 per cent (NEEMAZAL- T/S), Neem oil 300ppm, Spinosad 45 SC (TRACER), Malathion (JAITHION) were purchased from the local chemical dealers and used.

3.4.3 *In vivo* experiment

The field level experiment was carried out in the Instructional Farm, College of Agriculture, Padannakkad using the vegetable cowpea variety Lola. Since the area was prone to the attack of stem fly, *Ophiomyia phaseoli* it was decided to raise the seeds of vegetable cowpea in protrays and later the seedlings were shifted to the main field.

3.4.3.1 Preparation of seedlings

Potting mixture was prepared initially by mixing soil, coirpith compost and vermicompost in the ratio 1:1:1 and were filled in the protrays. During each season, 35 g of seeds needed for 2 cents were sown in protrays having 50 cavities per protray @ one seed per cavity. Three such protrays were taken during each season. The seedlings were shifted to the main field when they were of 20 days old.

3.4.3.2 Preparation of main field

The Details of the experiment are as follows.

Area- 2 cents	Variety-Lola	Design-RBD
No. of treatments- 9	No. of replications - 3	Seasons – kharif and rabi

Land preparations were done on the days prior to shifting of seedlings. Farm yard manure (FYM) and lime were applied during the time of first ploughing and NPK fertilizers during the last ploughing with the quantity recommended in the KAU, Package of Practices Recommendations: Crops 2016 (POP, KAU).

The seedlings were planted at a spacing of 1.5 x 0.45 m (Plate 4. a). There were four plants per treatment and the treatments were replicated thrice. After shifting, the seedlings were protected by mulching and by providing shade using coconut leaves to protect from scorching sun and also to protect from the attack of stem fly, *Ophiomyia phaseoli*. When the vines started trailing, trellies were fixed around the plants (Plate 4. b). Weeding and other cultural operations were done as per the POP recommendations. Treatments were applied at fortnightly intervals as soon as the pest infestation was seen.

3.4.3.3 Observations made on insect pests

For each treatment, observations were recorded from four plants at weekly intervals corresponding to standard weeks. The damage due to aphids, *Aphis craccivora* were assessed with total number of shoots, number of aphid infested shoots, total number of pods, number of pods infested with aphids, scoring of aphid colonies as low/medium/high based on standard scale (Egho, 2011).

The standard scale for scoring the aphid population was shown in Table 1. The scoring was done by observing the aphid colonies on each cowpea stands per treatment. Size of the colony was then observed visually and scored based on the scale. Twelve observations were recorded from each treatment and the average was calculated.

Plate 3. Experimental plot

(a) Field view - Two days after transplanting of seedlings

(b) Field view - One month after transplantingof seedlings

Table 1. Scale for assessing the population of aphids

Sl. No.	Rating	Number of aphids	Appearance
1	0	0	no infestation
2	1	1-4	a few individual colonies
3	3	5-20	a few isolated colonies
4	5	21-100	several small colonies
5	7	101-500	large isolated colonies
6	9	>500	Large continuous colonies

The damage of flower and pod borers, *Maruca vitrata* and *Lampides boeticus* were observed by counting the number of pod borer larvae per plant, total number of flowers and pods, number of damaged flowers and pods thereby expressing the percentage of damage.

The damage caused by pod bugs such as *Riptortus pedestris*, *Clavigralla gibbosa*, *Clavigralla tomentosicollis* and *Nezara viridula* were recorded by counting the number of nymphs/adults of pod bugs, total number of pods and number of infested pods.

The damage to the leaves caused by serpentine leaf miner, *Liriomyza trifolii* was recorded by counting the number of leaves attacked by leaf miner.

3.4.4 Biometric observation

Length of five randomly selected pods were measured from each replication and recorded.

3.4.5 Yield components

The yield parameters *viz.*, fresh weight of pods (g/plant), total yield obtained (g/plant), marketable yield (g/plant) were recorded and the benefit-cost ratio was calculated.

3.4.6 Statistical analysis

The data obtained from the field level experiment were tabulated and statistical analysis was done using analysis of variance (ANOVA). The data except yield and benefit-cost ratio were subjected to square root transformation.

Results

4. RESULTS

Field level experiment was conducted at the instructional farm of College of Agriculture, Padannakkad to manage the major pests of vegetable cowpea *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt by eco-friendly means during two seasons, kharif and rabi in 2016. (May - August and September - December). The study was undertaken to find out the efficacy of different entomopathogenic fungi, *Bt* formulation, biorationals and neem based insecticides.

The observations on pests, yield components, biometric observations were recorded, tabulated and analyzed statistically. The interpreted results are presented below.

4.1 EFFICACY OF DIFFERENT MICROBIAL, BIORATIONAL AND NEEM BASED INSECTICIDES AGAINST MAJOR PESTS OF YARD LONG BEAN

The efficacy of entomopathogenic fungi like *Beauveria bassiana*, *Metarhizium anisopliae, Lecanicillium lecanii, Bt* formulation, Spinosad, neem based insecticides were tested against major pests of yard long bean *viz.,* pod borers such as *Maruca vitrata* (Fabricius) and *Lampides boeticus* (L.), pod bugs such as *Riptortus pedestris* (F.), *Clavigralla gibbosa* Spinola, *Clavigralla tomentosicollis* (Stal.) and *Nezara viridula* (L.), sucking pests like aphids, *Aphis craccivora* Koch, serpentine leaf miner, *Liriomyza trifolii* (Burgess).

4.1.1 Mean number of pod borer larvae during kharif season from May 2016 to August 2016

The effect of entomopathogenic fungi, *Bt*, biorational and neem based insecticides were tested against pod borer larvae of *Maruca vitrata* and *Lampides boeticus* (Plate 5. a, Plate 5. b) during the period from May 2016 to August 2016 and the analyzed data were presented in the Table 2. Since the incidence of each of the pod borers was comparatively less, the observations were recorded as pod borer complex.

Seven days after first spray during kharif season revealed that treatment T_8 recorded minimum number of pod borer larvae (1.92) and T_9 recorded maximum pod borer larvae of 9.62. Treatments *viz.*, T_6, T_4, T_2 and T_3 was found on par with T_9 with 6.56, 6.78, 7.58 and 7.64 larvae respectively. Treatment T_8 was significantly different from other treatments. Treatment T_7 followed T_8 with 4.95 larvae per treatment. On fifteen days after first spray, there was a gradual increase in the larvae of pod borer in treatment T_8 (3.92) than previous week and minimum number was seen in treatment T_7 (3.28). Treatments T_8, T_1, T_3 and T_4 with larval number 3.92, 4.95, 5.15 and 5.25 were found on par with T_7.

The data obtained seven days after second spray revealed that, the mean pod borer larvae was reduced to 1.92 in T_7 which was minimum among other treatments followed by T_8 (2.92). The highest population was exhibited by T_9 (11.25). Treatment T_8 (2.92) was found on par with T_7 with comparatively low number of larvae. Fifteen days after second spray, the mean number of pod borer larvae was drastically reduced in T_7 (0.61) whereas T_9 recorded the highest larval population (10.97). Treatment T_4 with mean larval number 1.62 was statistically on par with T_7. On seventh day after third spray, the mean number of pod borer larvae was found 0.00 in T_7 which cause no infestation to the pods. Highest number of larvae was shown by T_9 (15.16). Treatments T_8, T_4 and T_5 were statistically on par with T_7 with 1.19, 0.53 and 1.82 mean number of larvae respectively.

From the results obtained fifteen days after third spray, no pod borers were found in T_7 (Spinosad 45 SC) (0.00) followed by T_4 (0.27). Treatments T_4 and T_1 were statistically on par with T_7 with 0.27 and 0.61 mean number of larvae respectively.

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Plate 4. Incidence of pod borers on yard long bean

(a) *Maruca vitrata*

(b) *Lampides boeticus*

Table 2. Mean number of pod borer larvae at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Number of pod borer larvae (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	6.29 (2.70)	4.95 (2.44)	3.62 (2.15)	2.31 (1.82)	0.98 (1.41)	0.61 (1.27)
T_2	7.58 (2.93)	6.23 (2.69)	6.95 (2.82)	3.62 (2.15)	2.64 (1.91)	4.95 (2.44)
T_3	7.64 (2.94)	5.15 (2.48)	3.92 (2.22)	2.92 (1.98)	2.64 (1.91)	3.62 (2.15)
T_4	6.78 (2.79)	5.25 (2.50)	4.56 (2.36)	1.62 (1.62)	0.53 (1.24)	0.27 (1.13)
T_5	5.65 (2.58)	8.61 (3.10)	6.18 (2.68)	2.45 (1.86)	1.82 (1.68)	4.61 (2.37)
T_6	6.56 (2.75)	7.94 (2.99)	5.55 (2.56)	2.53 (1.88)	1.92 (1.71)	4.61 (2.37)
T_7	4.95 (2.44)	3.28 (2.07)	1.92 (1.71)	0.61 (1.27)	0.00 (1.00)	0.00 (1.00)
T_8	1.92 (1.71)	3.92 (2.22)	2.92 (1.98)	2.31 (1.82)	1.19 (1.48)	1.92 (1.71)
T_9	9.62 (3.26)	12.61 (3.69)	11.25 (3.50)	10.97 (3.46)	15.16 (4.02)	16.3 (4.16)
C.D. (0.05 %)	0.49	0.45	0.67	0.50	0.70	0.35

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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4.1.2 Mean number of pod borer larvae observed during rabi season from September 2016 to December 2016

The data on mean number of pod borer larval complex of *M. vitrata* and *L. boeticus* obtained during rabi season from September 2016 to December 2016 was presented in Table 3. Since the incidence of each of the borer was comparatively less, observations were recorded as pod borer larval complex.

The mean number of pod borer larvae on seven days after first application of treatment was low in T_8 (Table 2). Second lowest population was recorded in T_7 which was on par with T_8. Highest number of pod borer larvae was found on T_9 (2.38) which were on par with T_3 (1.89) and T_2 (2.13). The treatments *viz.,* T_5, T_4, T_1, T_6, T_3 were found on par with each other with mean number 1.40, 1.46, 1.56, 1.72, 1.89 respectively. Treatment T_7 with 0.90 larvae per treatment was significantly different from T_5, T_4, T_1, T_6, T_3 and T_2 with 1.40, 1.46, 1.56, 1.72, 1.89 and 2.13 larval counts respectively. The mean number of larvae on 15 days after first treatment was very low in T_7 (0.82) compared to T9 (3.16). Treatment T_8 and T_1 also showed minimum number of larvae of 0.98 and 1.22 respectively, which was on par with T_7. Treatments T_4, T_2 and T_3 were found on par with each other with 1.31, 1.56 and 1.82 number of larvae respectively. Treatments T_6 (1.99) and T_5 (2.13) were on par with each other. The mean larval count in T_7 was significantly different from other treatments recording low number of larvae.

Seven days after second spray the mean larval count was again lowered to 0.48 in T_7. The highest number of larvae was recorded in treatment T_9 (3.08). The number of larvae was also low in treatments T_8 (0.74) and T_1 (0.90) which were on par with T_7. Though larval count was increased in T_2 than the previous week, the treatments T_4, T_3 and T_6 with mean larval count 1.13, 1.56 and 1.72 respectively were found on par with each other. T_7 was significantly different compared to other treatments. Significant reduction in number of larvae was found in treatment T_7 with 0.16 larvae per four plants on fifteen days after second spray (15 DASS) followed by T_1 (0.58). Maximum number of larvae was recorded in T_9 (2.74). Treatment T_4 and T_8 were on par with each other. The other treatments *viz.,* T_3, T_5 and T_2 with slight variation in the larval population was found statistically on par with each other with larval count 1.41, 1.58 and 1.73 respectively.

Seven days after third spray (7 DATS), the mean larval population was high in T_9 (3.62 larvae per four plants) and no population in T_7 (0.00) followed by T_1 and T_8 with 0.23 and 0.39 number of larvae respectively. Treatments T_1 (0.23 larvae) and T_8 (0.39 larvae) were statistically on par with each other. Treatments T_3 and T_5 with larval count 1.07 and 1.31 respectively were on par with each other. The treatments T_2 (1.89) and T_6 (1.72) were significantly on par with each other. Significant difference in the larval population was noticed fifteen days after third spray (15 DATS). The minimum number of larvae was recorded in T_7 (Spinosad 45 SC) (0.00) and maximum number of larvae was found in T_9 (3.49). The mean larval count was increased in T_2, T_3 and T_6 than previous week. Treatment T_1, T_8 and T_4 also recorded less number of larvae comparatively but T_7 was significantly different from all other treatments. Treatments T_1 and T_8 were found statistically on par with each other having 0.32 and 0.39 mean larval count respectively.

4.1.3 Mean per cent of flowers infested by larvae of *Maruca vitrata* during kharif season from May 2016 to August 2016

In the field experiment conducted, the observations to find out the percentage of flowers infested by larvae of *M. vitrata* (Plate 6. a, Plate 6. b) were taken at weekly intervals during kharif season from May 2016 to August 2016. The data obtained were statistically analyzed and presented in Table 4.

The mean per cent of flowers infested by pod borers was very low in treatment T_7, seven days after first spray during kharif season. T_7 showed significant difference

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Table 3. Mean number of pod borer larvae at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Number of pod borer larvae (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	1.56 (1.60)	1.22 (1.49)	0.90 (1.38)	0.58 (1.25)	0.23 (1.11)	0.32 (1.15)
T_2	2.13 (1.77)	1.56 (1.60)	1.89 (1.70)	1.73 (1.65)	1.89 (1.70)	1.99 (1.73)
T_3	1.89 (1.70)	1.82 (1.68)	1.56 (1.60)	1.41 (1.55)	1.07 (1.44)	1.31 (1.52)
T_4	1.46 (1.57)	1.31 (1.52)	1.13 (1.46)	0.91 (1.38)	0.66 (1.29)	0.56 (1.25)
T_5	1.40 (1.55)	2.13 (1.77)	1.75 (1.66)	1.58 (1.60)	1.31 (1.52)	1.07 (1.44)
T_6	1.72 (1.65)	1.99 (1.73)	1.72 (1.65)	2.08 (1.75)	1.72 (1.65)	1.89 (1.70)
T_7	0.90 (1.38)	0.82 (1.35)	0.48 (1.22)	0.16 (1.07)	0.00 (1.00)	0.00 (1.00)
T_8	0.48 (1.22)	0.98 (1.41)	0.74 (1.32)	0.91 (1.38)	0.39 (1.18)	0.39 (1.18)
T_9	2.38 (1.84)	3.16 (2.04)	3.08 (2.02)	2.74 (1.93)	3.62 (2.15)	3.49 (2.12)
C.D. (0.05 %)	0.18	0.15	0.19	0.12	0.10	0.08

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

in the per cent of flower infestation (18.44 per cent) among all other treatments. Treatments T_1 was found on par with T_7 with mean per cent of flower infestation 26.98 per cent. Maximum per cent of flower infestation was recorded in T_5 (74.69 per cent). Treatments *viz.,* T_8, T_2 and T_6 were statistically on par with each other having 47.72, 52.29 and 65.42 mean per cent of flower infestation respectively.Significant difference in the mean per cent of pod borer infested flowers was seen in treatment T_7 (11.04 per cent) fifteen days after first application of treatments. Maximum per cent of flower infestation was found in T_9 (76.44). Treatments T_1 and T_4 were found on par with each other having 19.16 and 22.42 per cent of flower infestation respectively. T_2 exhibited the second highest per cent of flower infestation with 62.20 larvae per treatment.

On seventh day after second application of treatments, the per cent of flower infestation was again lowered to in treatment T_7 (8.85 per cent) followed by T_1 (13.66 per cent). The flower infestation was maximum in treatment T_9 (85.30 per cent). Treatment T_1 was found on par with T_7. Treatments *viz.,* T_8, T_5 and T_6 were found on par with each other having 34.52, 36.69 and 44.83 per cent of flower infestation respectively.

Results obtained fifteen days after second spray showed that treatment T_7 recorded minimum per cent of flower infestation (3.12 per cent) and T_9 recorded maximum per cent of flower infestation (79.46 per cent). Treatments T_1 and T_4 were found on par with each other having 10.42 per cent and 12.76 per cent of flower infestation respectively. Seven days after third spray, that treatment T_7 (Spinosad 45 SC) recorded no infestation (0.00 per cent) whereas that treatment T_9 recorded maximum per cent of flower infestation (70.23 per cent). Treatments T_1 and T_4 were found on par with each other having 6.67 and 9.36 per cent of flower infestation respectively. Treatments *viz.,* T_6, T_5 and T_3 were found on par with each other having 29.69, 35.24 and 35.96 per cent of flower infestation respectively.

Table 4. Mean per cent of flowers infested by larvae of *Maruca vitrata* at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Percentage of infested flowers (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	26.98 (5.29)	19.16 (4.49)	13.66 (3.83)	10.42 (3.38)	6.67 (2.77)	2.34 (1.83)
T_2	52.29 (7.30)	62.20 (7.95)	53.02 (7.35)	47.86 (6.99)	41.25 (6.50)	27.09 (5.30)
T_3	73.30 (8.62)	59.99 (7.81)	56.76 (7.60)	43.08 (6.64)	35.96 (6.08)	20.80 (4.67)
T_4	31.26 (5.68)	22.42 (4.84)	16.30 (4.16)	12.76 (3.71)	9.36 (3.22)	8.36 (3.06)
T_5	74.69 (8.70)	60.93 (7.87)	36.69 (6.14)	32.87 (5.82)	35.24 (6.02)	14.44 (3.93)
T_6	65.42 (8.15)	59.84 (7.80)	44.83 (6.77)	37.19 (6.18)	29.69 (5.54)	18.18 (4.38)
T_7	18.44 (4.41)	11.04 (3.47)	8.85 (3.14)	3.12 (2.03)	0.00 (1.00)	0.00 (1.00)
T_8	47.72 (6.98)	30.02 (5.57)	34.52 (5.96)	24.50 (5.05)	22.42 (4.84)	29.58 (5.53)
T_9	72.78 (8.59)	76.44 (8.80)	85.30 (9.29)	79.46 (8.97)	70.23 (8.44)	53.61 (7.39)
C.D. (0.05 %)	1.20	0.60	0.73	0.70	0.39	0.36

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

The same trend of zero infestation was found in T_7 on fifteen days after third spray and maximum per cent of flower infestation was exhibited by T_9 (53.61 per cent). Treatment T_1 exhibited the second lowest per cent of flower infestation (2.34 per cent). Significant difference in the per cent of flower infestation was noticed among the treatments.

