"Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex"

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

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(ENTOMOLOGY)

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2015

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This is to certify that the thesis entitled ***"Studies on mass production of Beauveria bassiana (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex"*** *submitted in partial fulfilment of the requirement for the degree of* ***MASTER OF SCIENCE (Ag.)*** *in* ***Entomology*** *of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* ***Mr. Narendra Tank*** *under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instructions.*

All the assistance and help received during the course of the investigation has been acknowledged by him.

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LIST OF SYMBOLS

Symbol	Stand for
@	At the rate of
>	More than
<	Less than
±	Plus or minus
%	Percentage
^{0}C	Degree celsius

Abbreviation	
CD	Critical difference
cm	Centimeter
ha	Hectare
hr	Hour
SC	Soluble concentration
Kg	Kilogram
l	Litre
m	Meter
mrl	Meter row length
ml	Mililiter
mg	Milligram
Max	Maximum
Min	Minimum
NS	Non significant
RH	Relative humidity
SEm ±	Standard error of mean
SL	Soluble liquid
SMW	Standard Meteorological weeks
Temp	Temperature

INTRODUCTION

Historically, India is the largest producer, consumer and importer of pulses. The top producer of pulses in India is Madhya Pradesh, as it contributes 24% of the overall pulses production of the nation. Other major pulse producing states include Rajasthan and Uttar Pradesh (www.mapsofindia.com). As they serve a low-cost protein to meet the needs of the large section of the people, they have, therefore, been justifiably described as the poor man's meat. In general, pulses contain 20 to 25 per cent protein and 60 per cent carbohydrate per 100 g with the exception of soybean, which has as much as 43.2 per cent and 20.9 per cent, respectively (www.indiadiets.com). Pulses are also fairly good sources of thiamin and niacin and provide calcium, phosphorus and iron. On an average, 100 g of pulses contain 345 kcal energy, protein 24.5 g, calcium 140 mg, phosphorus 300 mg, thiamin 0.5 mg, riboflavin 0.3 mg and niacin 2 mg (Singh et al., 2002).

Pigeonpea is grown world over, mostly in tropical and sub-tropical countries for grains, green manuring, fodder and forage as sole crop, intercrop, mixed crop and in sequential cropping systems. The countries with notable pigeonpea production are India, Nepal and Myanmar in Asia, Malawi and Uganda along with some other countries in eastern Africa and the Dominican Republic in the Americas (Ahlawat and Shivakumar, 2006).

Pigeonpea is the second important pulse crop of India which has diversified uses as food, feed, fodder and fuel. Pigeonpea is also popularly known as arhar, tur, redgram, congopea, non eyepea etc. Pigeonpea is a rich source of protein (21.71%) and supplies a major share of protein requirement of the vegetarian population of the country. It is also a rich source of iron, iodine and essential amino acids like arginine, cystine and lysine (Singh et al., 2007). In India, during 2013-14 pigeonpea was cultivated in an area

about 3.8 million hectare with a production of 3.02 million tonnes and 776 kg/ha productivity (FAOSTAT 2013-14).

In Madhya Pradesh during 2013-14 pigeonpea was cultivated in an area of about 0.46 million hectare with production of 0.33 million tonnes and 713 kg/ha productivity (www.mpkrishi.org 2013-14). In Jabalpur, during 2013-14 it was cultivated in an area of 10,930 hectare with a total production of 9,700 tonnes and 886 kg/ha productivity (www.mpkrishi.org 2013-14). A large number of insect pests have been identified to infest pigeonpea. The low yields of pigeonpea crop are due to pod borer complex. Among the insect species infesting pigeonpea, the pod borer complex is reported to reduce the yield up to 27.77 per cent (Sahoo and Senapati, 2000). Pod infesting insect pests recorded at Jabalpur are pod fly (*Melanagromyza obtusa* Malloch), gram pod borer (*Helicoverpa armigera* Hubner), pod bug (*Clavigralla gibbosa* Spinola) and plume moth (*Exelastis atomosa* Walsingham). Out of the four pests, *M. obtusa* has been established as the most important pest on the basis of pod and grain damage which range from about 55 to 85 and 29 to 63 per cent, respectively (Landge and kumar 2009). Pod fly now has become important biotic constraint in increasing the production and productivity under subsistence farming conditions, irrespective of agro ecological zones. The survey of Marathwada region of Maharashtra during 2007–08 revealed that the damage by pod fly ranged from 25.5 to 36% (Anonymous 2008). The estimates of avoidable losses due to pod borer complex, mainly pod fly and gram pod borer were 43.5 and 30.2%, respectively (NCIPM 2012).

Management of pod borer complex in pigeonpea relies heavily on insecticides, often to the exclusion of other methods of control. Considerable number of insecticides has been tested and few of them found effective against the pod borers in pigeonpea (Yadav and Dahiya, 2004). Regular and indiscriminate uses of insecticides have induced resistance against several pests besides polluting our much precious environment.

Excessive and indiscriminate use of chemical pesticide usually gives rise to development of resistance to insecticides in the insect pests which becomes a severe problem in the developing countries due to unawareness

of the farming communities to handle insecticide resistance problems. Over the past 20 years, many workers have reported development of resistance in *H. armigera* to a number of chemical insecticides groups (pyrethroids, carbamates, chlorinated hydrocarbon, organophosphates) (Schulten, 1987, McCaffery et al., 1989).

Understanding this lacunes and previous experiences integration of different IPM strategies were followed. This study imphasis on the integration of entomopathogenic fungus and new recommended insecticide molecules for controlling pod borers.

The integration of microbial pesticides with chemical pest management practices requires detailed compatibility studies. Data from such studies would enable farmers to select appropriate compounds and schedule microbial and chemical pesticide treatments so that benefits from compatible sets can be accrued and with non compatible pairs, the deleterious effect of the chemical on the microbe in the biopesticide can be minimize. A microbial pesticide compatible with a commonly used chemical pesticide can be used simultaneously or sequentially with it. To harness the benefits of entomopathogenic fungus their compatibility with insecticides becomes decisive for combined use, while the potential inhibitory effects of insecticides on the entomopathogenic fungus cannot be ignored. The use of incompatible insecticides may inhibit the development and reproduction of these pathogens affecting IPM. If *Beauveria bassiana* has to be incorporated into a pest management programme it is essential to determine the effects of pesticides on it.

Mass production of entomopathogenic fungi is an essential component for their utilization in the IPM. Major obstacle in the mass multiplication of *B. bassiana* is its slow growth rate and non availability of suitable substrate (Gangwar 2013). The growth and development of entomopathogenic fungi depends upon the nutrient factors. Nutrients are the factors which provide energy for biosynthesis and thus help in growth and development of any microorganism. The knowledge of nutritional requirements is the main need in the cultivation of microorganisms. The carbohydrates, proteins, lipids , nucleic acids are made up of macro elements like carbon, hydrogen, nitrogen,

sulphur, phosphorus and these are involved in mechanisms like host pathogen interaction and self defence mechanisms (Yadav 2013) and add of 1% dextrose in mass production (Prasad and Pal 2014).

Beauveria bassiana is a fungus that grows naturally in soils throughout the world and acts as a parasite on various arthropod species, causing white muscardine disease; it thus belongs to the entomopathogenic fungi. It is being used as a biological insecticide to control a number of pests such as termites, thrips, whiteflies, aphids and different beetles. When the microscopic spore of the fungus comes in contact with the body of an insect host, they germinate, penetrate the cuticle and grow inside, killing the insect within a matter of days (Barbarin et al., 2012).

Therefore keeping this in view, present investigations were taken-up to study the compatibility of *B. bassiana* with recommended new generation chemicals in controlling pigeopea pod borer complex. Attempts were made to investigate on these aspects with the following objectives:

1. To study the influence of temperature and nutrient on mass production of *Beauveria bassiana* on local substrates.
2. To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex.
3. To study the population dynamics of pigeonpea pod infesting insect pest complex.

REVIEW OF LITERATURE

2.1. To study the influence of nutrient and temperature on mass production of *Beauveria bassiana* on local substrates:

Mazumder et al., (1995) evaluated locally available various industrial wastes as substrates for mass culturing of *Beauveria bassiana.* The results revealed rice husk supplemented with 2% dextrose to be the most suitable medium, yielding 5.80 x 10^7 conidia/ml of water.

James et al., (1998) reported that the constant temperatures between 15 and 35°C had a significant effect on both germination rate and vegetative growth of *B. bassiana,* with the fastest germination occurring at 25-32°C and the fastest growth occurring at 30°C. Although temperature affected the rate of conidial germination, total germination eventually reached 97-100% at all temperatures.

Sivasankaran et al., (1998) evaluated among the 5 different temperature conditions tested; radial growth, biomass production and sporulation were greater at 25^0C. Similarly susceptibility of third instar shoot borer (*Chilo infuscatellus*) larvae to fungal infection was higher when the larvae were held at 25^0C after treatment. Among the 5 relative humidity (RH) levels tested at 25^0C, the radial growth of the fungus was maximum at 90% RH, whereas biomass production and sporulation were greater at 100% RH. Higher mortality of borer larvae occurred at 100 and 90% RH levels and the susceptibility decreased as the RH increased.

Abraham et al., (2003) reported that the various concentrations (0.5, 1, 2, 3, 4, 5 and 6%) of sugarcane molasses, the 3-6% molasses was found to be highly suitable for the radial growth, biomass production and spore production of *B. bassiana*. The different concentrations (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%) of spent wash, a waste product from sugar factories tested for the growth and spore production of *B. bassiana*, did not support any fungal growth. Among the grains (sorgum, finger millet, pearl millet and rice) and tubers (potato, tapioca, beetroot and carrot) tested, rice recorded the maximum ($0.67x10^{10}$ g/100 ml) mycelial dry weight of the fungus, followed by

sorghum ($0.64x10^{10}$ g/100 ml), whereas spore production of *B. bassiana* was significantly higher in chopped carrots ($2.08x10^{10}$ spores/100 g), tapioca ($1.74x10^{10}$ spores/100 g) and potato ($1.67x10^{10}$ spores/100 g) compared to PDA medium ($1.45x10^{10}$ spores/100 ml). Among the agricultural byproducts (sugarcane bagasse, sugarcane pressmud, tapioca rind and coconut water) tested, sugarcane pressmud recorded the highest spore production ($1.85x10^{10}$ spores/100 g). Among the oil cakes (groundnut cake, cottonseed cake, neem cake, coconut cake and gingelly [sesame] cake) tested, spore production of *B. bassiana* was maximum ($5.35x10^{10}$ spores/100 g) on gingelly cake, followed by cottonseed cake ($4.31x10^{10}$ spores/100 g) and neem cake ($3.80x10^{10}$ spores/100 g).

Parmod and Saroj (2004) reprted various solid (rice bran, wheat bran, maize bran, press mud, rice husk and bagasse) and liquid (carrot broth, potato broth and sugar mill effluent) substrates, with or without 2% dextrose, for the culture of *B. bassiana* was evaluated. Flasks containing the various media were inoculated with a 14 days old culture of *B. bassiana* and incubated at 28 ± 2^0C and 60% relative humidity. The *B. bassiana* conidial suspension obtained from each substrate was inoculated ($1x10^7$) to C. auricilius 3rd instar larvae and larval mortality was observed at 28 ± 2^0C and 60% relative humidity. Among the solid media, wheat bran and maize bran resulted in the greatest fungal sporulation (5.53 and 5.52 x 10^7 conidia/ml, respectively). Suspensions obtained from all media caused more than 70% larval mortality. *B. bassiana* sporulated poorly in press mud, but the incorporation of dextrose significantly enhanced conidial production in this medium. The conidial suspension obtained from the medium consisting of rice husk resulted in high larval mortality (81.5%).