4.1.4 Mean per cent of flower infestation by larvae of *Maruca vitrata* during rabi season from September 2016 to August 2016

The mean per cent of flowers infested by larvae of *Maruca vitrata* during rabi season from September to December in the year 2016 were calculated by taking the observations at weekly intervals and the analyzed data presented in the Table 5.

The percentage of flowers infested by pod borer was less in T_7 (13.44 per cent) and highest percentage of infestation was recorded in T_9 with 55.40 per cent on seven days after first spray. Minimum flower infestation was also recorded in T_8 and T_4 having 14.28 per cent and 21.56 per cent which was on par with T_7. The other treatments *viz.*, T_1, T_5, T_6, T_3 and T_2 were on par with each other with 25.52, 33.69, 33.92, 35.84 and 38.18 per cent respectively.

Observations recorded on fifteen days after first spray showed significant difference in percentage of flowers infested between the treatments. Treatment T_7 recorded minimum percentage of flower infestation (5.65 per cent) and T_9 recorded maximum flower infestation (55.55 per cent). T_4 recorded second minimum percent of flower infestation (11.25 per cent) which was on par with T_7. Treatments T_8 (13.21 per cent) and T_1 (22.52 per cent) was on par with each other. Treatments T_3, T_5, T_2 and T_6 were on par with each other with 33.81, 34.04, 36.94 and 38.94 per cent respectively.

Percentage of flowers infested by pod borer was greatly reduced on seven days after second spray in T_7 (1.75 per cent). Treatments T_8 and T_4 were on par with T_7 showing 4.90 per cent and 6.23 per cent of flower infestation by pod borers. T_1 recorded second minimum per cent of flower infestation. Maximum percentage of infested flowers was recorded in T_9 (51.70 per cent). The treatments T_5, T_6, T_3 and T_2 were found on par with each other with 21.09, 22.91, 24.40 and 29.25 respectively. However, the treatments T_7, T_8 and T_4 were significantly different from other treatments.

There was a gradual decrease in the percentage of flower infestation in spinosad treated plot (T_7) after each spray and no infestation was found (0.00 per cent) over fifteen days after second spray. Maximum percent of flower infestation was recorded in T_9 (50.55 per cent). Treatment T_7 (0.00 per cent) were significantly different from other treatments. Treatments T_8, T_4, and T_1 with 2.88, 4.61 and 5.35 per cent were on par with each other. Treatments T_5, T_3 and T_6 with 17.49, 20.25 and 20.52 per cent of flower infestation respectively were found on par with each other.

On seven days after third spray, no flower infestation was recorded in T_7 (0.00 per cent) followed by T_8 with (1.16 per cent) which was on par with T_7. Treatment T_9 recorded maximum percent of flower infestation (43.89 per cent). Treatments T_4 (1.99) and T_1 (2.16) were on par with each other. Treatments T_5, T_3, T_6 and T_2 were found on par with each other having 15.89, 17.06, 19.52 and 19.70 per cent of flower infestation respectively.

Minimum per cent of flower infestation was recorded again in T_7 (0.00 per cent) on fifteen days after third spray which followed the same trend as previous week. Treatment T_9 recorded maximum per cent of flower infestation (41.90 per cent). Second lowest per cent of flower infestation was found in treatments T_4 and T_8 with 0.51 and 0.87 per cent infestation which were on par with each other. Treatments T_5 (13.28 per cent) and T_2 (18.09 per cent) were on par with each other. The treatments T_3 (19.79 per cent) and T_6 (24.90 per cent) were found on par with each other.

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Table 5. Mean per cent of flowers infested by larvae of *Maruca vitrata* at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Percentage of infested flowers (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	25.52 (5.15)	22.52 (4.85)	10.02 (3.32)	5.35 (2.52)	2.16 (1.78)	1.89 (1.70)
T_2	38.18 (6.26)	36.94 (6.16)	29.25 (5.50)	26.45 (5.24)	19.70 (4.55)	18.09 (4.37)
T_3	35.84 (6.07)	33.81 (5.90)	24.40 (5.04)	20.25 (4.61)	17.06 (4.25)	19.79 (4.56)
T_4	21.56 (4.75)	11.25 (3.50)	6.23 (2.69)	4.61 (2.37)	1.99 (1.73)	0.51 (1.23)
T_5	33.69 (5.89)	34.04 (5.92)	21.09 (4.70)	17.49 (4.30)	15.89 (4.11)	13.28 (3.78)
T_6	33.92 (5.91)	38.94 (6.32)	22.91 (4.89)	20.52 (4.64)	19.52 (4.53)	24.90 (5.09)
T_7	13.44 (3.80)	5.65 (2.58)	1.75 (1.66)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_8	14.28 (3.91)	13.21 (3.77)	4.90 (2.43)	2.88 (1.97)	1.16 (1.47)	0.87 (1.37)
T_9	55.40 (7.51)	55.55 (7.52)	51.70 (7.26)	50.55 (7.18)	43.89 (6.70)	41.90 (6.55)
C.D. (0.05 %)	1.00	1.09	1.09	0.65	0.61	0.59

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2ml/l of water – Standard check; T_9: Absolute control.

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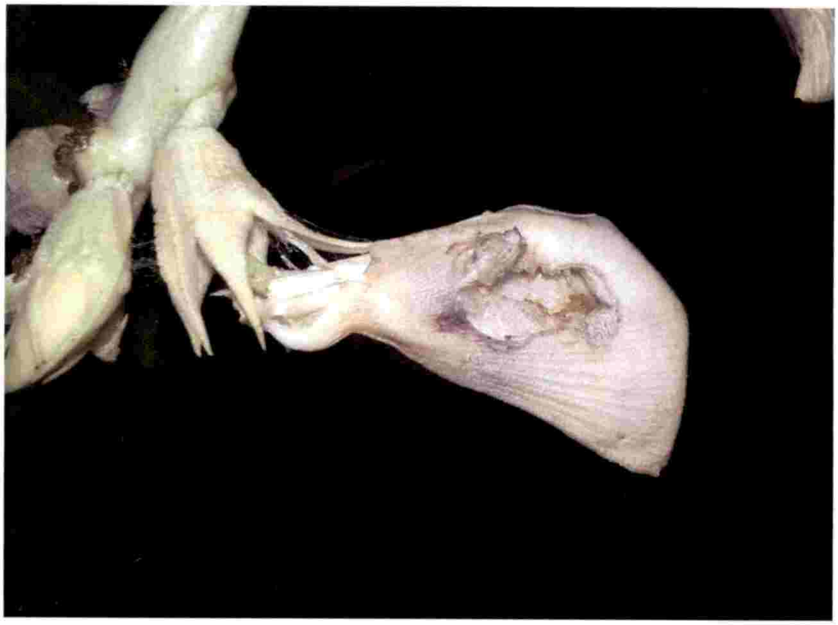
Plate 5. Infestation on flower by larvae of *Maruca vitrata*



(a) Infestation on flower at initial stage of attack

(b) Infestation on flower at final stage of attack

4.1.5 Mean per cent of pods infested by pod borer larvae during kharif season from May 2016 to August 2016.

The intensity of damage caused by pod borers (Plate 7. a, Plate 7. b) was expressed in percentage. The observations to find out the percentage of pods infested by pod borers were taken at weekly intervals during kharif season from May 2016 to August 2016. The data obtained were statistically analyzed and presented in Table 6.

Results obtained seven days after first spray showed that treatment T_7 recorded minimum per cent of pod infestation (22.13 per cent of flower infestation) and T_9 recorded maximum per cent of pod infestation (76.44 per cent of flower infestation). Treatments T_1 and T_4 were found on par with T_7 having 25.83 and 29.36 per cent of pod infestation respectively. Treatment T_2 was found on par with T_9 with 65.42 per cent of pod infestation. Minimum per cent of pod infestation was seen in T_7 (8.92 per cent) fifteen days after first spray and maximum per cent of pod infestation was exhibited by T_9 (79.28 per cent). Treatment T_4 (22.04) and T_1 (25.21) exhibited the second lowest per cent of pod infestation. Significant difference in the per cent of pod infestation was noticed in treatment T_7. Treatments T_4 and T_1 were found on par with each other.

Seven days after second spray, the pod infestation was again reduced in T_7 recorded minimum per cent of pod infestation (6.29 per cent). Treatment T_2 recorded maximum per cent of pod infestation (74.51 per cent). Treatments T_4 and T_1 were found on par with each other having 14.92 and 18.44 per cent of pod infestation respectively. Treatment T_9 was found on par with T_2 with 73.64 per cent of pod infestation. Results obtained fifteen days after second spray showed that, it was T_7 that recorded minimum per cent of pod infestation (3.16 per cent) and per cent of pod infestation was again increased in T_9 recording 82.90 per cent. Treatments T4 and T_1 were found on par with each other having 14.76 and 16.64

Table 6. Mean per cent of pods infested by pod borer larvae at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	25.83 (5.18)	25.21 (5.12)	18.44 (4.41)	16.64 (4.20)	11.88 (3.59)	2.38 (1.84)
T_2	65.42 (8.15)	68.55 (8.34)	74.51 (8.69)	53.46 (7.38)	46.74 (6.91)	39.57 (6.37)
T_3	51.41 (7.24)	37.68 (6.22)	56.76 (7.60)	48.00 (7.00)	28.05 (5.39)	29.14 (5.49)
T_4	2936 (5.51)	22.04 (4.80)	14.92 (3.99)	14.76 (3.97)	9.89 (3.30)	1.25 (1.50)
T_5	45.10 (6.79)	43.22 (6.65)	35.84 (6.07)	44.83 (6.77)	35.60 (6.05)	32.29 (5.77)
T_6	39.83 (6.39)	40.60 (6.45)	39.32 (6.35)	54.65 (7.46)	39.19 (6.34)	28.26 (5.41)
T_7	22.13 (4.81)	8.92 (3.15)	6.29 (2.70)	3.16 (2.04)	0.00 (1.00)	0.00 (1.00)
T_8	38.43 (6.28)	32.29 (5.77)	30.80 (5.64)	37.93 (6.24)	23.80 (4.98)	15.08 (4.01)
T_9	76.44 (8.80)	79.28 (8.96)	73.64 (8.64)	82.90 (9.16)	86.04 (9.33)	71.08 (8.49)
C.D. (0.05 %)	1.04	1.22	0.99	1.03	0.61	0.61

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

per cent of pod infestation respectively. Seven days after third spray, that treatment T_7 recorded the lowest per cent of flower infestation (0.00 per cent) whereas that treatment T_9 recorded maximum per cent of flower infestation of 86.04. Treatments T_4 and T_1 were found on par with each other having 9.89 and 11.88 per cent of pod infestation respectively.

Treatment T_7 followed the same trend of zero infestation on fifteen days after third spray which caused no damage to the pods and maximum per cent of flower infestation was exhibited by T_9 (71.08 per cent). Treatment T_4 exhibited the second lowest per cent of flower infestation (1.25 per cent). Treatment T_4 was found on par with T_7. Treatment T_7 was significantly different from other treatments.

4.1.6 Mean per cent of pods infested by pod borer larvae during rabi season from September 2016 to December 2016

Mean per cent of pods infested by pod borer during rabi season from September 2016 to December 2016 were presented in the Table 7. Seven days after first spray significant reduction in pod damage was shown by most of the treatments. Minimum per cent of pod damage was shown by treatment T_7 (20.52 per cent). The per cent of pod damage was high in treatment T_9 (81.99 per cent). Treatments *viz.,* T_1, T_8, T_4 and T_3 were on par with T_7 having 13.36, 32.40, 33.33 and 37.56 per cent of infestation. Treatment T_2 (75.21 per cent) was found on par with T_9.

Significant difference in the per cent of infested pods was seen fifteen days after first spray. Treatment T_7 (Spinosad) recorded the minimum percentage of infestation by pod borers (10.42 per cent) and treatment T_9 (control) had the maximum percentage of pod attack (67.55 per cent). Treatment T_2 (55.10) was found on par with T_9 showing less efficiency in controlling pod borer. The second lowest infestation was shown by treatment T_8 (17.14 per cent) which was on par

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Table 7. Mean per cent of pods infested by pod borer larvae at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	30.36 (5.60)	22.32 (4.83)	12.39 (3.66)	3.45 (2.11)	1.92 (1.71)	0.76 (1.33)
T_2	75.21 (8.73)	55.10 (7.49)	38.69 (6.30)	36.33 (6.11)	43.08 (6.64)	40.73 (6.46)
T_3	37.56 (6.21)	31.83 (5.73)	19.88 (4.57)	8.30 (3.05)	11.67 (3.56)	22.81 (4.88)
T_4	33.33 (5.86)	26.77 (5.27)	13.82 (3.85)	3.08 (2.02)	1.31 (1.52)	0.32 (1.15)
T_5	43.62 (6.68)	41.25 (6.50)	38.31 (6.27)	27.62 (5.35)	26.35 (5.23)	26.77 (5.27)
T_6	52.14 (7.29)	43.35 (6.66)	37.19 (6.18)	29.58 (5.53)	35.48 (6.04)	36.33 (6.11)
T_7	20.52 (4.64)	10.42 (3.38)	2.45 (1.86)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_8	32.40 (5.78)	17.14 (4.26)	7.46 (2.91)	2.88 (1.97)	1.01 (1.42)	1.16 (1.47)
T_9	81.99 (9.11)	67.55 (8.28)	83.45 (9.19)	84.37 (9.24)	78.03 (8.89)	69.22 (8.38)
C.D. (0.05 %)	1.89	0.99	1.47	1.73	1.48	1.34

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

with T_7. Treatment T_1, T_4 and T_3 were on par with each other with 22.32, 26.77 and 31.83 per cent of infestation respectively. Neem based insecticides *viz.,* T_5 and T_6 were on par with each other having 41.25 and 43.35 per cent respectively and were highly significant from T_7. Though all the treatments except T_9 exhibited a gradual decrease in percentage of pod infestation on seven days after second spray, the lowest percentage of pod infestation was seen in treatment T_7 with 2.45 per cent. The per cent of pod infestation was high in T_9 (83.45 per cent). Moreover, the per cent of infestation in T_9 gradually increased from 67.55 per cent in the previous week to 83.45 per cent. Treatment T_8 exhibited less per cent of infestation (7.46 per cent) which was on par with T_7. The treatments T_1, T_4 and T_3 were on par with each other as the per cent of infestation in these treatments were comparatively less. Treatments T_6, T_5 and T_2 with 37.19, 38.31 and 38.69 per cent respectively were on par with each other.

Significant difference was noticed among the treatments in per cent of pods attacked on fifteen days after second spray. Treatment T_7 exhibited the lowest per cent of pod infestation (0.00 per cent) whereas maximum per cent of infestation was shown by T_9 (84.37 per cent). Treatments *viz.,* T_8, T_4, T_1 and T_3 were on par with each other with 2.88, 3.08, 3.45 and 8.30 per cent of pod infestation respectively. Treatment T_2 with 36.33 per cent was found on par with the neem based insecticides T_5 and T_6 of 27.62 and 29.58 per cent respectively.

On seven days after third spray, lowest infestation was again recorded by treatment T_7 (0.00 per cent) and T_9 (78.03 per cent) exhibited maximum per cent of pod infestation. Treatments T_8, T_4 and $T_1$with 1.01, 1.31 and 1.92 per cent of pod infestation was on par with each other. Treatment T_2 (43.08 per cent) was found on par with T_5 and T_6 having 26.35 and 35.48 per cent respectively.

A significant decrease among the treatments in per cent of pod infestation was noticed on fifteen days after third spray. Treatment T_7 followed the same trend of 0.00 per cent of pod infestation. For the last three weeks treatment T_7 exhibited very lowest infestation which proved to be most promising among other

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Plate 6. Infestation of pod borer larvae on yard long bean

(a) Damage caused by *M. vitrata*

(b) Damage caused by *L. boeticus*

treatments. Maximum level of pod infestation was recorded in T_9 (69.22 per cent). The level of infestation slightly increased in treatments T_8 than previous week from 1.01 per cent in the last week to 1.16 in this week. Treatments T_4, T_1 and T_8 were on par with each other with 0.32, 0.76 and 1.16 per cent of infestation. Treatment T_3, T_5 and T_6 was found on par with each other with 22.81, 26.77 and 36.33 per cent of infestation respectively.

4.1.7 Mean number of nymphs and adults of pod bugs during kharif season from May 2016 to August 2016

The efficacy of different entomopathogenic fungi, *Bt*, biorational and neem based insecticides were evaluated against nymphs and adults (Plate 8) of pod bugs during the kharif season from May 2016 to August 2016 and the data was taken at weekly intervals and presented in the Table 8.

Seven days after first spray, treatments T_6 (0.00) and T_8 (0.00) recorded minimum number of nymphs and adults of pod bugs and T_9 recorded maximum nymphs and adults of pod bugs 1.07. Treatments *viz.*, T_1, T_3, T_5 and T_2 was found on par with each other with 0.23, 0.32, 0.32 and 0.39 mean number of nymphs and adults of pod bugs respectively.

On fifteen days after first spray, there was a gradual increase in the nymphs and adults of pod bugs in treatment T_8 (0.32) than previous week and no bugs were noticed in both treatments T_1 (0.00) and T_3 (0.00). Treatments T_6 and T_8 each exhibited 0.32 number of nymphs and adults of pod bugs which were found on par with T_1 and T_3. The data obtained seven days after second spray revealed that, the mean number of nymphs and adults of pod bugs was minimum in treatment T_3 (0.21) followed by T_1 (0.39) and T_6 (0.48). The highest population was exhibited by T_9 (5.05). Treatments *viz.*, T_1, T_6, T_4 and T_8 were found on par

Table 8. Mean number of nymphs and adults of pod bugs at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Number of nymphs and adults of pod bugs (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	0.23 (1.11)	0.00 (1.00)	0.39 (1.18)	0.63 (1.28)	0.23 (1.11)	0.56 (1.25)
T_2	0.39 (1.18)	1.75 (1.66)	2.31 (1.82)	2.38 (1.84)	1.04 (1.43)	3.32 (2.08)
T_3	0.32 (1.15)	0.00 (1.00)	0.21 (1.10)	1.99 (1.73)	0.90 (1.38)	1.40 (1.55)
T_4	0.48 (1.22)	1.68 (1.64)	0.84 (1.36)	0.96 (1.40)	0.66 (1.29)	4.29 (2.30)
T_5	0.32 (1.15)	1.094 (1.43)	1.52 (1.59)	1.59 (1.61)	0.76 (1.33)	0.63 (1.28)
T_6	0.00 (1.00)	0.32 (1.15)	0.48 (1.22)	0.79 (1.34)	1.04 (1.43)	1.28 (1.51)
T_7	0.48 (1.22)	1.65 (1.63)	2.13 (1.77)	2.31 (1.82)	0.90 (1.38)	3.88 (2.21)
T_8	0.00 (1.00)	0.32 (1.15)	0.98 (1.41)	0.98 (1.41)	0.23 (1.11)	0.90 (1.38)
T_9	1.07 (1.44)	4.10 (2.26)	5.05 (2.46)	6.18 (2.68)	2.13 (1.77)	7.46 (2.91)
C.D. (0.05 %)	0.08	0.35	0.47	0.58	0.29	0.49

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

with T_3 with 0.39, 0.48, 0.84 and 0.98 number of nymphs and adults of pod bugs respectively. Fifteen days after second spray, the mean number of nymphs and adults of pod bugs was minimum in T_1 (0.63) whereas T_9 recorded the highest nymphs and adults of pod bug population (6.18). All other treatments were found statistically on par with each other.

On seventh day after third spray, the mean number of nymphs and adults of pod bugs was lowered to 0.23 in both T_1 and T_8. Highest number of nymphs and adults of pod bugs was shown by T_9 (2.13). Treatments T_5, T_3 and T_7 were statistically on par with T_1 with 0.76, 0.90 and 0.90 mean number of nymphs and adults of pod bugs respectively. The results obtained fifteen days after third spray revealed that the number of nymphs and adults of pod bugs was increased to 7.46 in T_9. Treatment T_1 exhibited minimum number of nymphs and adults of pod bugs (0.56) followed by T_5 (0.63). Treatments T_5, T_8, T_6 and T_3 were statistically on par with T_1 having 0.63, 0.90, 1.28 and 1.40 mean number of nymphs and adults of pod bugs respectively.

4.1.8 Mean number of nymphs and adults of pod bugs in rabi season from September 2016 to December 2016

The data on mean number of nymphs and adults of pod bugs during rabi season from September 2016 to December 2016 were presented in Table 9.

On seven days after first spray (DAFS), greater reduction in population of nymphs and adults of pod bugs were shown by treatment T_8 (0.53). Treatment T_6 and T_5 were the best treatments next to T_8 with mean count of 0.79 and 1.19 nymphs and adults per treatment. Thus treatments T_6 and T_5 were on par with T_8. Maximum number of pod bugs was recorded in treatment T_9 (3.57). Treatments T_2 and T_7 with bug population of 2.57 and 2.96 was on par with T_9. Treatments T_1, T_3, T_4 were found on par with each other.

A significant difference in population of pod bugs was noticed among the treatments on 15 days after first spray (DAFS). T_6 exhibited minimum number of pod bugs (0.48) followed by T_8 and T_5 with mean population of 0.56 and 0.82 respectively. Thus treatments T_8 and T_5 were found statistically on par with T_6. Maximum number of bugs was recorded in T_9 (3.62). T_7 and T_4 having pod bug population of 2.88 and 3.45 was statistically on par with T_9. The other treatments *viz.,* T_1, T_3 and T_2 were found on par with each other with 1.89, 1.49 and 1.99 mean number of bugs respectively.

Observations recorded on seven days after second spray revealed that T_5 and T_8 both exhibited minimum number of pod bugs (0.32). Maximum number of bugs was recorded in T_9 (4.38). Treatment T_6 with mean count 0.39 was statistically on par with T_5 and T_8. Treatment T_3 also had comparatively low pod bug population (0.90). Treatments T_1 and T_2 were found statistically on par with each other with mean count of 1.65 and 2.13 respectively. Significant difference was noted among the treatments in the population of nymphs and adults of pod bugs on fifteen days after second spray. The lowest population was exhibited by treatment T_5 (0.14) followed by T_8 (0.23). Treatment T_6 with mean bug count 0.32 was statistically on par with T_5 and T_8. Highest population was recorded in T_9 (3.79).

On seven days after third spray, T_5 recorded no bugs (0.00) followed by T_8 and T_6 with mean bug population 0.06 and 0.14 respectively. Treatments T_8 and T_6 were on par with T_5. Maximum number of bugs was recorded in treatment T_9 (control) with 3.28 bugs. Also significant difference in the mean bug count was noticed among the treatments. Observations taken on fifteen days after third spray revealed that no bugs were noticed in both treatments T_5 (0.00) and T_6 (0.00). This was followed by T_3 and T_8 with mean population 0.14 in each treatment. Maximum number of bugs was recorded in T_9 with 4.24 bugs. Treatment T_7 (3.08) and T_4 (3.24) were found statistically on par with each other.

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Table 9. Mean number of nymphs and adults of pod bugs at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Number of nymphs and adults of pod bugs (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	1.65 (1.63)	1.89 (1.70)	1.65 (1.63)	1.49 (1.58)	1.16 (1.47)	0.90 (1.38)
T_2	2.57 (1.89)	1.99 1.73	2.13 (1.77)	2.06 (1.75)	1.82 (1.680	2.06 (1.75)
T_3	1.82 (1.68)	1.49 (1.58)	0.90 (1.38)	0.39 (1.18)	0.32 (1.15)	0.14 (1.07)
T_4	3.24 (2.06)	3.45 (2.11)	3.24 (2.06)	3.16 (2.04)	2.96 (1.99)	3.24 (2.06)
T_5	1.19 (1.48)	0.82 (1.35)	0.32 (1.15)	0.14 (1.07)	0.00 (1.00)	0.00 (1.00)
T_6	0.79 (1.34)	0.48 (1.22)	0.39 (1.18)	0.32 (1.15)	0.14 (1.07)	0.00 (1.00)
T_7	2.96 (1.99)	2.88 (1.97)	2.80 (1.95)	2.64 (1.91)	2.38 (1.84)	3.08 (2.02)
T_8	0.53 (1.24)	0.56 (1.25)	0.32 (1.15)	0.23 (1.11)	0.06 (1.03)	0.14 (1.07)
T_9	3.57 (2.14)	3.62 (2.15)	4.38 (2.32)	3.79 (2.19)	3.28 (2.07)	4.24 (2.29)
C.D. (0.05 %)	0.26	0.18	0.14	0.10	0.12	0.07

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

4.1.9 Mean Per cent of pods infested by nymphs and adults of pod bugs during kharif season from May 2016 to August 2016

The mean percentage of damage caused by nymphs and adults of pod bugs (Plate 9) during kharif season from May 2016 to August 2016 on the pods of vegetable cowpea after the application of treatments like entomopathogenic fungi, *Bt*, biorational and neem based insecticides were calculated to evaluate their efficacy from the period September to December 2016 and the data were subjected to statistical analysis and presented in the Table 10.

Seven days after first spray, significant difference in the per cent of pod infestation was seen in T_5. T_5 recorded minimum per cent of pod damage with 2.31 per cent. Treatment T_6, T_8 and T_3 with per cent of pod damage of 4.76, 7.00 and 10.08 per cent respectively was found to be on par with T_5. Highest per cent of pod infestation was seen in T_9 (49.55 per cent) followed by Treatment T_2 with 40.99 per cent of pod infestation.

Observations taken on fifteen days after first spray revealed that minimum per cent of pod damage was exhibited by treatment T_5 (Azadirachtin 1%) with 1.43 per cent which was lower than the previous week. Maximum per cent of pod damage was shown by T_9 (58.13 per cent). Treatment T_6 exhibited the second lowest per cent of pod infestation. Treatments *viz.,* T_6, T_8 and T_3 were on par with T_5 with 3.12, 5.35 and 8.61 per cent of infestation respectively. Seven days after second spray, minimum per cent of pod damage was found in T_6 (0.87 per cent) and maximum in T_9 (87.73 per cent). Treatment T_5 exhibited the second lowest per cent of pod infestation with 0.96. Treatments *viz.,* T_5, T_3 and T_8 were on par with T_6 with per cent of pod infestation 0.96, 4.47 and 5.55 respectively.

The per cent pod infestation on fifteen days after second spray revealed that drastic reduction in the pod damage was seen in T_5 (0.00 per cent) which caused no damage to pods. T_9 recorded maximum per cent of pod damage (91.16

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Table 10. Mean per cent of pods infested by nymphs and adults of pod bugs at weekly intervals during kharif season from May to August 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	29.36 (5.51)	24.80 (5.08)	30.69 (5.63)	34.04 (5.92)	26.24 (5.22)	46.74 (6.91)
T_2	40.99 (6.48)	46.19 (6.87)	88.11 (9.44)	70.23 (8.44)	49.55 (7.11)	66.40 (8.21)
T_3	10.08 (3.33)	8.61 (3.10)	4.47 (2.34)	3.00 (2.00)	1.13 (1.46)	0.00 (1.00)
T_4	42.42 (6.59)	46.47 (6.89)	43.22 (6.65)	38.43 (6.28)	25.62 (5.16)	40.60 (6.45)
T_5	2.31 (1.82)	1.43 (1.56)	0.96 (1.40)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_6	4.76 (2.40)	3.12 (2.03)	0.87 (1.37)	1.25 (1.5)	1.25 (1.5)	1.95 (1.72)
T_7	30.47 (5.61)	25.31 (5.13)	24.30 (5.03)	31.37 (5.69)	38.31 (6.27)	33.81 (5.90)
T_8	7.00 (2.83)	5.35 (2.52)	5.55 (2.56)	6.50 (2.74)	12.39 (3.66)	12.69 (3.70)
T_9	49.55 (7.11)	58.13 (7.69)	87.73 (9.42)	91.16 (9.60)	76.96 (8.83)	83.82 (9.21)
C.D. (0.05 %)	1.57	2.2	1.90	1.79	1.99	1.40

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

per cent). Treatments *viz.*, T_6, T_3 and T_8 with 1.25, 3.00 and 6.50 per cent of infestation was on par with T_5. Treatment T_2 (70.23 per cent) was on par with T_9.

A significant difference in per cent of pod infestation by pod bugs was noticed among the treatments 7 days after third spray. No pod damage was shown by T_5 (0.00 per cent) and maximum by T_9 (76. 96 per cent). Treatments *viz.*, T_3 and T_6 which recorded comparatively low damage of 1.13 and 1.25 per cent respectively was found on par with T_5. Treatment T_2 (49.55 per cent) was again on par with T_9.

Observations recorded fifteen days after third spray revealed that both treatments T_5 and T_3 exhibited no damage. Treatment T_6 (1.95 per cent) was found on par with T_3 and T_5. Maximum pod infestation was recorded in T_9 (83.82 per cent). Treatment T_6 (1.72 per cent) was on par with T_5. Treatment T_2 (66.40 per cent) was also statistically on par with T_9.

4.1.10 Mean per cent of pods infested by nymphs and adults of pod bugs during rabi season from September 2016 to December 2016

The data on percentage of damage caused by nymphs and adults of pod bugs on the pods of vegetable cowpea during rabi season from September to December 2016 were statistically analyzed and presented in the Table 11.

Seven days after first spray, significant difference in the per cent of pod infestation was seen in T_8. T_8 recorded no pod damage initially (0.00 per cent). Treatment T_5 with low per cent of pod damage (3.24 per cent) was found to be on par with T_8. Highest per cent of pod infestation was seen in T_9 (81.62 per cent). Treatment T_4 and T_7 with 67.39 per cent and 54.65 per cent of infestation was statistically on par with each other. Treatment T_6, T_3 and T_1 with per cent of pod infestation 17.74, 25.83 and 44.02 per cent respectively was on par with each other.

Observations taken on fifteen days after first spray revealed that minimum per cent of pod damage was exhibited by treatment T_5 (Azadirachtin 1%) with 1.95 per cent which was comparatively lower than the previous week. Though there was a gradual increase in the per cent pod damage in T_8 (4.61 per cent) than previous week, T_8 was found on par with T_5. Maximum per cent of pod damage was shown by T_9 (78.03 per cent). Treatments *viz.,* T_6, T_3 and T_1 were on par with each other with 14.13, 14.68 and 30.02 per cent of infestation respectively. Treatments T_4 and T_2 with 49.83 per cent and 57.90 per cent were statistically on par with T_9.

Seven days after second spray, minimum per cent of pod damage was found in T_5 (0.87 per cent) and maximum in T_9 (81.81 per cent). Treatments *viz.,* T_8, T_3 and T_6 with 1.59, 3.24 and 6.89 per cent were on par with T_5. Treatment T_1 and T_7 were statistically on par with each other. Treatments T_2 and T_4 were found on par with each other. However, T_5 was significantly different from all other treatments.

The per cent pod infestation on fifteen days after second spray revealed that drastic reduction in the pod damage was seen in T_5 (0.00 per cent). T_9 recorded maximum per cent of pod damage (69.05 per cent). Treatments T_3 and T_6 was on par with T_5 with 2.13 and 4.01 per cent of infestation respectively. Treatments T_1 and T_8 with 11.53 and 13.06 per cent of infestation was on par with each other. Treatments T_2 (25.21 per cent) and T_7 (32.29 per cent) was also on par with each other.

A significant difference in per cent of pod infestation by pod bugs was noticed among the treatments 7 days after third spray. No pod damage was shown by T_5 (0.00 per cent) and maximum by T_9 (82.17 per cent). Treatments *viz.,* T_3, T_1 and T_8 which recorded comparatively low damage was found on par with T_5 with 0.44, 3.16 and 3.53 per cent respectively.

Table 11. Mean per cent of pods infested by nymphs and adults of pod bugs at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	44.02 (6.71)	30.02 (5.57)	15.89 (4.11)	11.53 (3.54)	3.16 (2.04)	6.78 (2.78)
T_2	51.56 (7.25)	53.90 (7.41)	44.15 (6.72)	25.21 (5.12)	24.70 (5.07)	19.34 (4.51)
T_3	25.83 (5.18)	14.68 (3.96)	3.24 (2.06)	2.13 (1.77)	0.44 (1.20)	0.00 (1.00)
T_4	67.39 (8.27)	49.83 (7.13)	36.82 (6.15)	42.42 (6.59)	40.08 (6.41)	31.14 (5.67)
T_5	3.24 (2.06)	1.95 (1.72)	0.87 (1.37)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_6	17.74 (4.33)	14.13 (3.89)	6.89 (2.81)	4.01 (2.24)	3.92 (2.22)	5.45 (2.54)
T_7	54.65 (7.46)	46.74 (6.91)	30.24 (5.59)	32.29 (5.77)	31.83 (5.73)	25.31 (5.13)
T_8	0.00 (1.00)	4.61 (2.37)	1.59 (1.61)	13.06 (3.75)	3.53 (2.13)	3.36 (2.09)
T_9	81.62 (9.09)	78.03 (8.89)	81.81 (9.10)	69.05 (8.37)	82.17 (9.12)	70.57 (8.46)
C.D. (0.05 %)	1.81	1.94	1.78	1.27	1.16	0.86

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Plate 7. Incidence of pod bugs on yard long bean

Plate 8. Infestation of pod bugs on yard long bean

Observations recorded fifteen days after third spray revealed that pods were not affected by bugs in T_3 and T_5 (0.00 per cent). Maximum pod infestation was recorded in T_9 (70.57 per cent). Treatments T_8, T_6 and T_1 were on par with each other with 3.36, 5.45 and 6.72 per cent of infestation respectively. Treatments T_2 and T_7 were also found on par with each other.

4.1.11 Mean per cent of aphid infestation on shoots during kharif season from May 2016 to August 2016

The infestation on shoots due to aphids, *A. craccivora* (Plate 10) during kharif season from May 2016 to August 2016 was expressed as percentage of shoots infested and was presented in Table 12. The observation on infestation on shoots due to aphids, *A. craccivora* during rabi season from September to December 2016 was avoided, as no infestation were found on the shoots

During kharif season, there was a significant reduction in the shoot infestation due to aphids seven days after first spray in treatment T_5 (1.00 per cent). Maximum per cent of aphid infestation on shoots was seen in T_4 (2.02 per cent) followed by T_9 (2.88 per cent). Observations recorded on fifteen days after first spray revealed that minimum per cent of aphid infestation on shoots was seen in treatment T_8 (3.70 per cent) followed by T_5 (5.15 per cent) whereas maximum per cent of aphid infestation on shoots was recorded in T_9 (35.60 per cent). Other treatments except T_9 were statistically on par with each other. Treatment T_4 with 19.52 per cent of shoot infestation was found on par with T_9.

Seven days after second spray, greater reduction in the infestation due to aphids on shoots was seen in T_5 and T_1 with 0.00 per cent each. Treatment T_9 recorded maximum per cent of shoot infestation (13.89). Treatment T_8 with 1.52 per cent of shoot infestation was found on par with T_5 and T_1.