Patel and Kanaujia (2004) reported that *Beauveria bassiana* and *Metarhizium anisopliae* cultured at 15, 20, 25, 30 and 35^0C using PDA medium showed maximum biomass, radial growth, conidial-count and viability at 25^0C in case of *B.bassiana* followed by 30^0C whereas the most favourable temperature for growth and germination of *M. anisopliae* was 30^0C followed by 25^0C. There was a significant reduction in growth and sporulation of the

fungus when temperature was either raised to 35^0C or reduced to 20 and 15^0C.

Shimazu (2004) evaluated that the mycelial growth and germination rates of *B. bassiana* F-263 at various temperatures were investigated to determine the efficient culture conditions and tolerance of this strain to higher temperatures. Mycelial growth was quantified by measuring colony diameters at constant temperatures and occurred from 6 to 33^0C, with maximum growth at 30^0C. The fungus could recover and grow when transferred to 25^0C after exposure to higher temperatures, even if the fungus did not grow during high temperature exposures. The longest high temperature periods after which this fungus survived were 8 days at 35^0C and 4 days at 36^0C when initiated with hyphal bodies and more than 14 days at 35^0C and 7 days at 36^0C when initiated with conidia. At 25 to 30^0C, the conidial germination rate rose to almost 100% within 20 h. At 34^0C, germination was very low within 20 h, but almost 100% over 48 h. At 35^0C, germination was only 4.6% even more than 4 days after inoculation, although most conidia inflated within 24 h. No germination was observed at 36^0C, although most conidia inflated within 24 h. Growth rates of germ tubes from conidia were slower at temperatures higher than 33^0C.

Rao et al., (2005) evaluated various agricultural wastes and by products singly and in combinations in semi-solid or broth media for mass production of *Beauveria bassiana*. Eight substrates, *i.e*. rice husk (RH), rice bran (RB), rice straw (RS), wheat husk (WH), wheat straw (WS), used tea leaves (UTL), sawdust (SD) and maize cob shell (MCS) singly, and 3 combinations: RH+RB (1:1), RH+WB (1:1) and RB+WB (1:1), were selected for the mass multiplication of the isolates. Seven liquid media, i.e. Sabourd dextrose both (SDB), Sabourd maltose broth (SMB), Czapek's Dox solution, Richards's solution, carrot potato broth (CPB), potato dextrose broth (PDB) and molasses (2%)+Bakers' yeast (0.03%), were selected to observe the biomass production and sporulation. The combination of RH+RB followed by RH+WB resulted in the maximum sporulation among agro-based substrates. Among the broth media, SDM, followed by SMB, recorded the maximum sporulation and biomass production per unit volume.

Elanchezhyan et al., (2007) reported that the laboratory experiments were conducted to study the effect of temperature on the growth and sporulation of *B. bassiana* and *Nomuraea rileyi*. Among the different temperatures studied, incubation of *B. bassiana* seeded Petri plates at 25^0C only showed significantly maximum radial growth of 3.94 cm measured 15 days after inoculation, while the minimum mycelial growth of 3.01 cm was recorded at 35^0C.

David et al., (2008) evaluated the effect of temperature on germination, radial growth and virulence of selected isolates (two isolates of *B. bassiana* and nine of *M. anisopliae*) on *T. evansi* was also investigated in the laboratory. All the fungal isolates tested were pathogenic to the adult females of *T. evansi*, and there were significant differences in mortality between fungal isolates. The lethal time to 50% mortality (LT50) values ranged from 4.2 to 8.1 days and the LT90 values from 5.6 to 15.1 days. Temperature had significant effects on germination, radial growth and virulence of the various isolates. The best fungal germination was observed at 25 and 30^0C, while for the fungal radial growth it was 30^0C. All the isolates germinated and grew at all temperatures, but germination and radial growth varied with isolate and temperature. The selected isolates were allvirulent to *T. evansi*, but virulence varied also with isolate and temperature.

Sahayaraj and Namasivayam (2008) evaluated Various agricultural products and byproducts such as grains, vegetable wastes, seeds, rice husk, sawdust and liquid media such as coconut water, rice and wheat-washed water and rice-cooked water were evaluated for mass production of three entomopathogenic fungi, namely *B. bassiana*, *Paecilomyces fumosoroseus* and *Verticillium lecanii*. Among the grains, wheat supported maximum spore production for *B. bassiana* while sorghum recorded maximum spore production in *P. fumosoroseus* and *V. lecanii*. Similarly carrot, jack seeds and ladies finger also supported good growth and sporulation of all the three tested fungi. Coconut water supported maximum growth and sporulation.

Rajanikanth et al., (2010 and 2011) evaluated five substrates, *viz*., sorghum, rice bran, rice husk, pressmud and bagasse to identify the most suitable substrate for large scale multiplication of six strains of *B. bassiana*.

The results of the study showed sorghum as the most suitable substrate as it yielded highest conidial count for all the strains and the conidial viability was also highest in the conidia harvested from sorghum. The strain Bb-5A was found to be the most vigorous among all the strains as it recorded highest conidial count per gram of the substrate on all the substrates used and recorded highest mortality of *Spodoptera litura*.

Sachin et al., (2011) observed that the conidial production of *B. bassiana* was highest on media containing rice, sorghum, jowar husk, SDA and SDB. The least conidial growth was observed in cow urine and sugarcane baggase. However, among the substrates, the sugarcane baggase was the cheapest.

Ficiu et al., (2013) reported that the objective of this study was to select an optimal culture system for the production of the *B. bassiana* fungal biomass with high virulence, in order to realize a compound which will be used in the biological control of *phylloxera galicola.* The influence of different solid substrates on the production of *B. bassiana* fungal biomass was analyzed using the diphasic liquid-solid fermentation technique. The liquid phase, represented by a spore suspension with fungitoxic effect of *B. bassiana*, in an active growth phase, was mixed, in a ratio of 1/1 with the solid substrates represented by: barley, rice, broken maize and wheat. The best results were obtained on solid substrate represented by wheat which was selected for the production of fungal biomass. The worst results were obtained on broken maize. The selected culture substrat will be applied to ensure enough spores in order to achieve the compound which will be used in the vineyard.

Gangwar (2013) reported that addition of 1 per cent sucrose increased the growth and sporulation of *B. bassiana* in sorghum (6.65 × 109 cfu) and barnyard millet (6.24 × 109 cfu). However, population of *B. bassiana* was significantly reduced in sorghum and barnyard millet grains when amended with 2 per cent sucrose.

Rishi et al., (2013) conducted mass culturing of *B. bassiana* soil microbes on different agricultural products like rice powder, rice bran,

sorghum grain and agricultural waste. The fungus grew better on sorghum grain at normal room temperature of 25-28^{0}C with relative humidity of 60-65%. The spore load on these media varied from 500-550 spores/ml counted from 25 sq.mm squares of the haemocytometer.

Kaur and Joshi (2014) evaluated rice, wheat, maize, sorghum, mini potato tubers, rice bran and rice straw for mass production of three *B. bassiana Vuillemin* strains. They reported rice as the most suitable substrate for examined fungi as it yielded highest conidial count (31.8x10^5 cfu/g) and colony forming unit (30.5x10^5 cfu/g) whereas rice straw recorded minimum conidial count (12.2x10^5 cfu/g).

Smriti et al., (2015) in a experiment observed conidia production of insect pathogenic fungi *B. bassiana* (NCIM-1300) grown on four different substrates viz Spent Mushroom Substrate (SMS), Barley, Rice and Jatropha Press Cake was evaluated. In grains, highest conidial yield was on rice which was followed by barley. Among the agro-industrial residue, SMS show more spore production than Jatropha press cake. It was for the first time that Jatropha press cake and SMS were used as a substrate/support for the growth of *B.bassiana*. Both show good results and can be used in future for the commercial production of mycopesticide.

2.2. To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex

2.2. (i) Invitro studies on compatibility of *Beauveria bassiana* with some new generation insecticides:

Ying Sheng and Ming Guang (2002) studied the compatibility of *B. bassiana* conidia with 10 widely used pesticides. The results showed that negative effects of the pesticides on the germination of *B. bassiana* conidia increased with the increasing pesticide concentrations. Five insecticides, including imidacloprid 10% WP, yashiling 22% WP (a mixture of imidacloprid and buprofezin), methomyl 20% EC, triazophos 20% EC and fipronil 5% FF, exhibited high compatibility with *B. bassiana* conidia with germination rates exceeding 90% even at the highest concentration. The other two insecticides, chlorfluazuron 5% EC and fenvalerate 20% EC, greatly reduced the

germination rate of *B. bassiana* at the field-spray concentrations recommended, however, at lower concentrations, the germination rates increased by a big margin.

Amutha et al., (2010) evaluated compatibility of *B. bassiana* was studied in the laboratory condition with twelve commonly used insecticides for cotton pest management by poisoned food technique. The results were expressed as percentage of growth inhibition of *B. bassiana* colony on insecticide treated medium. Among the insecticides tested for their compatibility, only chlorpyriphos 20 EC was rated as relatively less toxic to *B. bassiana*, while, spinosad (45% SC), econeem (1%), quinalphos (25 EC), acetamprid (20%), endosulfan (35 EC) and thiodicarb (75 WP) were slightly toxic. Imidacloprid (17.80% SL) and triazophos (40 EC) were moderately toxic and profenofos (50 EC), indoxacarb (14.5 % EC) and methyldemeton were highly toxic. Results of the present study suggested that except profenophos, indoxacarb and methyldemeton, the rest of the insecticides tested can be safely used along with the entomopathogenic fungi *B. bassiana*.

Muhammad et al., (2010) reported that all insecticides significantly inhibited mycelial growth and conidial germination of the fungal pathogens. Lorsban was the most toxic insecticide to mycelia growth and conidial germination followed by Lannate, Larvin and Pirate. Cascade, Match, Steward and Proclaim were comparatively less toxic to mycelial growth (36.78-48.67% inhibition) and conidial germination (40.32-49.97% inhibition) of the fungal pathogens. Conversely, Runner, Capture, Abamectin and Curacron were compatible with significantly lesser inhibition in growth (25.19-36.47%) and conidial germination (27.78-43.66%) of the fungi. Tracer was found safe to conidial germination and growth of the fungi.

Yue Zhang and Shengli (2011) studied impacts of 7 insecticides and 3 herbicides on conidial germination, growth speed and sporulation of 10 isolates of *B. bassiana*. Results showed that all the pesticides inhibited spore germination at conventional concentration and the inhibition declined as the concentration was decreased. Diluted by 10 times, 8% cypermethrin, 30% benazolin and 6.9% fenoxaprop-ethyl became not significantly inhibitory. All pesticides significantly inhibited mycelium growth under conventional

concentration. Inhibition on some isolates by 1% emamectin benzoate, 40% chlorpyrifos, 4.5% beta-cypermethrin and 8% cypermethrin was significantly reduced after diluted by 10 times.

Nitin (2014) reported that the effect of insecticides on the mycelial growth of *B.bassiana* was conducted invitro amoung the tested emamectin benzoate 5 SG was found to be most compatible with least inhibition percentage followed by flubendiamide 20 SC and rynaxypyr 20 SC.

2.2 (ii) Invivo studies on efficacy of *B .bassiana* with some new generation insecticides against pod infesting insect pests:

Srinivasan and Durairaj (2007) reported that lowest *Helicoverpa* larval population was recorded in spinosad 45 SC (73 g a.i./ha) treated plots, followed by indoxacarb 14.5 SC, and maximum population in the untreated control.