Treatment T_3 recorded minimum per cent of aphid infestation on shoots (3.62 per cent) on fifteen days after second spray. Maximum per cent of aphid

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Table 12. Mean per cent of aphid infestation on shoots at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Aphid infestation on shoots (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	1.85 (1.69)	5.25 (2.50)	0.00 (1.00)	12.10 (3.62)	1.75 (1.66)	3.24 (2.06)
T_2	1.75 (1.66)	12.91 (3.73)	2.09 (1.76)	36.33 (6.11)	8.18 (3.03)	15.00 (4.00)
T_3	2.13 (1.77)	9.17 (3.19)	2.53 (1.88)	3.62 (2.15)	0.00 (1.00)	0.00 (1.00)
T_4	3.08 (2.02)	19.52 (4.53)	3.62 (2.15)	39.32 (6.35)	15.08 (4.01)	27.62 (5.35)
T_5	0.00 (1.00)	5.15 (2.48)	0.00 (1.00)	17.83 (4.34)	4.90 (2.43)	9.17 (3.19)
T_6	1.46 (1.57)	14.92 (3.99)	2.20 (1.79)	4.85 (2.42)	3.88 (2.21)	5.81 (2.61)
T_7	1.89 (1.70)	6.45 (2.73)	4.01 (2.24)	18.62 (4.43)	6.39 (2.72)	11.88 (3.59)
T_8	1.75 (1.66)	3.70 (2.17)	1.52 (1.59)	9.36 (3.22)	2.13 (1.77)	3.24 (2.06)
T_9	2.88 (1.97)	35.60 (6.05)	13.89 (3.86)	45.10 (6.79)	39.96 (6.40)	73.82 (8.65)
C.D.	0.47	1.77	0.65	1.54	1.10	1.56

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

infestation was shown by T_9 (45.10 per cent). Treatments *viz.,* T_6, T_8 and T_1 which was on par with T_3 also showed comparatively low level of infestation on pods with 4.85, 9.36 and 12.10 per cent of aphid infestation respectively on shoots.

Observations taken on seven days after third spray revealed that no aphid infested shoots were found in T_3 again exhibited minimum per cent of infested shoots (0.00 per cent) followed by T_1 (1.75 per cent). Treatments, T_1 and T_8 was found on par with T_3 having 1.75 and 2.13 per cent of aphid infestation on shoots. Treatment T_9 exhibited maximum per cent of aphid infestation (39.96 per cent).

Even fifteen days after third spray, T_3 was free from aphid infestation on shoots (0.00 per cent) which proved to be the effective treatment. Maximum aphid infestation was recorded in treatment T_9 (73.82 per cent). Treatments, T_1 and T_8 were found statistically on par with T_3 with each having 3.24 per cent of infestation respectively.

4.1.12 Mean per cent of aphid infestation on pods during kharif season from May 2016 to August 2016

The infestation on pods due to aphids, *A. craccivora* (Plate 11) during kharif season from May 2016 to August 2016 was expressed as percentage of pod infested and was presented in Table 13.

There was no incidence of aphids on pods seven days after first spray in treatment T_6 (0.00 per cent). Maximum per cent of aphid infestation was seen in T_9 (82.72 per cent) followed by T_4 (42.42 per cent). Treatments T_5 and T_3 with 1.82 and 2.13 per cent of infestation respectively were on par with the superior treatment T_6. Observations recorded on fifteen days after first spray revealed that minimum per cent of aphid infestation was seen in treatment T_3 (1.28 per cent) whereas maximum per cent of aphid infestation was recorded in T_9 (79.38 per cent). Treatments *viz.,* T_5, T_6 and T_7 with 1.31, 1.82 and 7.70 per cent of infestation respectively were on par with the superior treatment T_3. Treatments *viz.,* T_1, T_2, T_8 and T_4 with 23.40, 25.72, 26.66 and 36.94 per cent of pod infestation respectively were found on par with each other.

Table 13. Mean per cent of aphid infestation on pods at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	24.10 (5.01)	23.40 (4.94)	14.84 (3.98)	5.8 (2.61)	6.29 (2.70)	3.45 (2.11)
T_2	31.03 (5.66)	25.72 (5.17)	55.25 (7.50)	49.97 (7.14)	40.73 (6.46)	37.06 (6.17)
T_3	2.13 (1.77)	1.28 (1.51)	0.87 (1.37)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_4	42.42 (6.59)	36.94 (6.16)	16.47 (4.18)	13.89 (3.86)	32.17 (5.76)	28.59 (5.44)
T_5	1.82 (1.68)	1.31 (1.52)	0.96 (1.40)	1.82 (1.68)	1.01 (1.42)	1.82 (1.68)
T_6	0.00 (1.00)	1.82 (1.68)	0.87 (1.37)	2.42 (1.85)	1.52 (1.59)	2.13 (1.77)
T_7	11.39 (3.52)	7.70 (2.95)	10.69 (3.42)	29.58 (5.53)	29.58 (5.53)	30.36 (5.60)
T_8	9.67 (3.56)	26.66 (5.26)	19.25 (4.50)	10.76 (3.43)	2.88 (1.97)	1.82 (1.68)
T_9	82.72 (9.15)	79.38 (8.96)	61.41 (7.90)	42.82 (6.62)	52.14 (7.29)	63.16 (8.01)
C.D.	2.11	2.67	2.58	2.03	1.67	1.92

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Seven days after second spray, reduction in the infestation due to aphids was seen in T_3 (0.87 per cent) and T_6 (0.87 per cent). Treatments T_5 and T_7 with 0.96 and 10.69 per cent of infestation respectively were on par with the superior treatments T_3 and T_6. Maximum aphid infestation was seen in T_9 (61.41 per cent).

A drastic reduction in the per cent of aphid infestation on pods was seen in T_3 (0.00 per cent) on fifteen days after second spray followed by T_5 (1.82 per cent). Treatments *viz.*, T_5, T_6 and T_1 were found on par with T_3 with 1.82, 2.42 and 5.81 per cent of aphid infestation on pods. Treatment T_9 exhibited maximum per cent of aphid infestation (6.62 per cent).

Observations taken on seven days after third spray revealed that T_3 again recorded minimum per cent of aphid infestation (0.00 per cent). Maximum per cent of aphid infestation was shown by T_9 (52.14 per cent) which was higher than previous week. Treatments *viz.*, T_5, T_6 and T_8 which was on par with T_3 also showed comparatively low level of infestation on pods with 1.01, 1.52 and 2.88 per cent respectively.

Even fifteen days after third spray, T_3 was free from aphid infestation on shoots (0.00 per cent) which proved to be the effective treatment. Mximum aphid population was recorded in treatment T_9 (73.82 per cent). Treatments, T_1 and T_8 were found statistically on par with T_3 with each having 3.24 per cent of infestation respectively.

4.1.13 Mean per cent of aphid infestation on pods during rabi season from September 2016 to December 2016

The infestation on pods due to aphids, *A. craccivora* during rabi season from September 2016 to December 2016 was expressed as percentage of shoots infested and was presented in Table 14.

There was a significant reduction in the pod infestation due to aphids seven days after first spray in treatment T_3 (10.76 per cent). Maximum per cent of aphid infestation was seen in T_9 (78.38 per cent) followed by T_7 (64.44 per cent).

Table 14. Mean per cent of aphid infestation on pods at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Percentage of infested pods (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	39.83 (6.39)	30.02 (5.57)	7.52 (2.92)	9.43 (3.23)	1.65 (1.63)	0.58 (1.26)
T_2	59.52 (7.78)	51.70 (7.26)	35.72 (6.06)	33.10 (5.84)	12.32 (3.65)	16.64 (4.20)
T_3	10.76 (3.43)	14.68 (3.96)	0.00 (1.00)	5.10 (2.47)	0.00 (1.00)	0.00 (1.00)
T_4	57.98 (7.68)	58.44 (7.71)	32.87 (5.82)	43.08 (6.64)	19.79 (4.56)	18.09 (4.37)
T_5	25.83 (5.18)	20.71 (4.66)	0.87 (1.37)	16.05 (4.13)	5.30 (2.51)	2.38 (1.84)
T_6	34.52 (5.96)	32.29 (5.77)	1.34 (1.53)	11.39 (3.52)	5.96 (2.64)	2.76 (1.94)
T_7	64.44 (8.09)	46.33 (6.88)	16.72 (4.21)	35.24 (6.02)	20.25 (4.61)	12.03 (3.61)
T_8	27.62 (5.35)	22.13 (4.81)	11.96 (3.60)	25.07 (5.10)	3.53 (2.13)	4.29 (2.30)
T_9	78.38 (8.91)	80.18 (9.01)	54.80 (7.47)	51.41 (7.24)	37.19 (6.18)	27.72 (5.36)
C.D. (0.05 %)	2.71	1.37	2.48	2.65	2.07	1.25

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Observations recorded on fifteen days after first spray revealed that minimum per cent of aphid infestation was seen in treatment T_3 (14.68 per cent) whereas maximum per cent of aphid infestation was recorded in T_9 (80.18 per cent). Treatments T_5 and T_8 with 20.71 and 22.13 per cent of infestation respectively was on par with the superior treatment T_3. T_1, T_6 and T_7 were statistically on par with each other with 30.02, 32.29 and 46.33 per cent of pod infestation respectively. Treatments T_2 and T_4 with 51.70 and 58.44 per cent of pod infestation respectively were found on par with each other.

Seven days after second spray, complete reduction in the infestation due to aphids was seen in T_3 (0.00 per cent) which was significantly different from all other treatments. Maximum aphid infestation was seen in T_9 (54.80 per cent). T_5, T_6, and T_1 with 0.87, 1.34 and 7.52 respectively were found on par with T_3. Observations taken on fifteen days after second spray revealed that treatment T_3 exhibited no per cent of aphid infestation (5.10 per cent) followed by T_1 (9.43 per cent). Treatments *viz.,* T_1, T_6, T_5 and T_8 was found on par with T_3 having 9.43, 11.39, 16.05 and 25.07 per cent of aphid infestation respectively. Treatment T_9 exhibited maximum per cent of aphid infestation (51.41 per cent).

A drastic reduction in the per cent of aphid infestation was seen in T_3 (0.00 per cent) on seven days after third spray. Maximum per cent of aphid infestation was shown by T_9 (37.19 per cent). Treatments *viz.,* T_1, T_8, T_5 and T_6 which was on par with T_3 also showed comparatively low level of infestation on pods with 1.65, 3.53, 5.30 and 5.96 per cent of aphid infestation respectively.

Even fifteen days after third spray, T_3 recorded the no aphid infestation on pods (0.00 per cent) which proved to be the effective treatment. Maximum aphid infestation was recorded in treatment T_9 (27.72 per cent). Treatments *viz.,* T_1, T_5, T_6 and T_8 was found statistically on par with each other.

4.1.14 Scoring of aphid colonies on shoots based on standard scale during kharif season from May 2016 to August 2016

The effect of treatments like entomopathogenic fungi, *Bt*, biorational and neem based insecticides on aphid population on shoots were tested to find out their efficacy during kharif season from May 2016 to August 2016. Aphid colonies were scored based on a standard scale at weekly intervals and the data obtained were statistically analyzed and presented in Table 15. Aphid population on shoots were negligible during rabi season from September to December.

Seven days after first application of treatments, maximum aphid population score on shoots was recorded in T_9 (1.56) followed by T_7 (1.40). Minimum count of aphid population was seen in T_5 (0.00). Treatments T_3 and T_8 were statistically on par with each other with score 0.74 for both treatments.

Fifteen days after first spray, minimum aphid population score was seen in T_8 with a score of 0.46 followed by T_3 with score 0.56. High scoring of aphid population was recorded in T_9 (1.89). Treatments T_2 and T_4 were on par with T_9 with scoring 1.56 and 2.06 respectively.

Seven days after second spray, treatment T_1 and T_5 recorded very low aphid population on shoots each with score 0.00 followed by T_3 (0.39) and highest aphid population was seen in T9 with aphid population scoring 2.24. Treatments T_3 and T_5 were significantly different from all other treatments.

The scoring of aphid population on shoots was found low in treatment T_3 (0.29) on fifteen days after second spray. Maximum aphid colony scoring was seen in T_9 (1.75). Treatments $T_1$and T_6 was found on par with T_3 with scoring 0.29 and 0.46 respectively.

On seventh day after third spray, the population of aphid was drastically lowered in T_3 causing no damage to the shoots with score 0.00 followed by T_1 (0.23). Thus treatment T_1 was found on par with T_3. Highest aphid population score was

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Table 15. Scoring of aphid colonies on shoots based on standard scale during kharif season from May 2016 to August 2016

Treatments	Aphid scoring on shoots (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	0.90 (1.38)	0.74 (1.32)	0.00 (1.00)	0.39 (1.18)	0.23 (1.11)	0.23 (1.11)
T_2	1.07 (1.44)	1.56 (1.60)	1.72 (1.65)	1.72 (1.65)	1.89 (1.70)	1.56 (1.60)
T_3	0.74 (1.32)	0.56 (1.25)	0.39 (1.18)	0.29 (1.14)	0.00 (1.00)	0.00 (1.00)
T_4	1.07 (1.44)	2.06 (1.75)	1.89 (1.70)	1.56 (1.60)	1.56 (1.60)	1.72 (1.65)
T_5	0.00 (1.00)	0.90 (1.38)	0.00 (1.00)	0.90 (1.38)	0.90 (1.38)	0.90 (1.38)
T_6	0.90 (1.38)	1.07 (1.44)	0.90 (1.38)	0.46 (1.21)	0.39 (1.18)	0.56 (1.25)
T_7	1.40 (1.55)	0.90 (1.38)	1.56 (1.60)	1.72 (1.65)	1.56 (1.60)	1.25 (1.50)
T_8	0.74 (1.32)	0.46 (1.21)	1.07 (1.44)	0.90 (1.38)	0.74 (1.32)	0.56 (1.25)
T_9	1.56 (1.60)	1.89 (1.70)	2.24 (1.80)	2.06 (1.75)	2.24 (1.80)	2.24 (1.80)
C.D. (0.05%)	0.13	0.27	0.16	0.21	0.13	0.14

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

exhibited in T_9 (2.24). Treatment T_2 with aphid population score 1.89 was statistically on par with T_9.

Fifteen days after third spray, no aphid population score was seen in treatment T_3 (0.00). Treatment T_1 was found on par with T_3 with aphid population score 0.23. Maximum score of 2.24 was exhibited by treatment T_9. Treatments *viz.*, T_6, T_8 and T_5 with aphid population score 0.56, 0.56 and 0.90 respectively were found statistically on par with each other.

4.1.15 Scoring of aphid colonies on pods based on standard scale during kharif season from May 2016 to August 2016

The effect of treatments like entomopathogenic fungi, *Bt*, biorational and neem based insecticides on aphid population on pods were tested to find out their efficacy. Aphid colonies were scored based on a standard scale at weekly intervals during kharif season from May 2016 to August 2016 and the data obtained were statistically analyzed and presented in Table 16.

Seven days after first application of treatments, maximum aphid population score was recorded in T_9 (1.56) followed by T_7 (1.40). Minimum count of aphid population was seen in T_5 (0.00). A gradual increase in the aphid population was seen on fifteen days after first spray. High scoring of aphid population was recorded in T_9 (8.30). Minimum aphid population score of 0.76 was recorded on T_3. Treatments T_5 and T_6 were on par with T_3 with scoring 1.19 and 1.95 respectively.

Seven days after second spray, treatments T_3 and T_5 recorded very low aphid population each with score 0.76 and highest aphid population score was seen in T_9 with aphid population scoring 8.98. Treatments *viz.*, T_6, T_8 and T_7 were found on par with superior treatments with aphid population score 1.56, 3.45 and 3.84 respectively. The scoring of aphid population was found very low in treatment T_3 (0.00) on fifteen days after second spray. Maximum aphid colony scoring was seen in T_9 (8.98) with no fluctuation in population from previous

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Table 16. Scoring of aphid colonies on pods based on standard scale taken at weekly intervals during kharif season from May 2016 to August 2016

Treatments	Aphid scoring on pods (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	0.90 (1.38)	4.95 (2.44)	6.29 (2.70)	4.42 (2.33)	5.40 (2.53)	3.36 (2.09)
T_2	1.07 (1.44)	6.95 (2.82)	7.64 (2.94)	7.64 (2.94)	7.52 (2.92)	8.30 (3.05)
T_3	0.74 (1.32)	0.76 (1.33)	0.76 (1.33)	0.00 (1.00)	1.56 (1.60)	0.00 (1.00)
T_4	1.07 (1.44)	6.89 (2.81)	6.95 (2.82)	7.64 (2.94)	6.89 (2.81)	8.30 (3.05)
T_5	0.00 (1.00)	1.19 (1.48)	0.76 (1.33)	0.76 (1.33)	1.19 (1.48)	1.19 (1.48)
T_6	0.90 (1.38)	1.95 (1.72)	1.56 (1.60)	1.19 (1.48)	1.19 (1.48)	1.56 (1.60)
T_7	1.40 (1.55)	6.89 (2.81)	3.84 (2.20)	8.30 (3.05)	7.64 (2.94)	8.30 (3.05)
T_8	0.74 (1.32)	6.29 (2.70)	3.45 (2.11)	5.50 (2.55)	1.56 (1.60)	1.95 (1.72)
T_9	1.56 (1.60)	8.30 (3.05)	8.98 (3.16)	8.98 (3.16)	8.30 (3.05)	8.98 (3.16)
C.D. (0.05%)	0.13	0.97	1.30	0.97	1.09	1.25

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

week. Treatments T_5 and T_6 were found on par with T_3 with scoring 0.76 and 1.19 respectively.

Seven days after third spray, T_5 and T_6 recorded minimum aphid population each with score of 1.19. Treatments *viz.,* T_3, T_8 and T_1 were found statistically on par with superior treatments with 1.56, 1.56 and 5.40 aphid population score respectively. Maximum aphid population score was recorded in T9 (8.30). On fifteenth day after third spray, the population of aphid was again lowered in T_3 causing very little or no damage to the pods (0.00) followed by T_5 (1.19) and highest aphid population score was exhibited in T_9 (8.98). Treatments *viz.,* T_5, T_6, T_8 and T_1 were found statistically on par with superior treatments with 1.19, 1.56, 1.95 and 3.36 aphid population score

4.1.16 Scoring of aphid colonies on pods based on standard scale during rabi season from September 2016 to December 2016

The effect of treatments like entomopathogenic fungi, *Bt*, biorational and neem based insecticides on aphid population were tested to find out their efficacy. Aphid colonies were scored based on a standard scale at weekly intervals during rabi season from September 2016 to December 2016 and the data obtained were statistically analyzed and presented in Table 17.

Seven days after first application of treatments, maximum aphid population score was recorded in T_9 (6.84) followed by T_7 (4.90) and T_2 (3.70). Minimum count of aphid population was seen in T_3 (0.46). Treatments T_7 and T_2 were statistically on par with T_9. A gradual increase in the aphid population was seen on fifteen days after first spray. High scoring of aphid population was recorded in T_9 (8.12). Minimum aphid population score of 0.90 was recorded on T_3. Treatments T_8, T_5 and T_1 were on par with T_3 with scoring 1.56, 1.89 and 2.13 respectively.

Seven days after second spray, treatment T_3 recorded very low aphid population with score 0.00 followed by T_5 (0.06) and highest aphid population score was seen in T_9 with aphid population scoring of 5.76. T_3 exhibited

Table 17. Scoring of aphid colonies on pods based on standard scale taken at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Aphid scoring on pods (mean of 12 plants)					
	7DAFS	15DAFS	7DASS	15DASS	7DATS	15DATS
T_1	2.27 (1.81)	2.13 (1.77)	0.51 (1.23)	0.93 (1.39)	0.14 (1.07)	0.14 (1.07)
T_2	3.70 (2.17)	4.76 (2.40)	3.24 (2.06)	3.79 (2.19)	2.31 (1.82)	5.15 (2.48)
T_3	0.46 (1.21)	0.90 (1.38)	0.00 (1.00)	0.63 (1.28)	0.00 (1.00)	0.00 (1.00)
T_4	2.72 (1.93)	4.33 (2.31)	3.92 (2.22)	4.24 (2.29)	4.10 (2.26)	5.15 (2.48)
T_5	1.31 (1.52)	1.89 (1.70)	0.06 (1.03)	2.34 (1.83)	1.22 (1.49)	0.46 (1.21)
T_6	1.82 (1.68)	2.92 (1.98)	0.14 (1.07)	1.31 (1.52)	1.43 (1.56)	0.53 (1.24)
T_7	4.90 (2.43)	3.49 (2.12)	2.45 (1.86)	4.38 (2.32)	2.27 (1.81)	3.62 (2.15)
T_8	1.25 (1.50)	1.56 (1.60)	1.49 (1.58)	3.70 (2.17)	0.56 (1.25)	1.04 (1.43)
T_9	6.84 (2.80)	8.12 (3.02)	5.76 (2.60)	5.76 (2.60)	5.25 (2.50)	5.81 (2.61)
C.D. (0.05 %)	0.74	0.46	0.59	0.64	0.59	0.36

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Plate 9. Infestation of aphids on shoots of yard long bean

Plate 10. Infestation of aphids on pods of yard long bean

significant difference among all the treatments. The scoring of aphid population was found low in treatment T_3 (0.63) on fifteen days after second spray. Maximum aphid colony scoring was seen in T_9 (5.76) which were same as that of previous week. Treatments *viz.,* T_1, T_6 and T_5 were found on par with T_3 (0.00) with scoring 0.93, 1.31 and 2.34 respectively. On seventh day after third spray, the population of aphid was again lowered in T_3 (0.00) causing very little or no damage to the pods followed by T_1 (0.14) and highest aphid population score was exhibited in T_9 (5.25). A gradual decrease in the population of aphid was seen in all the treatments compared to the previous week. Treatments *viz.,* T_1, T_8, T_5 and T_6 were found statistically on par with T_3 with score 0.14, 0.56, 1.22 and 1.43 respectively.

Fifteen days after third spray, drastic decrease in the aphid population score was seen in treatment T_3. T_3 showed significant difference from all other treatments. T_1 also had low aphid population score (0.14) which was same as that of previous week. High aphid scoring was seen in treatment T_9 (5.81) followed by T_2 and T_4 each with aphid score 5.15. Treatments T_1, T_5, T_6 and T_8 were statistically on par with T_3 with score 0.14, 0.46, 0.53 and 1.04 respectively.

4.1.17 Mean number of leaves attacked by serpentine leaf miner observed at weekly intervals during rabi season from September 2016 to December 2016

The extent of damage caused by serpentine leaf miner on vegetable cowpea (Plate 12) during rabi season from September 2016 to December 2016 was calculated by taking the mean number of leaves attacked by leaf miner after the application of treatments like entomopathogenic fungi, *Bt*, biorational and neem based insecticides. The data obtained were statistically analyzed and presented in Table 18. The leaf miner incidence was absent during kharif season.

The mean number of leaves attacked by leaf miner was very low in treatment T_5 (2.80) on seven days after first application of treatments. The leaf miner attack was severe in T_9 (6.72). Treatments *viz.,* T_3, T_8 and T_6 with mean number of attacked leaves 4.56, 4.66 and 4.90 respectively was statistically on par

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Table 18. Mean number of leaves attacked by serpentine leaf miner at weekly intervals during rabi season from September 2016 to December 2016

Treatments	Number of attacked leaves (mean of 12 plants)					
	7 DAFS	15DAFS	7 DASS	15DASS	7 DATS	15DATS
T_1	6.07 (2.66)	3.70 (2.17)	3.62 (2.15)	2.88 (1.97)	2.24 (1.80)	2.06 (1.75)
T_2	5.96 (2.64)	5.25 (2.50)	4.66 (2.38)	3.70 (2.17)	3.79 (2.19)	2.96 (1.99)
T_3	4.56 (2.36)	3.36 (2.09)	2.64 (1.91)	2.06 (1.75)	2.96 (1.99)	2.45 (1.86)
T_4	6.23 (2.69)	5.30 (2.51)	5.45 (2.54)	5.40 (2.53)	4.15 (2.27)	3.04 (2.01)
T_5	2.80 (1.95)	2.24 (1.80)	2.06 (1.75)	1.31 (1.52)	0.90 (1.38)	0.63 (1.28)
T_6	4.90 (2.43)	4.01 (2.24)	2.92 (1.98)	2.38 (1.84)	2.45 (1.86)	1.85 (1.69)
T_7	5.70 (2.59)	4.61 (2.37)	5.05 (2.46)	3.79 (2.19)	2.88 (1.97)	2.57 (1.89)
T_8	4.66 (2.38)	4.38 (2.32)	5.30 (2.51)	4.71 (2.39)	3.08 (2.02)	2.42 (1.85)
T_9	6.72 (2.78)	6.95 (2.82)	7.23 (2.87)	7.82 (2.97)	7.7 (2.95)	7.12 (2.85)
C.D. (0.05 %)	0.17	0.29	0.24	0.22	0.26	0.28

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

with each other. Treatments *viz.,* T_2, T_1 and T_4 with mean number of attacked leaves 5.96, 6.07 and 6.23 respectively was statistically on par with T_9.

Fifteen days after first spray, the leaf miner attack was gradually lowered in T_5 (2.24) and the mean number of miner attacked leaves was high in T_9 (6.95). The treatment T_3 (3.36) was statistically on par with T_5. Treatments *viz.,* T_1, T_6, T_8 and T_7 were statistically on par with each other with 3.70, 4.01, 4.38 and 4.61 mean number of attacked leaves respectively.

Observations taken on seven days after second spray revealed that the leaf miner attack was significantly decreased in T_5 (2.06) whereas the mean number of attacked leaves was high in treatment T_9 (7.23). Seven days after second spray, treatments T_3 and T_6 also recorded less number of miner attacked leaves of 2.64 and 2.92 respectively. Thus, treatments T_3 and T_6 were found on par with T_5.

On 15th day after second spray, the mean number of miner attacked leaves was low in treatment T_5 (1.31) which is highly significant and high in Treatment T_9 (7.82). Treatments T_3, T_6 and T_1 with mean number of attacked leaves 2.06, 2.38 and 2.88 respectively were found on par with each other. Treatments T_2 and T_7 were also found on par with each other with mean number of attacked leaves 3.70 and 3.79 respectively.

The mean number of miner attacked leaves was reduced to 0.90 on seven days after third spray in treatment T_5 which is highly significant. Maximum number of attacked leaves was found in T_9 (7.70). Treatments *viz.,* T_1, T_6, T_7, T_3 and T_8 was found on par with each other with 2.24, 2.45, 2.88, 2.96 and 3.08 mean number of attacked pods respectively.

The mean number of miner attacked leaves was greatly reduced in treatment T_5 (0.63) on fifteen days after second spray. Highest attack was exhibited by T_9 (7.12) followed by T_4 (3.04). Treatments *viz.,* T_6, T_1, T_8, T_3 and T_7 with mean number of attacked leaves 1.85, 2.01, 2.42, 2.45 and 2.57 respectively were found on par with each other.

Plate 11. Serpentine leaf miner attack on leaves of yard long bean

4.2 BIOMETRIC OBSERVATIONS

4.2.1 Length of pods measured from the yield obtained during kharif season from May 2016 to August 2016

The length of pods was taken from 15 pods per treatment and their average was calculated during kharif season from May 2016 to August 2016. The data obtained were analyzed statistically and presented in the Table 19.

During kharif season, maximum pod length was recorded in T_7 (42.30 cm) and minimum pod length was shown by treatment T_6 (34.34 cm) followed by T_5 (34.50 cm). Treatment T_3 and T_8 with pod length 41.10 cm and 38.62 cm respectively was found on par with T_7.

4.2.2 Length of pods measured from the yield obtained during rabi season from September 2016 to December 2016

The length of pods was taken from 15 pods per treatment during rabi season from September 2016 to December 2016 and their average was calculated. The data obtained were analyzed statistically and presented in the Table 19.

During rabi season, maximum pod length was recorded in T_7 (48.4 cm) and minimum pod length was shown by treatment T_4 (35.83 cm) followed by T_2 (36.13 cm). Treatment T_3 and T_1 with pod length 45.79 cm and 43.01 cm respectively was found on par with T_7.

Table 19. Mean length of fifteen pods per treatment taken during kharif season (May to August 2016) and rabi season (September to December 2016)

Treatment	Length of pods (cm)	
	Kharif season	Rabi season
T_1	36.44	43.01
T_2	34.59	36.13
T_3	41.10	45.79
T_4	35.24	35.83
T_5	34.50	39.36
T_6	34.34	36.43
T_7	42.30	48.40
T_8	38.62	37.80
T_9	35.99	36.70
C.D. (0.05 %)	4.11	6.28

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

4.3 YIELD ATTRIBUTES OF YARD LONG BEAN TAKEN DURING KHARIF (MAY TO AUGUST 2016) AND RABI SEASON (SEPTEMBER TO DECEMBER 2016)

4.3.1 Assessment of yield components like freshweight, total yield and marketable yield obtained during kharif season from May 2016 to August 2016

The fresh weight of pods were taken after each harvest and recorded. Four harvests were made during kharif season from May 2016 to August 2016. Total yield was calculated by addition of the yield obtained from each harvests. Out of the total yield obtained, marketable yield was also calculated. The data obtained was subjected to statistical analysis and presented in Table 20.

From the fresh weight obtained during first harvest T_5 recorded the highest yield (87.80 g per plant) followed by T_3 (85.45 g per plant). Minimum yield was recorded in T_8 (60.66 g per plant). Treatments T_3, T_7 and T_6 with yield 85.45, 83.78 and 71.58 g per plant respectively was found on par with T_5. During the time of second harvest, T_7 exhibited higher yield of 145.75 g per plant whereas minimum yield was obtained in treatment T_9 (78.30 g per plant) followed by T_8 (79.58 g per plant). Treatment T_7 was significantly different in yield from all other treatments.

At the time of third harvest, the maximum yield was recorded again in T_7 (123.33 g per plant). Minimum yield of 85.75 g per plant was recorded in T_8 followed by T_9 (91.83 g per plant). Treatment T_3 was statistically on par with T_7. The fresh weight obtained during fourth harvest revealed that T_7 recorded the highest yield of 131.01 g per plant. Treatment T_1 with 128.46 g per plant was found on par with T_7 and minimum yield was recorded in T_9 (89.74 g per plant).

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Table 20. Effect of treatments on the yield attributes of yard long bean during kharif season from May 2016 to August 2016

Treatments	Fresh weight of pods (g/plant)				Total yield (g/plant)	Marketable yield (g/plant)
	First harvest	Second harvest	Third harvest	Fourth harvest	Total	Total
T_1	69.03	94.40	107.25	128.46	399.14	377.16
T_2	64.75	97.56	92.66	113.58	368.56	291.78
T_3	85.45	97.83	109.16	108.27	400.73	346.43
T_4	58.99	67.19	100.08	117.63	343.89	323.19
T_5	87.80	99.08	86.04	110.84	383.76	347.19
T_6	71.58	108.18	104.11	104.23	388.11	325.28
T_7	83.78	145.75	123.33	131.01	483.88	466.46
T_8	60.66	79.58	85.75	104.09	330.09	302.59
T_9	63.58	78.30	91.83	89.74	323.45	237.17
C.D. (0.05 %)	17.47	15.54	14.13	12.62	30.02	35.33

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

From the total yield calculated, treatment T_7 recorded higher yield of 483.88 g per plant followed by T_3 with yield of 400.73 g per plant. Treatments *viz.*, T_3, T_1, T_6 and T_5 were statistically on par with each other recording 400.73, 399.14, 388.11 and 383.73 g per plant respectively. The total yield obtained was low in treatment T_9 (323.45 g per plant) followed by T_8 (330.09 g per plant).

Highest marketable yield was also recorded in Treatment T_7 (466.46 g per plant) followed by T_1 with yield of 377.16 g per plant. Treatment T_9 recorded the lowest marketable yield of 237.17 g per plant. Treatments T_1, T_5 and T_3 were found to be on par with each other with 377.16, 347.19 and 346.43 g per plant respectively.

4.3.2 Assessment of yield components like fresh weight, total yield and marketable yield obtained during during rabi season from September 2016 to December 2016

The fresh weight of pods were taken after each harvest during rabi from September 2016 to December 2016 and recorded. During rabi season seven harvests were made. Total yield was calculated by addition of the yield obtained from each harvests. Out of the total yield obtained, marketable yield was also calculated. The data obtained was subjected to statistical analysis and presented in Table 21.

From the fresh weight obtained during first harvest of 60 days after planting (DAP), T_7 recorded the highest yield (24.30 g per plant) followed by T_3 (20.62 g per plant). Minimum yield was recorded in T_4 (6.00 g per plant). Treatments T_3, and T_9 with yield 20.62 and 19.16 g per plant respectively was found on par with T_7. During the time of second harvest, T_7 exhibited higher yield of 41.00 g per plant whereas minimum yield was obtained in treatment T_4 (23.45 g per plant) followed by T_6 (24.66 g per plant). Treatment T_1 with yield 35.33 g per plant was on par with T_7.

At the time of third harvest, the yield drastically increased in T_7 (144.25 g per plant). Minimum yield of 39.08 g per plant was recorded in T_1 followed by T_9 (40.00 g per plant). Treatment T_7 showed significant difference in the yield among all other treatments. The fresh weight obtained during fourth harvest revealed that T_2 recorded the highest yield of 89.83 g per plant followed by T_8 (78.66 g per plant). The yield was very low in treatment T_5 (38.04 g per plant). Treatments *viz.*, T_8, T_7 and T_3 was found on par with T_2 with 78.66 g, 75.04g and 74.77 g per plant respectively.

During the period of fifth harvest, the yield gradually increased in T_7 (117.00 g per plant) and low yield was recorded in T9 (39.33 g per plant). Treatments *viz.,* T_3, T_2, T_1 and T_8 with 101.66 g, 90.98 g, 90.83 g and 87.00 g per plant respectively was found on par with T_7 (117.00 g per plant). There was a significant difference in the yield obtained in treatment T_1 during sixth harvest. T_1 recorded higher yield of 331.31 g per plant and minimum yield was given by treatment T_9 (77.50 g per plant). Fresh weight obtained in the seventh harvest showed that the yield was high in T_2 (203.54 g per plant) and low in T_9 (60.00 g per plant). Treatments T_7, T_3, T_1 and T_6 with 145.40 g, 143.08 g, 137.40 g and 129.54 g per plant respectively were found to be on par with each other.

From the total yield calculated, treatment T_7 recorded higher yield of 738.74 g per plant followed by T_1 (692.71 g per plant) and T_2 (688 g per plant). Thus T_1 and T_2 were statistically on par with T_7. Minimum yield was recorded in treatment T_9 with 320.31 g per plant. Treatments T_3 and T_6 were found on par with each other with 602.78 g and 555.20 g per plant respectively. Highest marketable yield was also recorded in Treatment T_7 (718.24 g per plant) followed by T_1 and T_3 with yield of 629.13 g per plant and 580.72 g per plant respectively. Thus treatments T_1 was found statistically on par with T_7. Treatment T_9 recorded

Table 21. Effect of treatments on the yield attributes of yard long bean during rabi season from September 2016 to December 2016

Treatments	Fresh weight of pods (g/plant)							Total yield (g/plant)	Marketable yield (g/plant)
	First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest	Sixth harvest	Seventh harvest	Total	Total
T_1	17.25	35.33	39.08	41.50	90.83	331.31	137.40	692.71	629.13
T_2	16.76	28.33	90.41	89.83	90.98	168.12	203.54	688.00	456.91
T_3	20.62	27.31	83.62	74.77	101.66	151.69	143.08	602.78	580.72
T_4	6.00	23.45	72.66	59.90	43.66	166.66	63.65	436.00	410.37
T_5	13.00	30.25	66.58	38.04	71.66	162.75	109.01	491.31	455.62
T_6	12.50	24.66	105.70	39.66	76.33	166.79	129.54	555.20	529.10
T_7	24.30	41.00	144.25	75.04	117.00	191.74	145.40	738.74	718.24
T_8	12.46	32.50	52.83	78.66	87.00	123.62	107.30	494.40	473.03
T_9	19.16	28.35	40.00	55.96	39.33	77.50	60.00	320.31	249.25
C.D. (0.05 %)	5.38	6.57	16.04	26.42	31.12	48.12	33.81	47.73	54.92

T_1:*Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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the lowest marketable yield of 249.25 g per plant. Treatments T_3 and T_6 was found to be on par with each other having 580.72 g per plant and 529.10 g per plant respectively.