Singh et al., (2008) studied the relative performance of some newer and commonly used insecticides against insect-pest complex of short duration pigeonpea. The damage to pod and grain by various insect pests was found to be minimum in coragen 20% SC @ 40 g *a.i.*/ha and maximum in the control. Highest grain yield (615.2 kg/ha) was recorded from the plots treated with spinosad 45% SC @ 73 g *a.i./*ha.

Ambulker (2008) reported that two sprays of emamectin benzoate 5% SG @ 9 g *a.i.* /ha was found to be most effective in reducing *H. armigera* larval population and pod and grain damage and registered highest grain yield, followed by lamda-cyhalothrin 5% EC @ 37.5 g *a.i.* / ha and spinosad 45% SC @ 56 g *a.i.* / ha, respectively. Highest cost benefit ratio was obtained from lamda-cyhalothrin which was closely followed by emamectin benzoate, chlopyriphos 20 EC @ 100 g *a.i.* /ha and spinosad, respectively.

Das et al*.,* (2009) reported that two sprayings, initiating at 50% flowering and repeated at 10 days interval of rynaxypyr (coragen) 20 SC @ 30 - 40 g *a.i.*/ha was quite effective in controlling pigeonpea pod borer complex.

Landge (2009) studied the efficacy of newer chemicals and reported rynaxypyr 20 SC @ 40 g *a.i.*/ha to be most effective not only in reducing the pod borer larval population and damage but also registered highest grain yield. Maximum cost benefit ratio 1:5.61 was obtained from fenpropathrin 30 EC @ 100 g *a.i.*/ha, followed by endosulphan 35 EC @ 60 g *a.i.*/ha (1:4.00) and flubendamide 20 WDG @ 50 g *a.i.*/ha (1:2.35).

Babariya et al., (2010) investigation on chemical control of gram pod borer, *H. armigera* Hubner infesting pigeonpea indicated that among the different insecticides tested indoxacarb 0.0075% gave the highest per cent mortality of the pest followed by spinosad 0.009%, profenophos + cypermethrin 0.044% and endosulfan 0.07%. Indoxacarb 0.0075% recorded significantly highest grain yield (1486 kg/ha). While, highest cost benefit ratio of 1:18.94 was obtained from the treatment of endosulfan 0.07%.

Pawar (2010) studied the efficacy of newer chemicals and reported that all the chemicals proved their superiority over control in reducing the pod and grain damage and increasing the grain yield. Spinosad 45 SC @ 73 g *a.i.*/ha followed by rynaxypyr 20 SC @ 40 g *a.i.*/ ha were the most effective treatments on the basis of the effectiveness against pod borer complex on grain damage and grain yield.

Babu and Mallikarjun (2012) investigation on chemical control of gram pod borer, *H. armigera* Hubner infesting pigeonpea indicated that among the different insecticides tested, indoxacarb 0.0075 per cent gave the highest per cent mortality of the pest followed by spinosad 0.009 per cent, profenophos+cypermethrin 0.044 per cent and endosulfan 0.07 per cent. Endosulphon 0.07 per cent 0.0075 per cent recorded significantly highest grain yield (1486 kg/ha). While, highest cost benefit ratio of 1:18.94 was also obtained from the treatment of endosulfan 0.07 per cent.

Gopali et al., (2012) reported the treatments comprised indoxacarb 14.5 SC at 0.30 ml, spinosad 45 SC at 0.10 ml, emamectin benzoate 5 SG at

0.20 g, rynaxypyr 18.5 SC at 0.15 ml, methomyl 40 SP at 1.0 g, acephate 75 SP at 1.0 g, chlorpyrifos 20 EC at 2.5 ml, dimethoate 30 EC at 1.7 ml, neem seed kernel extract (NSKE) at 5%, and *V. lecanii* [*Lecanicillium lecanii*] at 1 x 1010conidia/l. Methomyl was found to be significantly superior, followed by chlorpyrifos and acephate, recording the highest grain yield (1.110 t/ha), net profit (27686) and benefit:cost ratio (4.54). Dimethoate and NSKE were moderately effective in reducing the pod bug population. The other treatments were found ineffective.

Sreekanth and Seshamahalakshmi (2012) conducted an experiment during Kharif, 2010 to evaluate the efficacy of different biopesticides against gram pod borer *H. armigera* (Hubner) and legume pod borer, *Maruca vitrata* (Geyer) on pigeon pea revealed that there is no significant difference between the treatments against pod damage due to gram pod borer, *H. armigera* since the population and there by pod damage was very low during the season. The untreated check has recorded only 1.63% pod damage due to *Helicoverpa*. The per cent inflorescence damage due to legume pod borer was lowest in spinosad 45% SC @ 73 g a.i/ha (4.74%), followed by *B. thuringiensis*-1 @ 1.5 kg/ha (10.52%) and *B. bassiana* SC formulation @ 300 mg/Lt (14.15%) with 80.9, 57.6 and 42.9 per cent reduction over control respectively as against control (24.79%). The pod damage due to *Maruca* was the lowest in spinosad (17.38%), followed by Bt.-1 (27.57%) and *B. bassiana* SC formulation @ 300 mg/lt (33.82%) as against control (45.84%) with 62.1, 39.9 and 26.2 per cent reduction over control respectively. The highest grain yield was recorded in spinosad 45% SC @ 73 g.i/ha treated plots (831.0 kg/ha), followed by Bt.1 @ 1.5 kg/ha (743.1 kg/ha) and *B. bassiana* SC formulation @ 300 mg/Lt (694.4 kg/ha) with 104.0, 82.4 and 70.5 per cent increase over control respectively as against the minimum yield of 407.4 kg/ha in the untreated check.

Vinayaka et al., (2013) evaluated efficacy of new insecticides with bioagent revealed that the lowest pod damage by *Helicoverpa* was recorded in spinosad, *M. anisopliae*, spinosad with 12.0%, podfly damage of 2.65% and field infestation of bruchid was 2.10% but lowest infestation of *Maruca* was in indoxacarb, *M. anisopliae*, indoxacarb with 0.78%. Total pod damage by pod borers was the least in s pinosad, *M. anisopliae,* spinosad (17.62%) followed

by indoxacarb, *M.anisopliae*, indoxacarb (22.58%) and flubendiamide, *M. anisopliae*, flubendiamide (22.76%) which were at par but statistically different from other treatments. The total seed damage by podborer complex of pigeonpea also followed the trend of total pod damage. Lowest total seed damage was observed in case of spinosad, *M. anisopliae,* spinosad with 16.98 per cent. Highest yield was recorded in case of spinosad, *M. anisopliae*, spinosad with 13.20 q per. The lowest yield was observed in untreated control with 4.06q ha -1 which was inferior to all other treatments.

Ajagol et al., (2014) evaluated IPM modules for management of pod borer complex in hybrid pigeonpea. The data indicated that pesticide based IPM module comprising of rynaxypyr 18.5SC, spinosad 45SC and flubendiamide 480SC proved to be cost effective by recording highest grain yield (2819 kg/ha).

Kapasi et al., (2014) a study was conducted to evaluate the bioefficacy of different oil carriers (sunflower oil, seamum oil, neem oil, mineral oil), sugar solution and water formulation to be used in ultra low volume sprayer (ULV) along with rynaxypyr 18.5 SC (Coragen) for the management of pod borer at the Agricultural Research Station, Gulbarga, Karnataka, India during the kharif season of 2011-2012. The results revealed that the sesamum oil carrier fits well with rynaxypyr 18.5 SC and recorded the lowest mean pod borer larval population after last spray (1.0 per five plants) the lowest pod damage (23.20%), grain damage (18.30%) and higher grain yield (9.43 q/ha) with a high B:C ratio of 3.64 in the plot sprayed with the sesamum oil carrier. The findings suggested that the sesamum oil carrier in ULV sprayer is suitable and practicable in pigeonpea ecosystem for effective management of pod borer with no risk of phytotoxicity, spray drift and operational difficulties. The foregoing studies indicated that the performance of sesamum oil carriers was superior to other carriers in terms of suppression of larval population, reduction in pod damage and harnessing higher yield.

Sreekanth et al., (2014) experimental results showed that the number of *Helicoverpa* larvae per plant were lowest in plots treated with chlorantraniliprole 20 SC (0.43), flubendiamide 480 SC (0.59) and spinosad 45 SC (0.85) as against untreated control plot (4.17) with 89.7, 85.9 and 79.6

percent larval reduction over control, respectively. Pod damage due to pod borer, *Helicoverpa* was lowest in plots treated with flubendiamide (1.16%), chlorantraniliprole (1.26%) and spinosad (1.92%) with 88.7, 87.7 and 81.2 per cent reduction over control respectively. The untreated plot has recorded maximum pod damage of 10.22%.

Sambathkumar et al., (2015) evaluated the efficacy of newer insecticides and botanicals followed by Indoxacarb against pod borers infesting redgram variety CO 6. Among newer insecticides, the significant least incidence of *M. vitrata* was recorded in indoxacarb 15.8 EC @ 75 g a.i./ha (3.1 webbings/ 10 plants) and chlorantraniliprole 18.5 SC 30 g a.i./ha (3.9 webbings/ 10 plants). The minimum larval population of *H. armigera* was recorded in chlorantraniliprole 18.5 SC @ 30 g a.i./ha (9.5 nos./ 10 plants) and indoxacarb 15.8 EC @ 73g a.i/ha (10.3 nos./ 10 plants). Low per cent pod fly grain damage (11.7) was recorded in chlorantraniliprole 18.5 SC @ 30 g a.i./ha with the highest yield of 892.2 kg/ha in indoxacarb 15.8 EC @ 75g a.i/ha. Among botanicals and combination of botanicals and indoxacarb spray, least number of Maruca webbings, minimum *Helicoverpa* larval population (18.3), *Helicoverpa* pod damage (16.3%) were recorded in Neem soap (10g) followed by indoxacarb (0.5ml) (5.7/ 10 plants) with maximum yield of 732.9 kg/ha in Pongamia soap (10g) followed by indoxacarb (0.5ml).

2.3. To study the population dynamics of pigeonpea pod infesting insect pest complex :

Das and Katiyar (1998) reported that pod fly was first noticed in the 43rd SW. Average temperature of about 20^{o}C coinciding with proper podding stage of the crop was found to be favourable for egg laying during 48th - 50th SW. Average temperature of 20^{o}C was also found to be favourable for maggot and pupal development and maximum maggot and pupal population were observed during 5th SW and 50th SW respectively.

Misra and Dash (2001) studied the seasonal activity of *C. gibbosa* on pigeonpea. The results revealed that all the stages (eggs, nymphs and adults) appeared simultaneously during the 46th standard week. The adult population

did not show any peak till harvest of the crop, rather it increased gradually from its appearance. The nymphal and total population showed a small peak around the 50th standard week, reaching the highest level during the 4th standard week. There after, the population declined up to harvest. Meterological variables like mean temperature and rainfall had no effect on egg laying, while mean relative humidity was highly negatively correlated with the tur pod bug population.

Reddy et al., (2001) studied the effects of temperature, relative humidity, rainfall, wind speed and sunshine on the population of pigeonpea pests, *i.e. H. armigera*, *Exelastis atomosa* and *M. vitrata* in New Delhi, India during the *kharif* season of 1996 and 1997. The population of the insects showed positive correlation with maximum temperature (except *Empoasca kerri*), minimum temperature (except *Megalurothrips usitatus* and *Exelastis atomosa*) and morning relative humidity. A negative correlation between insect population and relative humidity (except *Empoasca kerri*), wind speed (except *Mylabris pustulata*) and sunshine (except *Megalurothrips usitatus* and *Mylabris pustulata*) was observed.

Akhilesh and Paras (2005) studied during 1994-96 in Uttar Pradesh, India, to determine the effects of different meteorological factors on the insect pest population in pigeon pea cv. UPAS 120. All the meteorological parameters showed non-significant effects (whether positive or negative) on pests of pigeon pea. Temperature, relative humidity and water evaporation had negative correlations with population build up of blue butterfly and pod bug. Pod bug population showed a negative relationship with rainfall and a positive relationship with wind velocity and sunshine hours. Rainfall had a positive impact on blue butterflies while wind velocity had a negative relation with the population. In case of plume moth, the maximum minimum and average temperatures, minimum relative humidity, water evaporation and sunshine hours had positive effects on the population build up of the pest, while the rainfall, wind velocity, maximum and average relative humidities showed negative effects. Rainfall, wind velocity, maximum, minimum and average temperatures and maximum, minimum and average relative humidities had a positive impact on the population build up of legume pod

borer (*Maruca testulalis* [*Maruca vitrata*]), while water evaporation and sunshine hours showed a negative impact. In case of pod fly, rainfall, wind velocity, minimum and average temperatures and relative humidity had negative effects, while maximum temperature, relative humidity, water evaporation and sunshine hours showed non-significant positive effects on the population build up. The average population of *Lampides boeticus*, *E. atomosa*, *C. gibbosa* and *M. testulalis* was 1.31, 0.92, 1.67 and 0.93 plants-5, respectively. The average pod fly population was 3.53 pods-10.

Deshmukh et al., (2005) studied the correlation of pigeonpea pod borers with weather parameters and reported that none of the weather parameters showed any effect on the population build-up of *H. armigera* eggs. The maximum and minimum temperatures were negatively correlated with *H. armigera* larvae. There was no correlation on the population build-up and weather parameters for *E. atomosa* except minimum temperature and morning relative humidity. Both of them exhibited significant negative correlation with *E. atomosa* population.

Ambulker, (2008) observed that first appearance of *H. armigera* eggs and larvae during 41st and 42nd standard week respectively.

Kaushik et al., (2008) studied the impact of various abiotic factors on population build up of pigeonpea pests *viz., H. armigera* (Hubn), *E. atomosa, C. gibbosa* (Spin.), *M. obtusa* (Mall) on pigeonpea cultivar Asha.

Mahalle (2008) studied the population dynamics of major insect pests during reproductive stage and found that pod fly eggs and pupae were negatively and positively correlated with morning relative humidity and evaporation respectively.

Rana et al., (2008) reported that *H. armigera, E. atomosa, C. gibbosa* and *M. obtusa* were noticed from the flowering to the podding stage of pigeonpea crop *i.e.* from December to February.

Landge (2009) studied the population dynamics of major insect pests and found that sunshine and evening vapour pressure had negative impact on red gram plume moth larvae. Further maximum temperature, sunshine and

evaporation had negative impact and evening relative humidity, morning relative humidity, evening vapour pressure and minimum temperature had positive impact on immature stages of pod fly population respectively.

Rathore (2011) observed first appearance of gram pod borer, *H. armigera*; pod bug, *C. gibbosa* during 47th standard week and pod fly, *M. obtusa* during 52nd standard week.

Yadav et al., (2011) from Modipuram, Meerut, Uttar Pradesh reported that pod fly *M. obtusa (Malloch)* maggots in pigeonpea pods were first observed in the first week of October (90-100 days old crop) and peaked up to 47th week i.e. first week of November when crop was 100 to 125 days old and thereafter population declined to zero level with maturity in the first week of December, thus the pest remained active for nearly two months. The maggot population started building up when the maximum temperature dropped below 32ºC and attained the peak when it further declined. The present findings suggest that maximum temperature below 30ºC and minimum temperature between 8.1-17ºC and average relative humidity around 60-70% is conducive for population build up of the pest. Correlation between maggot population and rainfall for current, one, two and three weeks before was found significant and negative, indicating adverse effect of rainfall.

Dwivedi et al., (2014) reported that the maximum population of gram pod borer was recorded on 44th Standard Week (12.75/m2) on maximum temperature of 33ºC, minimum 18.20ºC and R.H. 71.70%. The maximum tur pod fly population 26.0/m2 was observed on maximum temperature of 31.70ºC, minimum 15.20ºC and R.H. 87.30%. As for variety Bahar the maximum population of leaf webber 14.50/m2 was observed on maximum temperature of 34.30ºC, minimum 21.20ºC and R.H. 65.0%. The population of gram pod borer 6.75/m2 was observed on maximum temperature of 26.10ºC, minimum 8.50ºC and R.H. 55.40%. The highest population of tur pod fly (16.25/m2) was observed on maximum temperature of 28.30ºC, minimum 10.90 degrees C and R.H. 59.90%. The population of gram pod borer was maximum (13.75/m2) and tur pod fly (23.0/m2) was recorded on maximum temperature of 33.30ºC, minimum 18.20 ºC and

R.H. 71.70% in variety UPAS-120. The maximum population of gram pod borer 6.25/m2 was recorded on maximum temperature of 25.50 ºC, minimum 6.30ºC and R.H. 90.20% and maximum population of tur pod fly was recorded (15.25/m2) on maximum temperature of 24.40ºC, minimum 7.40ºC and R.H. 64.07% in 5th Standard Week.

Pandey and Das (2014) observed a field experiment was carried out during rainy season of 2012 at Jabalpur, Madhya Pradesh to determine the population and correlation with abiotic factors of Hemiptaran insects on pigeonpea (*Cajanus cajan* L.). Population of different Hemiptaran insects was observed from 36th standard week (first week of September 2012) to 5th standard week (last week of January to first week of February 2013). The abiotic factors also affected the population built up of the insect pests. Jassid (*Empoasca fabae* Harris) population exhibited significant correlation with maximum and minimum temperatures and evaporation, whereas stink bug population was correlated with wind speed. However, there was negative correlation between evaporation and pod bug nymph and adult population.

MATERIALS AND METHODS

This chapter includes details of the material used and methodology followed during the course of present investigation. In accordance with the objectives, the studies were divided into three sections as detailed below.

1. Influence of temperature and nutrient on mass production of *Beauveria bassiana* on local substrates
2. To study the bioefficacy and compatibility of *B. bassiana* with new generation insecticides against pigeonpea pod borer complex

2.1 Invitro studies on compatibility of *B. bassiana* with new generation insecticides

2.2 Invivo studies on efficacy of *B. bassiana* with some new generation insecticides against pod infesting insect pests

3. To study the population dynamics of pigeonpea pod borer complex

3.1 Location :

The present investigation entitled, "Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex" was carried out in the experimental field of Department of Entomology, Live Stock Farm, Adhartal, JNKVV, Jabalpur (M.P.) during *kharif* 2014-15. The laboratory studies were conducted in the Entomology Laboratory, College of Agriculture, JNKVV, Jabalpur (M.P.).

3.2 Climatic condition :

Jabalpur "The Marble City" is the district and the central part of Madhya Pradesh, situated between $22^0$49' and $24^0$8' North latitude and $78^0$2' and $80^0$58' East longitude, at an altitude of 411.78 m above the mean sea level.

Jabalpur represents the agro-climatic region of "Kymore Plateau and Satpura Hills" and lies in rice-wheat crop zone of the state. Generally, Jabalpur has typical subtropical climate with hot dry summers and cool dry winters. Temperature extremes vary between minimum temperature of 2^{o}C in

December and January months to maximum temperature of 45^{o}C in May and June months. The average annual rainfall mostly received between mid - June to first week of October with occasional showers in limited quantum during the winter months, ranges between 1000-1500 mm. The relative humidity remains minimum, 20 to 35% during summer and medium, 40 to 60% during winter season, while it attains maximum values of 80 to 95% during rainy season.

3.3 Climatic condition during the crop season :

The weather condition during the course of studies from July, 2014 to January, 2015 is presented in Appendix 1.

3.3.1. Influence of temperature and nutrient on mass production of *B. Bassiana* on local substrates :

Experimental details :

Main treatments : 14

Sub treatments : 2 (With and without dextrose)

Sub- sub treatments : 4 (25^{0}C, 30^{0}C, 35^{0}C & room temperature)

Replication : 3

Design : Double split plot

The following solid substrates were used for mass multiplication of *B. bassiana:*

Table no. 1 Substrates used for mass multiplication of *B. bassiana*

Treatment codes	Group	Substrates
I	**Solid Media**	
T_1	**Whole grains**	Wheat, *Triticum aestivum* (L)
T_2		Rice, Oryza sativa (L)
T_3		Maize ,*Zea mays* (L)
T_4		Sorghum, *Sorghum bicolour* (L)
T_5	**Broken grains**	Wheat
T_6		Rice
T_7		Maize
T_8		Sorghum
T_9	**Bran**	Wheat
T_{10}		Rice
T_{11}	**Husks**	Wheat
T_{12}		Rice
II	**Liqiud Media**	
T_{13}	**Water soaked**	Wheat
T_{14}		Rice

Media preparation :

Whole grain and broken grains :

Wheat, *Triticum aestivum* (L); rice, *Oryza sativa* (L); maize, *Zea mays* (L); sorghum, *Sorghum vulgare* Pers. were used for estimating the sporulation and viability of the spores *B. bassiana* at 25ºC, 30ºC, 35ºC and room condition. For this purpose, 100 g of each grain was washed and soaked in water overnight except rice which was soaked for 2 – 3 hours. The excess water was drained by decanting and shade drying them for half an hour to further remove the excess moisture. The grains were packed separately in 250 gm polythene bags, with cotton plug and auto calved at 15 psi for 30 minutes. After cooling, 5 mm fungal disc was inoculated into each flask under laminar air flow chamber. They were incubated in BOD incubator at 25ºC, 30ºC, 35ºC for 15 days. Three replications (with dextrose) and three replication (without dextrose) were maintained for each treatment. To avoid clumping, after 7 days of inoculation, the polythene were shaken vigorously to separate the grain and to break the mycelial mat.

Bran and husk :

100 g each of the bran and husk, 50 ml of sterile distilled water was added in a 250 gm polythene bags. The substrates were sterilized in an

autoclave at 15 psi for 30 minutes. After sterilization the substrates were artificially inoculated with 5 mm fungal disc under laminar air flow chamber. Each treatment was replicated three times. After inoculation, the polythene bags were incubated at 25 ^{0}C, 30^{0}C, 35^{0}C and room temperature for 15 days. The polythene bags were shaken daily for the uniform growth of the fungus.

Effect of substrate on sporulation of *B. bassiana :*

The spores of the fungus grown on various substrates were estimated by using haemocytometer. For this purpose, 10 g or ml homogenous grains or solution sample was drawn from each replicate of uniformly sporulating flask and was transferred to 100 ml sterilized distilled water containing Tween 80 (0.05%) solution in 250ml conical flask. The flasks were shaken in mechanical shaker for 10 minutes. The suspension was filtered through double layered muslin cloth. Counting of spore's were made after the serial dilution of the suspension using double ruled Neubauer haemocytometer for determining the number of conidia in 1 g of the substrate (Hokkanen and Lynch 1998). Observations were taken on 10^{th,} 20th and 30th days after inoculation of the fungus.