4.4 ECONOMIC ANALYSIS

4.4.1 Economics of production of yard long bean during kharif season from May 2016 to August 2016

The data obtained by calculating the economics of production of yard long bean during kharif season from May 2016 to August 2016 were presented in Table 22.

From the data obtained, maximum net returns were recorded in treatment T7 (63250.00) followed by T1 and T3 with net returns 36249.80 and 23803.50 respectively. By applying treatment T7, an amount of Rs.1.5 was obtained for every one rupee invested against the treatment T9 which had a return of only Rs. 0.46. Treatment T1 when applied earned a return of Rs. 1.31 for every one rupee invested. The biorational insecticide, Spinosad gave the highest benefit-cost ratio.

4.4.2 Economics of production of yard long bean during rabi season

The data obtained by calculating the economics of production of yard long bean during rabi season from September 2016 to December 2016 were presented in Table 23.

From the data obtained, maximum net returns were recorded in treatment T_7 (162325.90) followed by T_1 and T_3 with net returns 138297.00 and 118691.60. Application of biorationals insecticide, Spinosad (T_7) gave a return of Rs. 2.26 for every one rupee invested. By applying treatment T_1, an amount of Rs.2.18 was obtained for every one rupee invested against the treatment T_9 which had a return of only Rs. 0.86.

Tabie 22. Economics of cultivation of yard long bean during kharif season from May 2016 to August 2016

Treatments	Economics of yard long bean					
	Production cost excluding insecticides (Rs./ha)	Cost of insecticides (Rs./ha)	Total expenditure (Rs./ha)	Gross Income (Rs./ha)	Net income (Rs./ha)	B : C ratio
T_1	115062.00	1440.00	116502.00	152751.80	36249.80	1.31
T_2	115062.00	1440.00	116502.00	118172.30	1670.30	1.01
T_3	115062.00	1440.00	116502.00	140305.00	23803.50	1.20
T_4	115062.00	1240.00	116302.00	130895.30	14593.30	1.12
T_5	115062.00	2947.50	118009.50	140612.60	22602.63	1.19
T_6	115062.00	13500.00	128562.00	131739.80	3177.75	1.02
T_7	115062.00	10607.00	125669.00	188919.00	63250.00	1.50
T_8	115062.00	1350.00	116412.00	122549.60	6137.62	1.05
T_9	115062.00	0.00	115062.00	96055.88	-61679.60	0.46

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Table 23. Economics of cultivation of yard long bean during rabi season from September 2016 to December 2016

Treatments	Economics of yard long bean					
	Production cost excluding insecticides (Rs./ha)	Cost of insecticides (Rs./ha)	Total expenditure (Rs./ha)	Gross Income (Rs./ha)	Net income (Rs./ha)	B : C ratio
T_1	115062.00	1440.00	116502.00	254799.00	138297.00	2.18
T_2	115062.00	1440.00	116502.00	185051.30	68549.25	1.58
T_3	115062.00	1440.00	116502.00	235193.60	118691.60	2.01
T_4	115062.00	1240.00	116302.00	166201.90	49899.88	1.42
T_5	115062.00	2947.50	118009.50	184528.10	66518.63	1.56
T_6	115062.00	13500.00	128562.00	214288.90	85726.88	1.66
T_7	115062.00	10607.00	125669.00	290887.90	162325.90	2.26
T_8	115062.00	1350.00	116412.00	191578.50	65909.5	1.52
T_9	115062.00	0.00	115062.00	100946.30	-15465.8	0.86

T1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T6: Neem oil emulsion 5% (50ml/l of water); T7: Spinosad 45 SC @ 0.4 ml/l of water ; T8: Malathion 50 EC @ 2ml/l of water – Standard check; T9: Absolute control

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Discussion

5. DISCUSSION

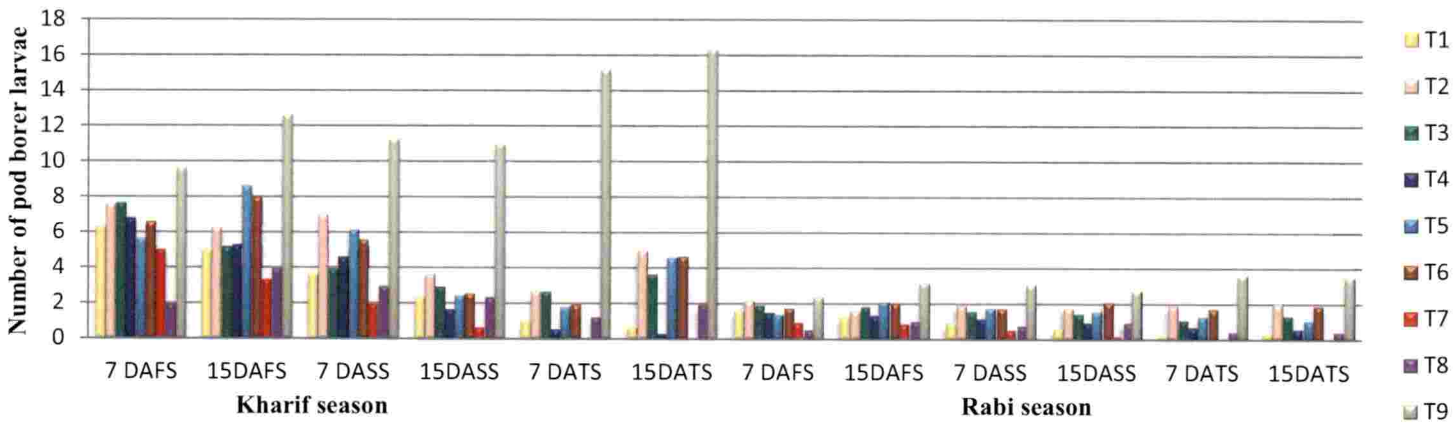
The results obtained from the field level experiment conducted on the topic "Eco-friendly management of major pests of yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" during two seasons *viz.*, kharif (May 2016 to August 2016) and rabi (September 2016 to December 2016) are discussed in this chapter.

5.1 EFFICACY OF DIFFERENT MICROBIAL, BIORATIONAL AND NEEM BASED INSECTICIDES AGAINST MAJOR PESTS OF YARD LONG BEAN

5.1.1 Effect of microbials, biorational and neem based insecticides against pod borer larvae during kharif season (May to August 2016) and rabi season (September to December 2016).

From the results obtained, it was concluded that Spinosad 45 SC was effective in reducing the number of pod borer larvae during both kharif and rabi seasons from May to August 2016 and September to December 2016 respectively after three consecutive application of treatments. Fifteen days after first spray there was a decrease in number of pod borer larvae and gradually reduced in subsequent sprays. By seven days after third spray no larval population could be seen. Spinosad 45 SC was found to be superior over all other treatments. (Table 2 and 3; Fig. 1). The findings of Yadav and Singh (2014) that the larval population of *M. vitrata* was found to be very low three days after first spray of Spinosad 45 SC in mung bean was in line with the above results. In the present study, though Malathion 50 EC showed good control of pod borer larvae at the initial stage, later Spinosad competes with the efficacy of Malathion and thus Spinosad is adjudged as the best treatment in reducing larvae of pod borer over other treatments. The efficacy of the same in pigeon pea was reported by Rao *et al.* (2007) in which Spinosad could bring about more than 70 per cent of reduction in population of *M. vitrata.* The present study is in agreement with Kumar and

Fig. 1. Number of pod borer larvae observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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Muthukrishnan (2016) that Spinosad 45 SC assured 76.4 per cent reduction in number of larvae of pod borer, *Lampides boeticus* in pigeon pea.

Bacillus thuringiensis formulation 2× 10^8 cfu/ml showed effectiveness next to Spinosad 45 SC in controlling the larval population of pod borers during kharif season in the year 2016 (Table 2; Fig. 1). The number of pod borers was greatly reduced fifteen days after third spray. Similar findings were made by Sunitha *et al.* (2008) that Spinosad exhibited higher efficacy in lowering the larval population of *M. vitrata* followed by *Bt.* During rabi season *Beauveria bassiana* @ 10^7 spores/ml of water also found effective than *Bt* in controlling pod borer larvae (Table 3. Fig. 1). However, the present finding that Spinosad is highly effective against the larvae of pod borers is consistent with the report of Ipsita *et al.* (2014) that there was a greater reduction in the number of pod borer larvae (2.6 per 10 plants) when Spinosad 45 SC was treated. The report of Adsure and Mohite (2015) revealed that Spinosad 45 SC could bring down the larval population to a great extent even after first spray reconfirmed the present study.

5.1.2 Effect of microbials, biorational and neem based insecticides against pod borers infesting flowers and pods during kharif season (May to August 2016) and rabi season (September to December 2016).

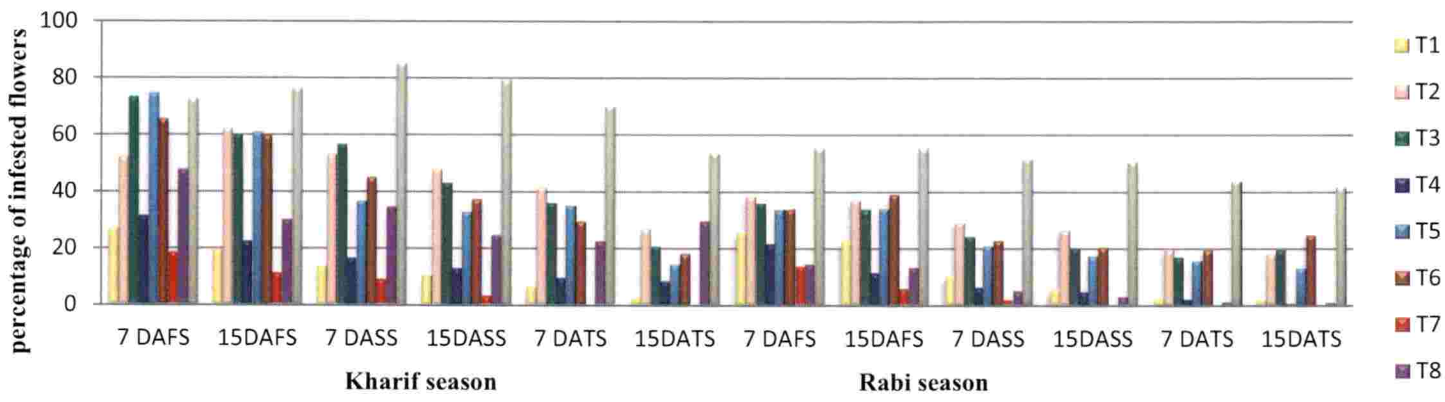
The data on mean percentage of flowers infested by larvae of *Maruca vitrata* during kharif and rabi seasons from May to August 2016 and September to December 2016 respectively (Table 4 and 5; Fig 2) revealed that Spinosad 45 SC treated plot recorded minimum per cent of infestation. After two sprays of Spinosad 45 SC at fortnightly intervals there was drastic reduction in the flower infestation. No infestation was found after third spray which showed the effectiveness of Spinosad. The present study is in line with the report of Sreekanth *et al.* (2015) that the application of Spinosad resulted in minimum inflorescence damage of 6.21 per cent in pigeon pea compared to the control having 31.18 per cent. The effectiveness of the same was reported by Sreekanth and Seshamahalakshmi (2012) in pigeon pea that Spinosad 45 SC 73g a.i/ha resulted in low inflorescence damage. Hence, the present study is consistent with the findings reported earlier.

The mean per cent of pod infestation by pod borer larvae were also minimum in Spinosad 45 SC treated plot during both kharif and rabi seasons in the year 2016. (Table 6 and 7; Fig 3) During both seasons, after two sprays the infestation to the pods lowered in great extent. After third spray, no damage was seen on pods. The report of Ipsita *et al.* (2014) conveyed that Spinosad 45 SC resulted in only 6.66 per cent of pod infestation compared to control having 27.02 per cent pod damage when sprayed 40 days after sowing endorsed the present study. The effect of the same was again reinforced by the findings of Anitha and Parimala (2014) in which the lowest pod damage of 5.1 per cent was obtained in Spinosad treated plot. The present study and earlier findings ratified the efficacy of Spinosad in reducing the per cent of pod damage in vegetable cowpea.

Bacillus thuringiensis formulation @ 2×10^8 cfu/ml @ 1 ml/l of water was found to be the next effective treatment after Spinosad in reducing the pod damage during both kharif and rabi seasons. After three consecutive sprays at fortnightly intervals, the per cent of pod damage decreased far better in *Bt* treated plot. Similar findings were made by Yadav and Singh (2014) in which Spinosad when applied recorded the lowest pod damage of 3.67 per cent followed by *Bt* with 4.33 per cent pod damage. The report of Dhaka *et al.* (2011) that Spinosad @ 500 ml/ha exhibited low percentage of pod infestation three days after second spray followed by *Bt* @ 1500 g/ha also substantiated the present study.

Spinosad is a biorational insecticide with novel mode of action produced from soil bacterium *Saccharopolyspora spinosa*. Since it is non- systemic in nature, it is effective when the insect ingest it as done by lepidopteran caterpillars and causing no harm to natural enemies. It has low toxicity to mammals. Sparks *et al.* (2012) explained that Spinosad 45 SC was allowed to use in organic farming as the level of toxicity was less than Malathion.

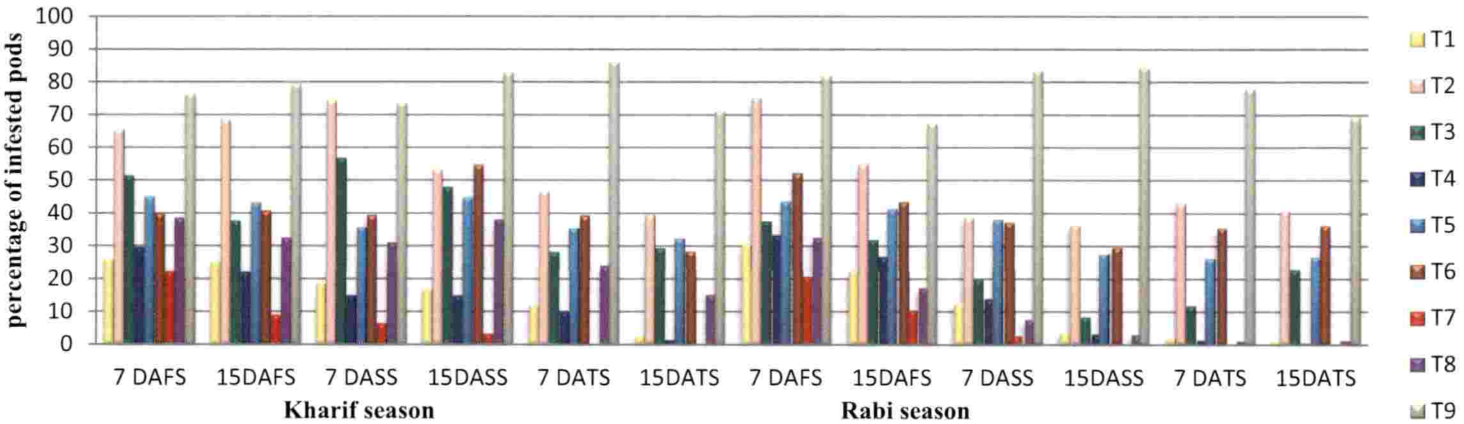
Fig. 2. Mean per cent of flowers infested by larvae of *Maruca vitrata* observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Fig. 3. Mean per cent of pods infested by pod borer larvae observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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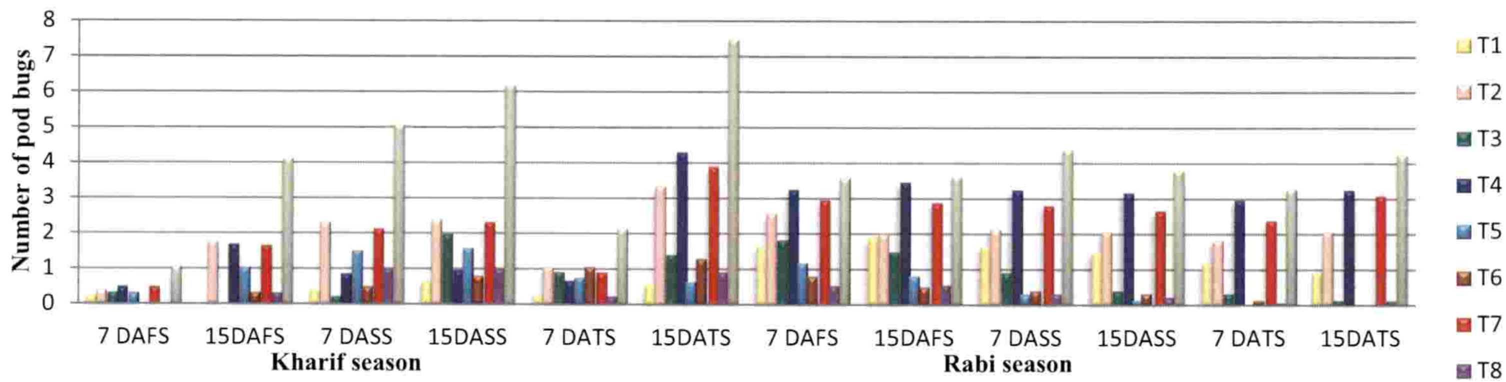
5.1.3 Effect of microbials, biorational and neem based insecticides against nymphs and adults of pod bugs during kharif season (May to August 2016) and rabi season (September to December 2016).

The pod bugs *viz., R. pedestris, C. tomentosicollis, C. gibbosa* and *N. viridula* were encountered in the field during both seasons. The mean number of nymphs and adults of pod bugs was found minimum in plot treated with *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water) during kharif season (May to August 2016) followed by Azadirachtin 1 per cent (Table 8; Fig. 4). The report of Ekesi (1999) suggested that *Beauveria bassiana* isolate CPD 9 could cause mortality of pod bug, *C. tomentosicollis* at a higher rate was supportive to the present finding.