Viability of the spores :

To determine the fungus colony forming units per ml, 1ml of formulation will suspended in 10ml of 0.05% sterilized tween -80 solution for making serial dilution. Prepared serial dilution will plated at 1ml per plate on PDA medium as per dilution plating method. The plates will gently rotate for uniform spreading of spore suspension and incubated at 25^{0}c. Each treatment will three replicated. The CFU counts will be recorded on 7th day after plating.

Biomass and Dry matter production :

After 30 days of incubation, take final weight of mycelium mat of each substrate after mycelium mat keep in hot air oven for 20 min and taken of dry weight of mycelium mat. Each treatment will three replicated with and without dextrose, decreasing and increasing weight of biomass and dry matter was worked out separately using the following formula:

$$BW\% = \frac{A_1 - C}{C} \times 100$$

$$DW\% = \frac{A_1 - B_1}{A_1} \times 100$$

Where BW%= Percentage of Biomass

DW% = Percentage of Dry matter

A1 = Final weight of Mycelium mat

B1 = Decreasing and increasing weight of mycelium mat after drying

C = Control

3.3.2. To study the bioefficacy and compatibility of *B. bassiana* with new generation insecticides against pigeonpea pod borer complex :

3.3.2.1: Invitro studies on compatibility of *B. bassiana* with new generation insecticides :

Experimental details :

Desig :CRD

No of replication :5

No of treatments :7

Methodology :Poisoned food technique

Six new generation insecticides viz., Indoxacarb 14.5 SC, Spinosad 45SC, Rynaxypyr 20 EC, Flubendiamide 20 EC, Emamectin benzoate 5 SG, and Triazophos 40EC were evaluated by poisoned food technique in Potato Dextrose Agar (PDA) medium. Twenty ml of PDA medium having insecticide of required concentration was poured into Petriplates aseptically and allowed to solidify under laminar flow cabinet. One ml of *B. bassiana* solution which contained 10^4spore/ml was inoculated at the center of the petriplate containing PDA. Growth medium (PDA) without insecticide but inoculated with fungus served as an untreated check. The plate was incubated in BOD at 25^0C and was replicated five times. The diameter of the growing culture was measured at 2 days interval after innoculation and continued upto 10^{th} day.

The data were expressed as percentage growth inhibition of *B. bassiana* by insecticides treated PDA (Hokkanen and Kotiluoto, 1992).

$$X = \frac{Y-Z}{Y} \times 100$$

Where X, Y, Z stand for percentage of growth inhibition, radial growth of fungus in untreated check and radial growth of fungus in poisoned medium, respectively.The biopesticides were further classified in evaluation categories of 1- 4 scoring index.

1 = harmless (<50% reduction in beneficial capacity)

2 = slightly harmful (50-79%)

3 = moderately harmful (80-90%)

4= harmful (>90%) in toxicity tests in vitro according to Hassan's Classification scheme (Hassan, 1989). The data obtained from various experiments were statistically analyzed.

$$= \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left\{\sum x^2 - \frac{(\sum x)^2}{n}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{n}\right\}}}$$

Table 2: Treatment details of insecticides used compatibility studies with *B. bassiana* in lab condition

Tre. Code	Treatments	Dose
T_1	*Beauveria bassiana*	1×10^8 spores/ml
T_2	*B.bassiana*+ Indoxacarb	1×10^4 spores/ml + 30g a.i./ha
T_3	*B. bassiana* + Spinosad	1×10^4 spores/ml + 36.5g a.i./ha
T_4	*B. bassiana* + Rynaxpyr	1×10^4 spores/ml + 20g a.i./ha
T_5	*B. bassiana* +Flubendamide	1×10^4 spores/ml + 25g a.i./ha
T_6	*B.bassiana*+ Emamectin benzoate	1×10^4 spores/ml + 5.5g a.i./ha
T_7	*B. bassiana* + Triazophos	1×10^4 spores/ml +300ml a.i./ha

3.3.2.2: Invivo studies on efficacy of B. bassiana with some new generation insecticides against pod infesting insect pests :

A field experiment was laid out in a randomized block design with 14 treatments and with three replications. The details of the experiment were as follows :

Experimental details :

Design	:	RBD
Variety	:	TJT-501
Replications	:	03
Plot size	:	3m x 4m
Number of rows/ plot	:	06
Row length	:	4.0 m
Spacing (R x P)	:	0.60 m x 0.20 m
Number of treatments	:	14
Date of sowing	:	08/07/2014
Date of germination	:	15/07/2014
Number of weedings	:	02
Number of irrigation	:	Rainfed
Spraying schedule	:	1st spray on 29/11/2014
		2nd spray on 10/12/2014
		3rd spray on 21/12/2014
Sprayer used	:	Knapsack sprayer
Requirement of water for 1ha	:	1000 l

Fig.1 : Layout plan of experimental trial

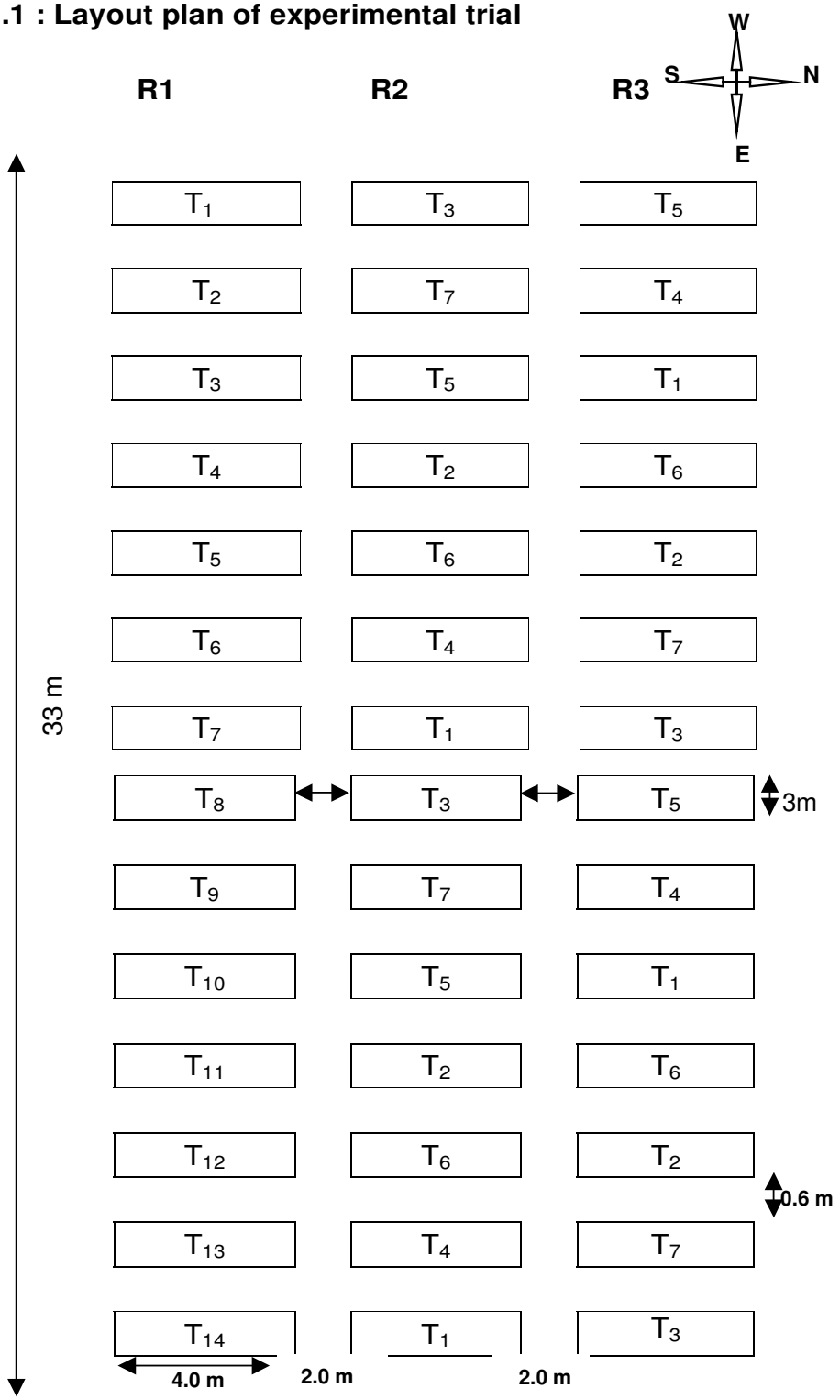


Table no. 3. Treatment details used compatibility studies with *B. bassiana* in field condition

Tr. Code	Treatment	Dose
T_1	Indoxacarb 14.5SC	60g a.i./ha
T_2	Spinosad 45SC	73g a.i./ha
T_3	Rynaxypyr 20EC	40g a.i./ha
T_4	Flubendiamide 20EC	50g a.i./ha
T_5	Emamectin benzoate 5%SG	11g a.i./ha
T_6	Triazophos 40EC	600ml a.i./ha
T_7	*Beauveria bassiana*	1×10^8 spores/ml
T_8	*B.bassiana*+ Indoxacarb	1×10^4 spores/ml + 30g a.i./ha
T_9	*B. bassiana* + Spinosad	1×10^4spores/ml+ 36.5g a.i./ha
T_{10}	*B. bassiana* + Rynaxpyr	1×10^4 spores/ml + 20g a.i./ha
T_{11}	*B. bassiana* +Flubendamide	1×10^4 spores/ml + 25g a.i./ha
T_{12}	*B.bassiana*+Emamectin benzoate	1×10^4 spores/ml + 5.5g a.i./ha
T_{13}	*B. bassiana +* Triazophos	1×10^4spores/ml+300ml a.i./ha
T_{14}	Control	No spray

Methods of observations:

Pre treatment observations were 24 hours before spray while post treatment observations will be recorded at 3, 7 and 10 days after spraying on 5 plants per treatment per replication. Gram pod borer eggs were recorded on 10 cm twig / plant, gram pod borer larvae, plume moth larvae & pupae, green stink bug adult & nymph per 5 plants and pod fly eggs, maggot & pupae, pod bug egg masses on 25 pods / 5 plants.

Further the efficacy of different treatments against tur pod fly, pod borer, tur plume moth and tur pod bug were judged by assessing the pod and grain damage. Grain yield were also recorded per treatment per replication at maturity.

Pods of 5 plants were collected from each plot / treatment per replication at maturity 160 pods (from pods of 5 plants) were observed and on the basis of symptoms or damage caused by different pod

borer complex were identified, counted and percentage pod and grain damage was worked out.

The pigeonpea pods and grains were classified as damage caused by *M. obtusa*, *H. armigera, E. atomosa* and *C. gibbosa* on the basis of characteristic distinguishing symptoms as summarized below :

The symptoms of the pod damage caused by *M. obtusa* could be distinguished by the presence of tiny pin head exit holes on the pod, while in case of grain damage, the size of the grains were reduced and galleries were formed on the grains as a result of feeding by the maggot. Pupae or pupal cases were also found embedded with damaged grains (Singh and Tan Emerden, 1979).

The damage due to *H. armigera* could be distinguished by the presence of large sized holes on the pods. The grains were partially or wholly eaten by the larvae (Saxena, 1981).

The damage due to *E. atomosa* could be distinguished by the presence of tiny irregular holes on the pods and size of the holes was smaller than that caused by *H. armigera*. The damaged grains were cotered with fungal growth due to larval faecal deposition (Ayyar, 1940).

The damage due to *C. gibbosa* could be distinguished by the twisting of pods and imparting a sickly appearance with shriveled grains, followed by reduction in the grain size that can be crushed to powder when gently pressed between finger tips (Das, 1990).

The per cent damage to pods and grains due to *M. obtusa, H. armigera, E. atomosa* and *C. gibbosa* was worked out separately using the following formula:

$$\text{Per cent pod or grain damage} = \frac{\text{Number of pods or grains damaged by a particular insect}}{\text{Total number of pods or grains examined}} \times 100$$

Statistical Analysis :

Correlation and regression studies :

Correlation and regression of the abiotic factors on major insect pest population were worked out by using the formula as suggested by Snedecor and Cochran (1967).

$$\text{Correlation 'r'} = \frac{\frac{\sum x . \sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{n}\right)\left(\sum y^2 - \frac{(\sum y)^2}{n}\right)}}$$

Test of significance of correlation coefficient

$$t = \frac{r}{\sqrt{(1 - r^2)}} \times \sqrt{n - 2}$$

$$\text{Regression } \hat{Y} = a + b \times (R^2)$$

Where,

'n' is the number of sets of observations and 'r' is the correlation coefficient and value of 't' based on (n - 2) degree of freedom.

Data recorded on various aspects *viz.,* insect counts, pod and grain damage *etc.* were tabulated and subjected to statistical analysis, by using the techniques of analysis of variance (Panse and Sukhatme, 1967). Treatment significance was tested by 'F' test. If 'F' test expressed the significant difference between the treatments mean values, critical difference (CD) at 5% level of significance was computed.

The data on pest population and the percentage data (pod and grain damage by various pod infesting pests) of chemical control trial were transformed to square root and arcsin transformed values, respectively. The data thus transformed was subjected to statistical analysis for knowing the significance of different treatments. Similarly, data on grain yield were also subjected to statistical analysis.

Following analysis of variance table was used :

Skeleton of analysis of variance (ANOVA)

Source of variation	D.F.	SS	MSS	F cal.	F tab.
Block (r)	r – 1	SSB	SSB/r - 1 = b	b/c	
Treatment (t)	t – 1	SST	SST/t - 1 = a	a/c	
Error	(t - 1) (r - 1)	SSE	SSE/(t - 1) (r - 1) = c		
Total	(rt - 1)				

Standard error for observation mean :

$$SEm\pm = \frac{\sqrt{EMS}}{r}$$

Critical difference (CD) :

$$CD = \sqrt{2} \times SEm \times t\ (5\%)\ \text{at error df}$$

Where,

EMS = Error mean sum of square

r = number of replications

t = 't' Table value at 5% probability level

SEm± = Standard error of mean

CD = Critical difference

3.3.3 To study the population dynamics of major insect pests of pigeonpea :

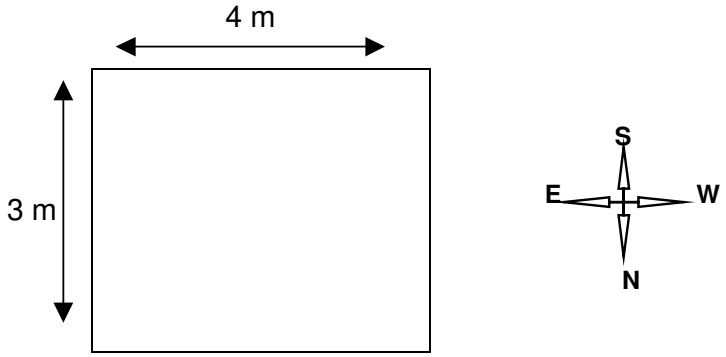
For conducting studies on population dynamics of major insect pests the experimental details were as follows :

Experimental Details :

Plot size	:	3m x 4m
No. of rows	:	06
Row length	:	4.0m
Spacing (Row x Plant)	:	0.60 x 0.20 m

Variety	:	TJT -501
Date of sowing	:	08/07/2014
Date of germination	:	15/07/ 2014
Number of weeding	:	02
Number of irrigations	:	Rainfed
Plant protection measures	:	Unprotected

Fig.2: Layout plan of experiment



Observations on different insect pests were recorded as detailed below :

Observations on different major insect pests were recorded twice in a standard week from pigeon pea.

Observations on population dynamics of different pod borer insects were recorded on randomly selected plants, twice in a standard week. Gram pod borer eggs on 10 cm twig / plants, gram pod borer larvae, plume moth larvae & pupae, green stink bug adult & nymph per 5 plants and pod fly eggs, maggot & pupae, pod bug egg masses on 25 pods / 5 plants.

Simultaneously a corresponding weekly record of meteorological data *viz*. minimum and maximum temperature, morning and evening relative humidity, morning and evening vapour pressure, total rainfall per week, number of rainy days per week, wind speed, sunshine and evaporation were collected. The influence of the different meteorological parameters on major insect population was studied by graphical super imposition technique.

3.4 Statistical Analysis of data :

I) Correlation and regression studies :

Correlation and regression of the abiotic factors on immature stages of gram pod borer were worked out by using the formula as suggested by Snedecor and Cochran (1967).

Correlation 'r' $$\frac{\sum x.\sum y}{n}$$
$$\sqrt{(\sum x^2 - (\frac{\sum x)^2}{n} (\sum y^2 - \frac{(\sum y)^2}{n}}$$

Where,

Regression Y = a + b x (R^2)

a = Intercept

b = Régression coefficient

R^2 = Coefficient of multiple détermination

Test of significance 'r'

$$t = \frac{r}{\sqrt{1 - r^2}} \sqrt{n - 2}$$

II) Analysais of variance- Randomized Block Design :

The data were subjected to statistical analysis after tabulation. The population count data of egg and larva were transformed to while percentage data were transformed to $\sqrt{X + 0.5}$ their angular values. The data so obtained were analyzed by using the analysis of variance techniques as given below Following analysis of variance were used.

Skeleton of "Analysis of Variance":

Sources of variance	d.f	S.S.	M.S.S.	F. Cal	F. Table
Replications	(r-1)	SSR	SSR/r-1=a	a/c	
Treatments	(t-1)	SST	SST/t-1=b	b/c	
Error	(r-1) (t-1)	SSE	SSE/(r-1)(t-1)=c	-	

Total	(rt-1)	-	-	-	

Where,

r = number of replications

t = number of treatments

SSR = replication mean sum of square

SST = treatment mean sum of square

SSE = error mean sum of square

d.f = Degree of freedom

The significance among different treatment means was judged by critical difference (C.D.) at 5% level of significance for comparison among the treatments, for which the marginal means of each treatment was considered. The following formula was used for various estimations.

(1) Standard error of mean = $S.Em \pm = \frac{\sqrt{E.ms}}{r}$

(2) Critical difference (C.D.) = SEm X $\sqrt{}$ 2 x t at 0.05

Where,

Ems = error mean sum of square

t = 't' value at 5 % level at error d.f.

r = number of replications

SEm ± = standard error of any treatment mean

CD = Critical Difference

(3) Per cent pod damage

Per cent pod damage was calculated under different treatments as per formula.

$$\text{Per cent pod damage} = \frac{\text{No of damaged pod}}{\text{Total number of pods observed}} \text{ X100}$$

(4) Grain yield

Grain yield was calculated under different treatments as per formula

Yield kg/ha = Conversion factor x grain yield / plot

Where,

$$\text{Conversion factor} = \frac{10000}{\text{Net plot size}} \text{ in sq. m.}$$

(5) Cost benefit Ratio (CB ratio)

CB ratio was calculated under different treatments as per formula

$$\text{CB Ratio} = \frac{\text{Net profit obtained from per ha of particular treatment}}{\text{Cost of the same treatment /ha}}$$

IV. Analysis of variance – Complete Randomized Design :

Analysis of different variables was carried out to know the degree of variation amongst all the treatments. The data were statistically analyzed and the analysis of variance has been given in appendix and the skeleton of ANOVA for complete randomized design (CRD) is presented in table given below :

Skeleton of Analysis of Variance (ANOVA) :

Sources of variation	**d.f.**	**S.S.**	**M.S.S.**	**F cal.**	**F tab.**
Treatments	t-1	SSt	MSSt	MSSt / MSSe	
Error	n-t	SSe	MSSe		
Total	n-1				

n = Total number of observations.

t = Number of treatments.

The 'F' test was applied to check the overall significance of various treatments in general and comparison of individual treatment was made with the help of critical difference at 5 % level of significance, which was calculated as given below:-

$$\text{SEm} \pm \text{ for treatment} = \frac{\sqrt{\text{MSSe}}}{\text{No. of replications}} \times 100$$

SEd for treatment = SEm x √2

CD for treatment = SEd x 't' value at 5% error degree of freedom

Where,

SEm± = Standard Error of treatment means

S.Ed = Standard Error of difference between two treatments

CD = Critical difference

RESULTS

The findings of the experiment on "Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex" is described in this chapter under respective objectives.

4.1 To study the influence of nutrient and temperature on mass production of *Beauveria bassiana* on local substrates:

The experiment on mass production studies was under taken on fourteen substrates (Factor A) with and without nutrient (Factor B) and at four different temperatures (Factor C) for determining a suitable medium for growth and sporulation of *Beauveria bassiana*. The observations were recorded on 10^{th}, 20^{th} and 30^{th} day after inoculation and the data presented in Table 4 to 14.

4.1.1 Spore count at different days after inoculation:

4.1.1.a Ten days after inoculation: The data presented in table no. 4

Factor A: Substrates :

Among the different substrates evaluated, significantly highest conidial count (3.41 × 10^8 spores/ml) was recorded on broken wheat grains, which was followed by broken rice grains (3.33× 10^8 spores/ml), wheat husk (3.22× 10^8 spores/ml) and whole sorghum grains (3.16× 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole maize grains (2.87 × 10^8 spores/ml), whole wheat grains (2.66× 10^8 spores/ml), whole rice grains (2.70× 10^8 spores/ml), wheat bran (2.41× 10^8 spores/ml), rice bran (2.37× 10^8 spores/ml), broken sorghum grains (2.33× 10^8 spores/ml) and water soaked rice (2.12× 10^8 spores/ml), however they did not differ significantly from each other. The next group of substrates were broken maize grains (2.04 × 10^8 spores/ml), followed by water soaked wheat (1.58× 10^8 spores/ml), but they differed significantly from each other. The least spore count was recorded in rice husk (1.37 × 10^8spores/ml).

Table no. 4 Influence of substrates (A), nutrient (B) and temperature (C) on spore production of *Beauveria bassiana* at 10 days after inoculation

Mean spore counts (1×10^8spores/ml) at 10 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	2.66 (1.75)	B_1	2.39 (1.66)	C_1	1.95 (1.54)
A_2	2.70 (1.74)	B_2	2.72 (1.74)	C_2	2.59 (1.72)
A_3	2.87 (1.77)			C_3	2.97 (1.83)
A_4	3.16 (1.86)			C_4	2.71 (1.73)
A_5	3.41 (1.98)				
A_6	3.33 (1.94)				
A_7	2.04 (1.58)				
A_8	2.33 (1.63)				
A_9	2.41 (1.67)				
A_{10}	2.37 (1.66)				
A_{11}	3.22 (1.93)				
A_{12}	1.37 (1.32)				
A_{13}	1.58 (1.42)				
A_{14}	2.12 (1.61)				
SEm ±	0.06	0.02		0.02	
CD at 5%	0.18	0.07		0.06	

( ) Figures in parentheses are square root transformed values

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest conidial count (2.73×10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (2.39×10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest conidial count (2.97×10^8 spores/ml) was recorded at 30^0C. This was followed by conidial counts recorded at 35^0C (2.71×10^8 spores/ml) and at 25^0C (2.59×10^8 spores/ml), but they were all were at par with each other. Least spore count (1.95×10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

Interactions :

The interaction of substrates with and without nutrient and substrates with various temperature were found to be non significant. Similarly interaction of nutrient and temperature was also found to be non significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the sporulation of entomopathogenic fungus.