The effect of *B. bassiana* in controlling bugs was restricted to kharif season only. It might be due to high humidity resulting from the rain during that period, favoured spores of *Beauveria* to germinate and infect at a faster rate. Similar findings were reported by Sivasankaran *et al.* (1998) that high level of water is required for the spores of entomopathogenic fungi to germinate. James *et al.* (1998) reported that 96 per cent of ambient humidity is required for *B. bassiana to* germinate. In the present study, *Beauveria bassiana* exhibited less effect during rabi season because of scarcity of rain and high temperature. This statement is supported by Umadevi *et al.* (2005) that isolates of *B. bassiana* got inhibited at a condition of high temperature and less water availability.

During rabi season higher efficiency was shown by Azadirachtin 1 per cent followed by neem oil 5 per cent (Table 9; Fig. 4). By seven days after third spray of Azadirachtin 1 per cent, no incidence of pod bugs was noticed. Azadirachtin has the ability to hamper the growth of immature stages. Singh (2014) reported that Azadirachtin at higher concentration caused mortality of giant pod bug, *Anoplocnemic curvipes* in cowpea corroborate the above finding. Mordue and Nisbet (2000) reported that the behavioural sensitivity of hemipterans to azadirachtin was 100-500 ppm.

Fig. 4. Mean number of nymphs and adults of pod bugs observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

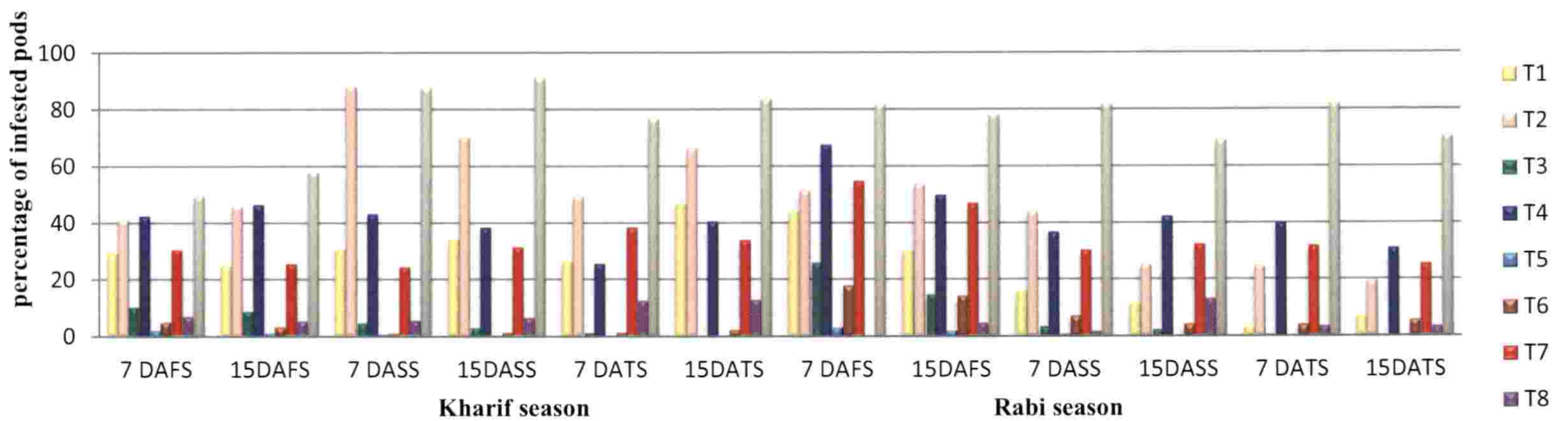
Neem oil 5 per cent showed consistent reduction in number of pod bugs after three sprays and no pod bugs were seen 15 days after third spray The effect of Neem oil was also circumstantiated by Degri and Sodangi (2013) that the population of pod sucking bugs can be reduced by application of Neem oil four times. During rabi season, *Lecanicillium lecanii* also showed slow decrease in number of pod bugs after three consecutive sprays. Gopali *et al.* (2013) ratified the efficacy of *L. lecanii* by reporting that 1 x 10^{10} spores of *L. lecanii* could reduce the pod bug population in pigeon pea. Ligappa and Hegde (2001) also reported similar findings that entomopathogenic fungi can control pod bug *Clavigralla tomentosicollis*. But in the present study, the performance of Neem oil was moderate during kharif season. It might be due to the rain during that period.

Since Azadirachtin exhibited reduction in pod bugs after two sprays during both seasons, it is said to be the effective treatment as it interfere with the growth and reproducing capacity of insects. It also creates feeding impediment in insects so that insects deter away from the Azadirachtin sprayed plots. The combined action of Azadirachtin as changing the physiological growth habits and feeding deterrence in insects is responsible for the lowering of bug population in the present study. The findings of Nisbet *et al.* (1993) that feeding of hemipteran insects was inhibited completely when they are treated with Azadirachtin 500 ppm ratified the present study.

5.1.4 Effect of microbials, biorational and neem based insecticides against pod infestation by pod bugs during kharif season (May to August 2016) and rabi season (September to December 2016).

Minimum per cent of pods infested by nymphs and adults of pod bugs were shown by Azadirachtin 1 per cent during both kharif and rabi seasons (Table 10 and 11; Fig. 5). The attack of pod bugs *viz., R. pedestris, C. tomentosicollis, C. gibbosa* and *N. viridula* was encountered in the field and severe pod damage was noticed in the young pods of one week old. Azadirachtin exhibited a dire reduction in the per cent of pod damage even after two sprays.

Fig. 5. Mean per cent of pods infested by nymphs and adults of pod bugs observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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During kharif and rabi seasons, no pod damage was found after fifteen days of second spray which proved to be the effective treatment. Thus Azadirachtin helps in increasing the market value of the pods and moreover it is non toxic to humans. The findings of Koona *et al.* (2001) showed that with increase in the pod age, the damage to the pods was minimized and the crucial period of infestation was seen in pods of eight days old.

Soyelu and Akingbohungbe (2007) reported that greater reduction in the yield of cowpea was caused by fourth instar nymphs of every bug species. The findings of Mordue and Nisbet (2000) found that hemipterans are sensitive to high concentration of Azadirachtin resulting in 100 per cent antifeedancy, thereby reducing the pod damage. In the present study, *L. lecanii* was also found to reduce the percentage of pod infestation but only fifteen days after third spray.

5.1.5 Effect of microbials, biorational and neem based insecticides against aphid infestation on shoots, pods and aphid population during kharif season (May to August 2016) and rabi season (September to December 2016).

Mean per cent of aphid infestation on shoots was low in plot treated with *L. lecanii* @ 10^7 spores/ml of water during kharif season (Table 12; Fig. 6). The per cent of aphid infestation to the shoots was zero after three consecutive sprays of *L. lecanii* at fortnightly intervals. It was noticed that those shoots infected by aphids vigorously at the earlier stage showed retarded growth and distortion of shoots. The leaf area of such infested plants found reduced. The reduction of aphids on shoots helps in vigorous growth of shoots which increases the photosynthetic activity and thereby increases in yield. *Beauveria bassiana* was found next to *L. lecanii* in reducing the shoot infestation. Similar result was reported by Saranya *et al.* (2010) that *L. lecanii* @ 1×10^8 spores/ml caused 100 per cent mortality of *A. craccivora* in cowpea followed by *B. bassiana.*

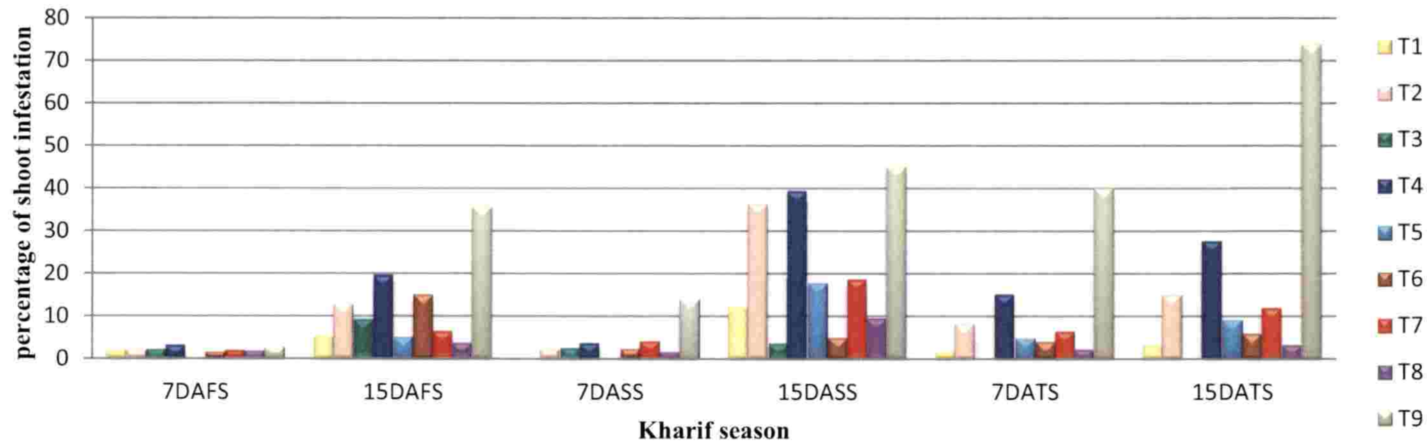
There was no aphid infestation on the shoots during rabi season and thus it was not statistically analyzed.

The mean per cent of aphid infestation on pods was low in *L. lecanii* treated plot during both kharif and rabi seasons (Table 13 and 14; Fig. 7). By second application of liquid formulation of *L. lecanii* @ 10^7 spores/ml of water, there was substantial decrease in aphid population on pods and complete reduction of aphid infestation on pods was noticed after three consecutive sprays. This result is in line with the findings of Halder *et al.* (2013) that application of *L. lecanii* VL-1 isolate resulted in 80.8 per cent mortality of black bean aphid, *A. craccivora.*

The population of aphids were scored based on standard scale on shoots and on pods to find out the intensity of aphid infestation. A score of 9 was given for large continuous colonies, score 7 for large isolated colonies, score 5 for several small colonies, score 3 for a few isolated colonies, score 1 for a few individual colonies and score 0 represents no infestation. From the results obtained it was noticed that during kharif season, after three sprays of *L. lecanii* @ 10^7 spores/ml of water the aphid population on shoots disappeared completely (Table 15; Fig. 8). There were no aphid colonies on shoots during rabi season.

Aphid population on pods was consistently reduced in plot treated with liquid formulation of *L. lecanii* @ 10^7 spores/ml of water during both kharif and rabi seasons (Table 16 and 17; Fig. 9). Three sprays are sufficient for the reduction of aphid population and no aphid infestation on pods was seen after three sprays. The result is in confirmation with the work of Ramanujam *et al.* (2017) in which it was found that cowpea when sprayed thrice with *L. lecanii* @ $1x10^8$ cfu/ml spores on 30^{th}, 45^{th} and 60^{th} days after planting exhibited 78.01 per cent of reduction in aphid population. The findings of Nirmala *et al.* (2006) that the application of *L. lecanii* @ $1x10^7$ spores/ml recorded maximum of 80.8 per cent mortality in *A. craccivora* reconfirmed the present study.

Fig. 6. Mean per cent of aphid infestation on shoots observed at weekly intervals during kharif season from May to August 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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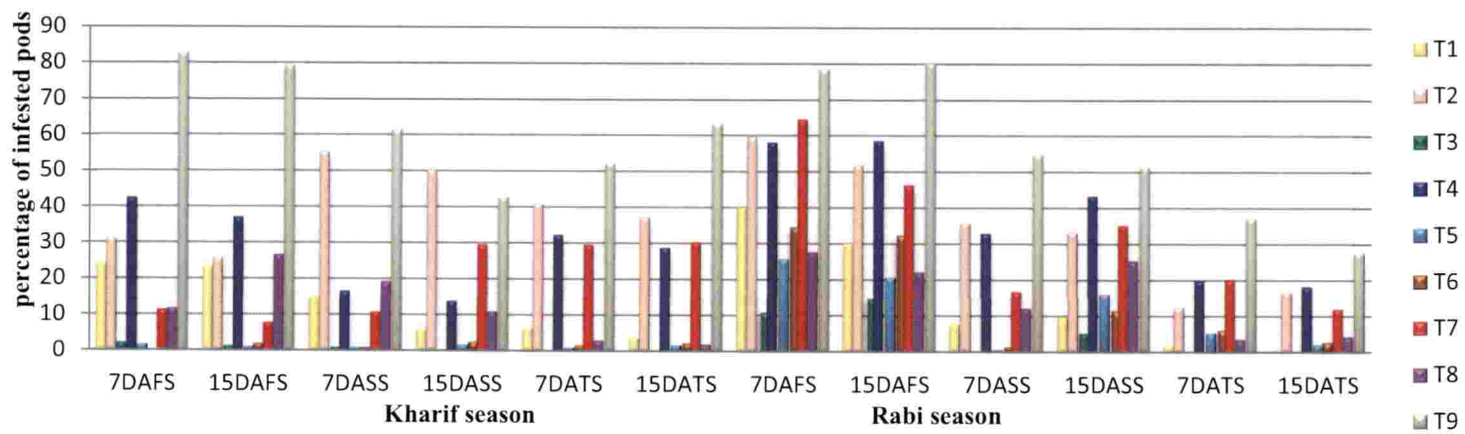
Fig. 7. Mean per cent of aphid infestation on pods observed at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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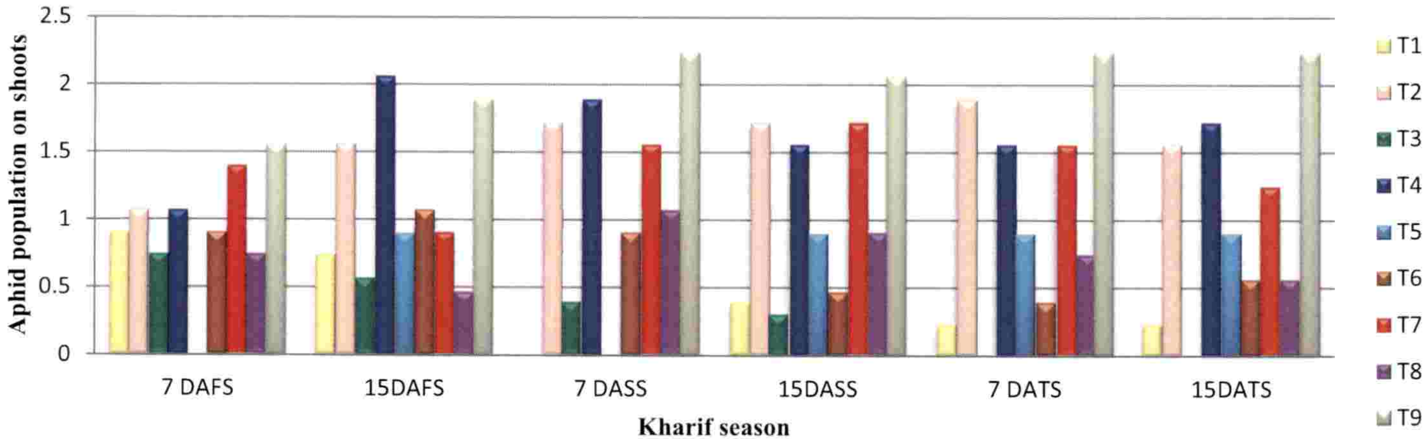
Fig. 8. Scoring of aphid colonies on shoots based on standard scale taken at weekly intervals during kharif season from May to August 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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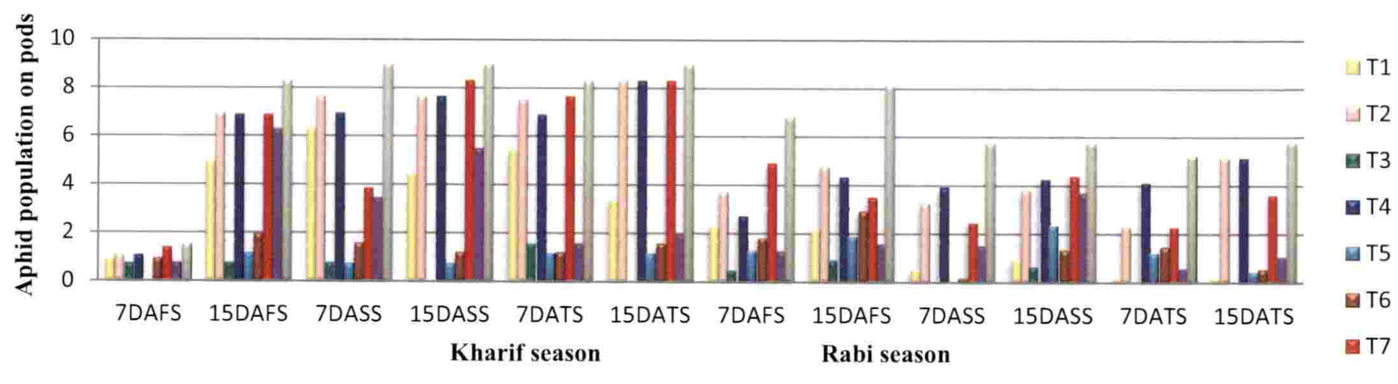
Fig. 9. Scoring of aphid population on pods based on standard scale taken at weekly intervals during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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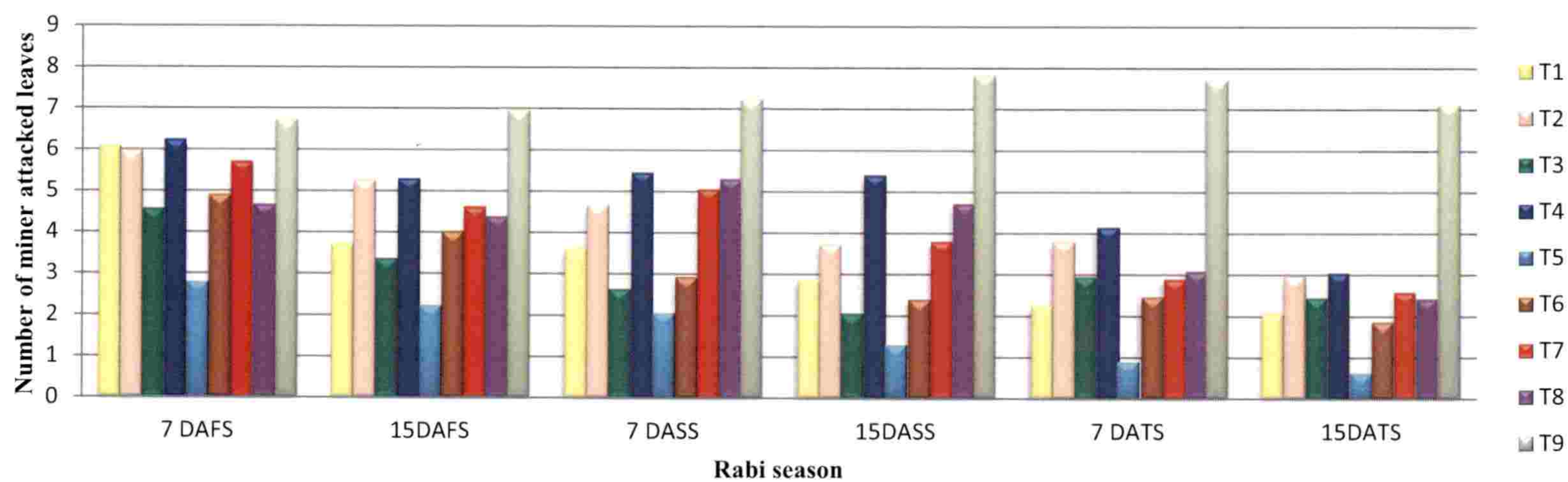
Application of *L. lecanii* was found effective at high humid conditions as the spores get destroyed by heavy sunlight. This is in line with the report of Samson and Rombach (1985) that the spores of *L. lecanii* are slimy so they cannot be disseminated by wind. Infection occurs by passing of spores through insect or through water droplets. Because of this nature, only the hosts are infected and non-hosts act as vectors. *L. lecanii* infect by penetrating the fungal hyphae through the integument and death of insect occurred within 10 days.