4.1.1.b Twenty days after inoculation: The data presented in table no. 5

Factor A: Substrates :

Among the different substrates evaluated, significantly highest conidial count (4.00 × 10^8 spores/ml) was recorded on broken wheat grains, which was followed by broken rice grains (3.83× 10^8 spores/ml), wheat husk (3.67× 10^8 spores/ml), whole sorghum grains (3.63× 10^8 spores/ml), whole rice grains (3.33× 10^8 spores/ml) and whole maize grains (3.33 × 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole wheat grains (3.17× 10^8 spores/ml), broken maize grains (3.08 × 10^8 spores/ml), wheat bran (2.71× 10^8 spores/ml), broken sorghum grains (2.58× 10^8 spores/ml), rice bran (2.58× 10^8 spores/ml) and water soaked rice (2.54× 10^8 spores/ml), however they did not differ significantly from each other. The next substrate was water soaked wheat (2.33× 10^8 spores/ml). The least spore count was recorded in rice husk (1.71 × 10^8spores/ml).

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest conidial count (3.21 × 10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (2.86 × 10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest conidial count (3.38 × 10^8 spores/ml) was recorded at 30^0C. This was followed by conidial count recorded at 25^0C (3.10× 10^8 spores/ml) and at 35^0C (3.06×

10^8 spores/ml), but they were all at par with each other. Least spore count (2.61×10^8spores/ml) was recorded at room temperature (25 ± 5°C).

Interactions :

The interaction of substrates with and without nutrient and substrate with various temperature were found to be non significant. Similarly interaction of nutrient and temperature was also found to be non significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the sporulation of entomopathogenic fungus.

Table no.5 Influence of substrates (A), nutrient (B) and temperature (C) on spore production of *Beauveria bassiana* at 20 days after inoculation

Mean spore counts (1×10^8spores/ml) at 20 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	3.17 (1.90)	B_1	2.86 (1.81)	C_1	2.61 (1.73)
A_2	3.33 (1.95)	B_2	3.21 (1.91)	C_2	3.10 (1.87)
A_3	3.33 (1.95)			C_3	3.38 (1.95)
A_4	3.63 (2.02)			C_4	3.06 (1.87)
A_5	4.00 (2.12)				
A_6	3.83 (2.06)				
A_7	3.08 (1.88)				
A_8	2.58 (1.74)				
A_9	2.71 (1.78)				
A_{10}	2.58 (1.74)				
A_{11}	3.67 (2.04)				
A_{12}	1.71 (1.47)				
A_{13}	2.33 (1.67)				
A_{14}	2.54 (1.73)				
SEm ±	0.06		0.03		0.02
CD at 5%	0.18		0.07		0.06

( ) Figures in parentheses are square root transformed values

4.1.1.c Thirty days after inoculation: The data presented in table no. 6

Factor A: Substrates :

Among the different substrates evaluated, significantly highest conidial count (4.96×10^8 spores/ml) was recorded on broken rice grains which was

followed by wheat husk (4.83× 10^8 spores/ml), broken wheat grains (4.75× 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole sorghum grains (4.13× 10^8 spores/ml), whole rice grains (3.67× 10^8 spores/ml), whole wheat grains (3.58× 10^8 spores/ml), whole maize grains (3.58 × 10^8 spores/ml), broken maize grains (3.58 × 10^8 spores/ml) and wheat bran (3.54× 10^8 spores/ml), however they did not differ significantly from each other. The next group of substrates were water soaked rice (3.33× 10^8 spores/ml), rice bran (3.21× 10^8 spores/ml), broken sorghum grains (2.96× 10^8 spores/ml) and water soaked wheat (2.83× 10^8 spores/ml), but all were at par with each other. The least spore count was recorded in rice husk (1.96 × 10^8spores/ml).

Table no. 6 Influence of substrates (A), nutrient (B) and temperature (C) on spore production of *Beauveria bassiana* at 30 days after inoculation

Mean spore counts (1 × 10^8spores/ml) at 30 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	3.58 (2.01)	B_1	3.48 (1.97)	C_1	3.35 (1.94)
A_2	3.67 (2.04)	B_2	3.80 (2.06)	C_2	3.76 (2.04)
A_3	3.58 (2.01)			C_3	3.86 (2.07)
A_4	4.13 (2.15)			C_4	3.58 (2.01)
A_5	4.75 (2.28)				
A_6	4.96 (2.33)				
A_7	3.58 (2.01)				
A_8	2.96 (1.84)				
A_9	3.54 (2.00)				
A_{10}	3.21 (1.92)				
A_{11}	4.83 (2.30)				
A_{12}	1.96 (1.55)				
A_{13}	2.83 (1.82)				
A_{14}	3.33 (1.95)				
SEm ±	0.05		0.02		0.02
CD at 5%	0.15		0.05		0.06
Interaction A X C					
SEm ±	0.08				
CD at 5%	0.21				

( ) Figures in parentheses are square root transformed values

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest conidial count (3.80 × 10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (3.48 × 10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest conidial count (3.86 × 10^8 spores/ml) was recorded at 30^0C. This was followed by conidial counts recorded at 25^0C (3.76× 10^8 spores/ml) and at 35^0C (3.58× 10^8 spores/ml), but all were at par with each other. Least spore count (3.35 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

Interactions :

The interaction of substrates with and without nutrient and interaction of nutrient and temperature were found to be non significant. However, interaction of substrates and temperature was found to significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the sporulation of entomopathogenic fungus.

4.1.1.d Overall mean : The data presented in table no. 7

Factor A: Substrates :

Among the different substrates evaluated, significantly highest conidial count (4.04 × 10^8 spores/ml) was recorded on broken wheat grains, which was followed by broken rice grains (4.03 × 10^8 spores/ml) and wheat husk (3.93× 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole sorghum grains (3.58 × 10^8 spores/ml), whole rice grains (3.21 × 10^8 spores/ml), whole maize grains (3.20 × 10^8 spores/ml), whole wheat grains (3.13 × 10^8 spores/ml), however they did not differ significantly from each other. The next group of substrates were broken maize grains (2.90 × 10^8 spores/ml), wheat bran (2.88 × 10^8 spores/ml), rice bran (2.71 × 10^8 spores/ml), water soaked rice (2.67 × 10^8 spores/ml), broken sorghum grains (2.58 × 10^8 spores/ml) and water soaked wheat (2.25× 10^8

spores/ml), however they did not differ significantly from each other. The least spore count was recorded in rice husk (1.65 × 10^8spores/ml).

Table no. 7 Influence of substrates (A), nutrient (B) and temperature (C) on spore production of *Beauveria bassiana* overall mean

Mean spore counts (1 × 10^8spores/ml) overall mean					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	3.13 (1.90)	B_1	2.89 (1.82)	C_1	2.64 (1.75)
A_2	3.20 (1.92)	B_2	3.21 (1.91)	C_2	3.13 (1.89)
A_3	3.21 (1.93)			C_3	3.39 (1.96)
A_4	3.58 (2.01)			C_4	3.06 (1.88)
A_5	4.04 (2.12)				
A_6	4.03 (2.12)				
A_7	2.90 (1.83)				
A_8	2.58 (1.75)				
A_9	2.88 (1.82)				
A_{10}	2.71 (1.78)				
A_{11}	3.93 (2.10)				
A_{12}	1.65 (1.46)				
A_{13}	2.25 (1.65)				
A_{14}	2.67 (1.77)				
SEm ±	0.03	0.005		0.008	
CD at 5%	0.08	0.014		0.021	
Interaction A X C					
SEm ±	0.03				
CD at 5%	0.08				
Interaction A X B					
SEm ±	0.02				
CD at 5%	0.05				
Interaction A X B X C					
SEm ±	0.04				
CD at 5%	0.12				

( ) Figures in parentheses are square root transformed values

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest conidial count (3.21 × 10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (2.89 × 10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest conidial counts (3.39 × 10^8spores/ml) was recorded at 30^0C. This was followed by conidial counts recorded at 25^0C (3.13 × 10^8 spores/ml) and at 35^0C (3.06 × 10^8 spores/ml), but all the three were at par with each other. Least spore count (2.64 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

Interactions :

The interaction of substrates with and without nutrient and substrate with various temperatures were found to be significant. However, interaction of nutrient and temperature was found to be non significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature also had significant impact on the sporulation of entomopathogenic fungus.

4.1.2 Spore viability at different days after inoculation:

4.1.2.a Ten days after inoculation: The data presented in table no. 8

Factor A: Substrates :

Among the different substrates evaluated, significantly highest spore viability (2.88 × 10^8 spores/ml) was recorded on broken wheat grains, which was followed by broken rice grains (2.88 × 10^8 spores/ml), wheat husk (2.88 × 10^8 spores/ml) whole sorghum grains (2.79 × 10^8 spores/ml) and whole maize grains (2.46 × 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole rice grains (2.29 × 10^8 spores/ml), whole wheat grains (2.21× 10^8 spores/ml), wheat bran (2.13 × 10^8 spores/ml), broken sorghum grains (2.04 × 10^8 spores/ml), broken maize grains (1.96 × 10^8 spores/ml), rice bran (1.88 × 10^8 spores/ml) and water soaked rice (1.88 × 10^8 spores/ml), however they did not differ significantly from each other. The next substrate was water soaked wheat (1.33× 10^8 spores/ml), while least spore viable count was recorded in rice husk (1.17 × 10^8spores/ml).

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest spore viability (2.41 × 10^8 spores/ml) was

recorded on substrates containing nutrient and was lowest (1.98 × 10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest spore viability (2.54 × 10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore count recorded at 25^0C (2.33 × 10^8 spores/ml) and at 35^0C (2.13 × 10^8 spores/ml), but all were at par with each other. Least spore viability (1.77 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

Table no. 8 Influence of substrates (A), nutrient (B) and temperature (C) on spore viability of *Beauveria bassiana* at 10 days after inoculation

Mean viable spore counts (1 × 10^8spores/ml) at 10 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	2.21 (1.63)	B_1	1.98 (1.55)	C_1	1.77 (1.48)
A_2	2.29 (1.65)	B_2	2.41 (1.68)	C_2	2.33 (1.66)
A_3	2.46 (1.71)			C_3	2.54 (1.72)
A_4	2.79 (1.80)			C_4	2.13 (1.60)
A_5	2.88 (1.82)				
A_6	2.88 (1.82)				
A_7	1.96 (1.55)				
A_8	2.04 (1.57)				
A_9	2.13 (1.60)				
A_{10}	1.88 (1.52)				
A_{11}	2.88 (1.83)				
A_{12}	1.17 (1.17)				
A_{13}	1.33 (1.34)				
A_{14}	1.88 (1.52)				
SEm ±	0.05	0.01		0.02	
CD at 5%	0.15	0.04		0.06	
Interactions B X C					
SEm ±	0.03				
CD at 5%	0.08				

( ) Figures in parentheses are square root transformed values

Interactions :

The interaction of substrates with and without nutrient and substrates with various temperature were found to be non significant. However, interaction of nutrient and temperature was found to be significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the spore viability of entomopathogenic fungus.