5.1.6 Effect of microbials, biorational and neem based insecticides against serpentine leaf miner during rabi season from September to December 2016.

From the results obtained, serpentine leaf miner was effectively controlled by Azadirachtin 1 per cent during rabi season. After Azadirachtin, neem oil was noted to be the next effective treatment (Table 18; Fig. 10). Similar findings were made by Rai *et al.* (2014) that management of leaf miner can be effectively done by spraying NSKE 5 per cent. The leaf miner attack on the leaves at the initial stage of crop growth created an adverse effect on its development. But attack on the later stages did not affect the plant growth as there was enough foliage to compensate the damage caused to the leaves. Leaf miner attack could be seen from the cotyledon stage itself. The intake of Azadirachtin makes the larvae to enter in to pupal stage earlier thereby affecting the metamorphosis. This mode of action helps to control the following generations of leaf miner. The findings of Seal *et al.* (2002) that the application of Azadirachtin 4.5 ml/l along with a surfactant Agridex 0.5 per cent exhibited consistent reduction of leaf miner larvae in cowpea corroborates with the present findings. No leaf miner attack was found during kharif season.

Fig. 10. Mean number of leaves attacked by serpentine leaf miner observed at weekly intervals during rabi season from September to December 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

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5.2 BIOMETRIC OBSERVATIONS

5.2.1 Length of the pods measured from the yield obtained during kharif season (May to August 2016) and rabi season (September to December 2016).

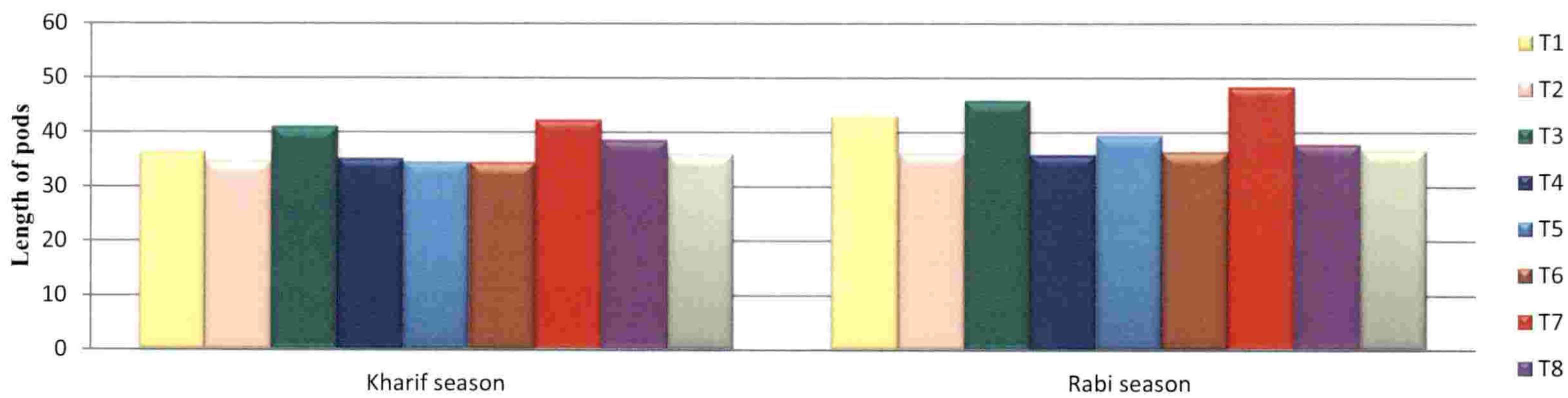
The biometric observation like length of pods was taken to find out whether there is any influence for the treatments. From the mean length of fifteen pods taken, pod length of 42.30 cm was found to be the maximum which was exhibited in spinosad treated plot and a minimum pod length of 34.34 cm was observed in neem oil treated plot during kharif season (Table 19; Fig. 11). Also during rabi season, maximum pod length of 48.40 cm was shown by spinosad treated plot and minimum length of 35.83 in *Bt* treated plot. The reason for variation in the lengths depends on the cell proliferation that occurs within the pods instead of cell elongation. No significant difference was noted in the length of pods between treatments because the pod length is regulated by the combined action of hormone gibberellins, other sugars and mechanism of nutrition signalling. Similar opinion was raised by Veyres *et al.* (2008) by identifying a gene named sweetie that encodes glycosyl transferase enzyme which helps in regulation of sugar flux thereby pod length. Thus pod length is a genetically influenced character.

5.3 YIELD ATTRIBUTES

5.3.1. Yield of yard long bean during kharif season (May to August 2016) and rabi season (September to December 2016).

The total and marketable yield was found maximum in spinosad treated plot during both kharif and rabi season. This was followed by *B. bassiana* treated plot (Table 20 and 21; Fig. 12). Though severe pest infestation was noticed during both seasons, it is because of the higher efficacy of spinosad in controlling the most destructive pod borers, it could yield better. Similar findings were reported by Anitha and Parimala (2014) in pigeon pea that spraying of spinosad 45 SC resulted in least pod damage of 5.1 per cent with greater yield of 1237 kg/ha.

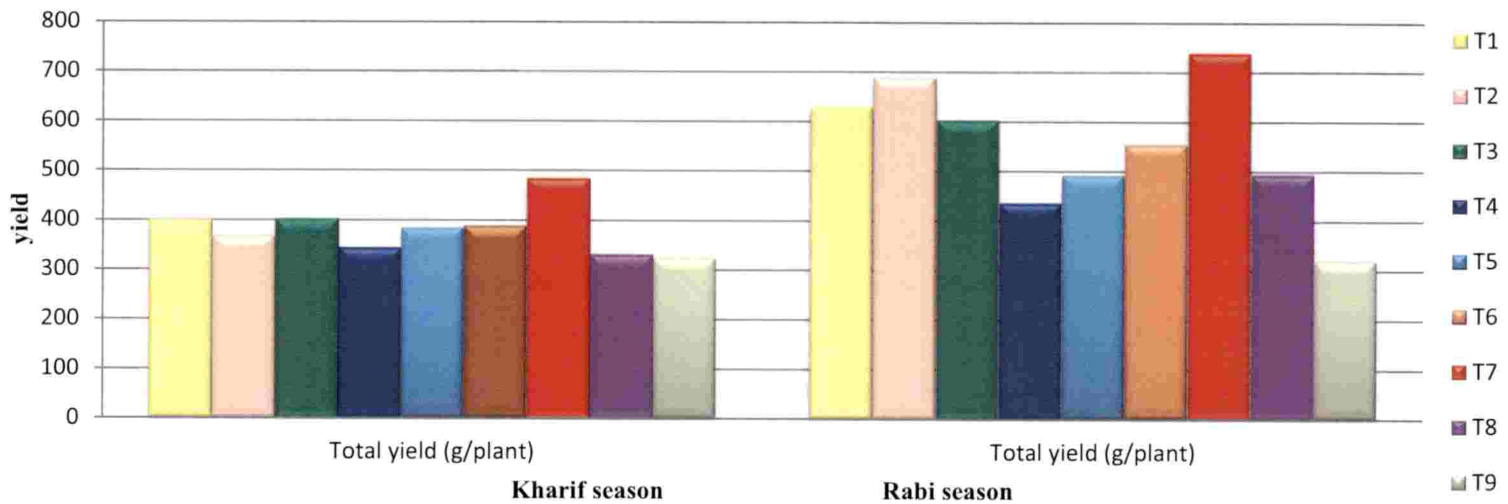
Fig. 11. Mean length of pods per treatment taken during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2× 10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

Fig. 12. Effect of treatments on the yield of yard long bean during kharif season (May to August) and rabi season (September to December) in the year 2016



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water); T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water); T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water); T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water; T_5: Neem based insecticide (Azadirachtin 1% @ 5 ml/l of water); T_6: Neem oil emulsion 5% (50 ml/l of water); T_7: Spinosad 45 SC @ 0.4 ml/l of water ; T_8: Malathion 50 EC @ 2 ml/l of water – Standard check; T_9: Absolute control.

The report of Sreekanth and Seshamahalakshmi (2012) that spinosad treated plot exhibited high grain yield of 831 kg/ha in pigeon pea reinforced the present study. Gopali *et al.* (2013) also reported that application of spinosad in pigeon pea gave a yield of 0.787 t/ha compared to the control. From these earlier findings and present finding it can be concluded that application of Spinosad aids in obtaining higher yield by reducing pest attack.

5.4 ECONOMICS OF PRODUCTION OF YARD LONG BEAN DURING KHARIF SEASON (MAY TO AUGUST 2016) AND RABI SEASON (SEPTEMBER TO DECEMBER 2016)

The highest benefit-cost ratio was given by spinosad during both kharif and rabi seasons followed by *B. bassiana* treated plot. During kharif season, spinosad gave a return of Rs. 1.50 for every one rupee invested and *B. bassiana* gave a return of Rs.1.31 for every one rupee invested (Table 22; Fig 13). During rabi season, spinosad gave a return of Rs. 2.26 for every one rupee invested followed by *B. bassiana* with a return of Rs. 2.18 for every one rupee invested (Table 23; Fig 13). Spinosad though it is costly, high yield from spinosad treated plot could provide an additional amount than the amount invested which compensated the high cost of spinosad. The net returns were high for Spinosad during both seasons. Though *B. bassiana* encountered major pests, it didn't affect the yield severely during both seasons and moreover, *B. bassiana* is cost effective that raised the benefit-cost ratio near to spinosad.

Summary

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6. SUMMARY

The research study entitled "Eco-friendly management of major pests of yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" was carried out with an intention to study the efficacy of different microbial agents, neem based and biorational insecticides along with a standard check against major pests of yard long bean *viz*., cowpea aphid, serpentine leaf miner, flower and pod borers, and pod bugs during two seasons; kharif and rabi from May 2016 to August 2016 and from September 2016 to December 2016 respectively at the Instructional Farm of College of Agriculture, Padannakkad.

A field experiment was conducted with nine treatments and three replications. The variety 'Lola' released by KAU was selected for the study. The cultivation practices were done based on the Package of Practices Recommendations: Crops 2016 (POP, KAU). The treatments applied were; T_1: *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water), T_2: *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water), T_3: *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water), T_4: *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water, T_5: Neem based insecticide (Azadirachtin 1 per cent @ 5ml/l of water), T_6: Neem oil emulsion 5 per cent, T_7: Spinosad 45 SC @ 0.4 ml/l of water , T_8: Malathion 50 EC @ 2ml/l of water – Standard check, T_9: Absolute control. All the treatments were applied at fortnightly intervals and observations were recorded at weekly intervals corresponding to standard weeks.

The following are the salient findings of present investigation.

- After evaluating the efficacy of different microbial agents, neem based and biorational insecticides along with a standard check against pod bores by consecutive spray at fortnightly intervals it was found that Spinosad 45 SC was effective in reducing the number of pod borers during both kharif and rabi seasons.

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- The percentage of flowers and pods infested by pod borers were drastically reduced by the application of Spinosad 45 SC compared to other treatments during both kharif and rabi seasons.

- During kharif season, *Beauveria bassiana* found most effective in reducing the mean number of nymphs and adults of pod bugs and its effect was lowered during rabi season. It may be due to high temperature and low rainfall during rabi season which reduced the ability of *Beauveria* spores to germinate and cause infection. Azadirachtin 1 per cent and Neem oil 5 per cent perpetually showed reduction in number of bugs during rabi season after three consecutive sprays at fortnightly intervals.

- Azadirachtin 1 per cent incessantly lowered the percentage of pods infested by pod bugs during both kharif and rabi seasons after three consecutive sprays at fortnightly intervals which was found to be effective.

- *Lecanicillium lecanii* exhibited consistent reduction in the aphid population on shoots and number of aphid infested shoots after three consecutive sprays at fortnightly intervals.

- *Lecanicillium lecanii* was found to be the most effective treatment in controlling the aphid population in pods and caused exorbitant reduction in the percentage of aphid infested pods after three consecutive sprays at fortnightly intervals during kharif and rabi seasons.

- Azadirachtin 1 per cent was found to be the most effective treatment in controlling serpentine leaf miner after three consecutive sprays at fortnightly intervals.

- Though pod length is an inheriting character, in the present study maximum length was observed in Spinosad 45 SC treated plot during both kharif and rabi seasons.

- With respect to total yield, Spinosad 45 SC performed higher in terms of pod weight (gram per plant) during kharif and rabi seasons with 483.88 g/plant and 738.74 g/plant respectively.

- The marketable yield was also higher in Spinosad 45 SC treated plots with 466.66 g/plant and 718.24 g/plant during kharif and rabi seasons.

- Among the treatments, high benefit–cost ratio of 1.50 and 2.26 was shown by Spinosad during kharif and rabi seasons.

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Abstract

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ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF YARD LONG BEAN, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.

by

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ABSTRACT

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ABSTRACT

The study entitled "Eco-friendly management of major pests of yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" was carried out in the Instructional farm of College of Agriculture, Padannakkad, Kasaragod during two seasons *viz.*, kharif (May to August) and rabi (September to December) in the year 2016. The vegetable cowpea variety 'Lola' released by KAU was selected for the study. The study was undertaken with an intention to find out the efficacy of different microbial agents, neem based and biorational insecticides.

The experimental design was RBD with 9 treatments and three replications. The treatments included; T1- *Beauveria bassiana* (liquid formulation @ 10^7 spores/ml of water), T2- *Metarhizium anisopliae* (liquid formulation @ 10^7 spores/ml of water), T3- *Lecanicillium lecanii* (liquid formulation @ 10^7 spores/ml of water), T4- *Bt* formulation 2×10^8 cfu/ml @ 1 ml/l of water, T5- Neem based insecticide (Azadirachtin 1 per cent @ 5 ml/l of water), T6- Neem oil emulsion 5 per cent (50 ml/l of water), T7- Spinosad 45 SC @ 0.4 ml/l of water, T8- Malathion 50 EC @ 2ml/l of water (standard check), T9- Absolute control. All the treatments were imposed at fortnightly intervals just after the initial attack of pest was seen and observations were recorded at weekly intervals corresponding to standard weeks. The data were subjected to square root transformation and analyzed using ANOVA.

After three consecutive sprays of Spinosad 45 SC @ 0.4 ml/l of water at fortnightly intervals there was complete reduction of pod borer larvae during kharif and rabi season. The percentage of flowers and pods infested by pod borer larvae were also reduced completely and no infestation was noticed after three consecutive sprays of Spinosad during both seasons. Thus it was found that Spinosad 45 SC was effective in reducing the number of pod borers, percentage of flowers infested and percentage of pods infested. During kharif season, *Beauveria bassiana* was found to be the most effective treatment in reducing the nymphs and adults of pod bugs with minimum number of 0.56 bugs per plant followed by 0.63

bugs in T_5 compared to T_9 with 7.46 bugs per plant after three consecutive sprays. During rabi season, Azadirachtin 1 per cent showed no incidence of pod bugs after three sprays and Neem oil 5 per cent consistently reduced number of bugs to zero on 15 days after third spray whereas T_9 exhibited maximum number of 4.26 bugs/plant. The effect of *Beauveria bassiana* was lowered during rabi season. It might be due to the inability of *Beauveria* spores to germinate and cause infection during that season because of inadequate humidity.

Azadirachtin 1 per cent incessantly lowered the per cent of pods infested by pod bugs to zero even after two sprays during both seasons and leaf miner attacked leaves was also found minimum in plot treated with Azadirachtin 1 per cent (0.63 leaves/plant) compared to T_9 (7.12 leaves/plant). The aphid population on shoots and per cent of aphid infestation on shoots were found to be zero after three consecutive sprays of *Lecanicillium lecanii* at fortnightly intervals during kharif season. *Lecanicillium lecanii* also lowered the aphid population on pods and caused exorbitant reduction in the percentage of infested pods during both seasons after three sprays. Though pod length is an inheriting character, maximum length of 42.30cm and 48.40cm was shown by T_7 during kharif and rabi seasons respectively. During both seasons *viz.*, kharif and rabi, the total and marketable yield was high in T_7 with highest benefit – cost ratio of 1.50 and 2.26 respectively.