4.1.2.b Twenty days after inoculation: The data presented in table no. 9

Factor A: Substrates :

Among the different substrates evaluated, significantly highest spore viability (3.54×10^8 spores/ml) was recorded on broken rice grains, which was followed by broken wheat grains (3.46×10^8 spores/ml), wheat husk (3.38×10^8 spores/ml), whole sorghum grains (3.29×10^8 spores/ml) and whole rice grains (2.96×10^8 spores/ml), but all were at par with each other. The next group of substrates were whole wheat grains (2.83×10^8 spores/ml), whole maize grains (2.79×10^8 spores/ml), broken maize grains (2.67×10^8 spores/ml), broken sorghum grains (2.50×10^8 spores/ml), wheat bran (2.46×10^8 spores/ml) and rice bran (2.42×10^8 spores/ml), however they did not differ significantly from each other. The next group of substrates were water soaked rice (2.25×10^8 spores/ml) and water soaked wheat (2.13×10^8 spores/ml), but both were at par with each other. The least viable spore count was recorded in rice husk (1.50×10^8spores/ml).

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest spore viability (2.96×10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (2.49×10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest spore viability (2.99×10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore count recorded at 25^0C (2.82×10^8 spores/ml), but both were at

par with each other. The next viable spore count of (2.62 × 10^8 spores/ml) was recorded at 35^0C while the least spore viability (1.77 × 10^8spores/ml) was recorded at room temperature (25 ± 5°C) but both were at par with each other.

Interactions :

The interaction of substrates with and without nutrient and substrates with various temperature were found to be non significant. Similarly interaction of nutrient and temperature was also found to be non significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the spore viability of entomopathogenic fungus.

Table no. 9 Influence of substrates (A), nutrient (B) and temperature (C) on spore viability of *Beauveria bassiana* at 20 days after inoculation

Mean viable spore counts (1 × 10^8spores/ml) at 20 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	2.83 (1.81)	B_1	2.49 (2.49)	C_1	2.48 (1.70)
A_2	2.96 (1.85)	B_2	2.96 (2.96)	C_2	2.82 (1.80)
A_3	2.79 (1.81)			C_3	2.99 (1.85)
A_4	3.29 (1.93)			C_4	2.62 (1.75)
A_5	3.46 (1.97)				
A_6	3.54 (1.99)				
A_7	2.67 (1.77)				
A_8	2.50 (1.71)				
A_9	2.46 (1.71)				
A_{10}	2.42 (1.69)				
A_{11}	3.38 (1.96)				
A_{12}	1.50 (1.40)				
A_{13}	2.13 (1.61)				
A_{14}	2.25 (1.65)				
SEm ±	0.05	0.02		0.02	
CD at 5%	0.14	0.06		0.06	

( ) Figures in parentheses are square root transformed values

4.1.2.c Thirty days after inoculation: The data presented in table no. 10

Factor A: Substrates :

Among the different substrates evaluated, significantly highest spore viability (4.71 × 10^8 spores/ml) was recorded on broken rice grains, which was followed by wheat husk (4.54 × 10^8 spores/ml) and broken wheat grains (4.46 × 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole sorghum grains (3.83 × 10^8 spores/ml), wheat bran (3.50 × 10^8 spores/ml), whole rice grains (3.38 × 10^8 spores/ml) whole maize grains (3.38 × 10^8 spores/ml), broken maize grains (3.33 × 10^8 spores/ml) and whole wheat grains (3.33 × 10^8 spores/ml), but all were at par with each other. The next group of substrates were water soaked rice (3.13 × 10^8 spores/ml), rice bran (3.08 × 10^8 spores/ml), broken sorghum grains (2.75 × 10^8 spores/ml) and water soaked wheat (2.71 × 10^8 spores/ml), however they did not differ significantly from each other. The least spore viability was recorded in rice husk (1.96 × 10^8spores/ml).

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrate was found to be non significant.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest spore viability (3.64 × 10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore count recorded at 25^0C (3.58 × 10^8 spores/ml), but both were at par with each other. The next viable spore count was recorded at 35^0C (3.33 × 10^8 spores/ml) while least viable spore count (3.18 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C), but both were at par with each other.

Interactions :

The interaction of substrates with and without nutrient and interaction of nutrient and temperature were found to be non significant. However, interaction of substrates with temperature was found to be significant**.**

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the spore viability of entomopathogenic fungus.

Table no. 10 Influence of substrates (A), nutrient (B) and temperature (C) on spore viability of *Beauveria bassiana* at 30 days after inoculation

Mean viable spore counts (1 × 10^8spores/ml) at 30 days after inoculation					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	3.33 (1.95)	B_1	3.39 (1.95)	C_1	3.18 (1.80)
A_2	3.38 (1.96)	B_2	3.48 (1.98)	C_2	3.58 (2.00)
A_3	3.33 (1.95)			C_3	3.64 (2.02)
A_4	3.83 (2.08)			C_4	3.33 (1.95)
A_5	4.46 (2.20)				
A_6	4.71 (2.27)				
A_7	3.38 (1.95)				
A_8	2.75 (1.78)				
A_9	3.50 (1.99)				
A_{10}	3.08 (1.89)				
A_{11}	4.54 (2.24)				
A_{12}	1.96 (1.55)				
A_{13}	2.71 (1.78)				
A_{14}	3.13 (1.90)				
SEm ±	0.05	0.02		0.02	
CD at 5%	0.15	NS		0.06	
Interaction A X C					
SEm ±	0.08				
CD at 5%	0.21				

( ) Figures in parentheses are square root transformed values

4.1.2.d Overall mean : The data presented in table no. 11

Factor A: Substrates :

Among the different substrates evaluated, significantly highest spore viability (3.70 × 10^8 spores/ml) was recorded on broken rice grains, which was followed by broken wheat grains (3.60 × 10^8 spores/ml) and wheat husk (3.60 × 10^8 spores/ml), but all were at par with each other. The next group of substrates were whole sorghum grains (3.31 × 10^8 spores/ml), whole rice grains (2.88 × 10^8 spores/ml), whole maize grains (2.86 × 10^8 spores/ml),

whole wheat grains (2.79 × 10^8 spores/ml), broken maize grains (2.70 × 10^8 spores/ml) and wheat bran (2.67 × 10^8 spores/ml), however they did not differ significantly from each other. The next group of substrates were rice bran (2.46 × 10^8 spores/ml), broken sorghum grains (2.43 × 10^8 spores/ml) and water soaked rice (2.42 × 10^8 spores/ml), but all were at par with each other. The next substrate was water soaked wheat (2.06 × 10^8 spores/ml) while least viable spore count was recorded in rice husk (1.54 × 10^8spores/ml), and they differed significantly from each other.

Table no. 11 Influence of substrates (A), nutrient (B) and temperature (C) on spore viability of *Beauveria bassiana* overall mean

Mean viable spore counts (1 × 10^8spores/ml) overall mean					
Substrates (A)	**Mean**	**Nutrient (B)**	**Mean**	**Temperature (C)**	**Mean**
A_1	2.79 (1.81)	B_1	2.62 (1.74)	C_1	2.48 (1.70)
A_2	2.88 (1.84)	B_2	2.95 (1.84)	C_2	2.91 (1.83)
A_3	2.86 (1.83)			C_3	3.06 (1.87)
A_4	3.31 (1.94)			C_4	2.69 (1.77)
A_5	3.60 (2.01)				
A_6	3.70 (2.06)				
A_7	2.67 (1.77)				
A_8	2.43 (1.70)				
A_9	2.70 (1.72)				
A_{10}	2.46 (1.71)				
A_{11}	3.60 (2.02)				
A_{12}	1.54 (1.42)				
A_{13}	2.06 (1.58)				
A_{14}	2.42 (1.70)				
SEm ±	0.05		0.01		0.02
CD at 5%	0.15		0.04		0.06
Interactions A X B					
SEm ±	0.03				
CD at 5%	0.10				
Interactions A X C					
SEm ±	0.03				
CD at 5%	0.09				
Interactions B X C					
SEm ±	0.01				
CD at 5%	0.04				
Interactions A X B X C					
SEm ±	0.05				
CD at 5%	0.13				

( ) Figures in parentheses are square root transformed values

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrates revealed that significantly highest viable spore count (2.95 × 10^8 spores/ml) was recorded on substrates containing nutrient and was lowest (2.62 × 10^8 spores/ml) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly highest spore viability (3.06 × 10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore counts recorded at 25^0C (2.91 × 10^8 spores/ml) and at 35^0C (2.69 × 10^8 spores/ml) while least viable spore count (1.77 × 10^8spores/ml) was recorded at room temperature (25 ± 5°C), and they differed significantly from each other.

Interactions :

The interaction of substrates with and without nutrient, interaction of substrates with various temperature and interaction of nutrient with temperature were found to be significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature had significant impact on the spore viability of entomopathogenic fungus.

4.1.3 Rate of increase in growth:

Rate of increase of growth of *B.bassiana* was calculated and the data presented Table 12 and depicted in fig 4

4.1.3.a. 10 to 20 days after inoculation:

The rate of increase in growth of *B.bassiana* from 10^{th} to 20^{th} days after inoculation among different substrates was found to be significant. The highest rate of increase in growth of fungus was recorded on broken maize grains (33.98%) followed by water soaked wheat (32.97%), rice husk (24.20%), whole rice grains (22.46%) and whole wheat grains (17.54%), and they differed significantly from each other. The next group of substrates were whole sorghum grains (17.11%) and whole maize grains (17.85%), but both at par with each other. The next group of substrates were water soaked rice

(16.83%), broken rice grains (15.27%) and broken sorghum grains (14.30%), but all were at par with each other. The next group of substrates were wheat bran (13.58%) and wheat husk (10.76%) while least growth rate of the fungus was recorded on rice bran (10.29%), however they did not differ significantly from each other.

Table no. 12 Rate of increase in growth of *B. bassiana* at different days after inoculation :

Substrates	Rate of increase in growth of *B. bassiana* (%) (DAI)	
	10 to 20 DAI	20 to 30 DAI
A_1	17.54 (24.46)	12.30 (20.26)
A_2	22.46 (27.39)	9.67 (18.08)
A_3	17.85 (23.61)	11.14 (19.29)
A_4	17.11 (23.67)	12.52 (20.13)
A_5	15.87 (22.92)	15.42 (22.59)
A_6	15.27 (21.75)	23.58 (28.92)
A_7	33.98 (35.48)	14.77 (22.22)
A_8	14.30 (20.22)	13.28 (21.24)
A_9	13.58 (19.46)	24.69 (29.34)
A_{10}	10.29 (17.11)	20.89 (26.26)
A_{11}	10.76 (18.18)	23.41 (28.16)
A_{12}	24.20 (27.93)	13.94 (18.81)
A_{13}	32.97 (34.80)	18.29 (24.04)
A_{14}	16.83 (21.93)	23.98 (29.12)
SEm ±	0.22	0.17
CD at 5%	0.63	0.48

( ) Figures in parentheses are arcsin transformed values

DAI = Days after inoculation

4.1.3.b. 20 to 30 days after inoculation:

The rate of increase in growth of *B.bassiana* from 20th to 30th days after inoculation among different substrates was found to be significant. The highest rate of increase in growth was recorded on wheat bran (24.69%) followed by water soaked rice (23.98%) and broken rice grains (23.58%), but all were at par each other. The next group of substrates were wheat husk (23.41%), rice bran (20.89%) and water soaked wheat (18.29%), but they did not differ significantly from each other. The next group of substrates were broken wheat grains (15.42%) and broken maize grains (14.77%), but both

were at par with each other. The next group of substrates were whole wheat grains (13.28%) and whole sorghum grains (12.52%), but both were at par with each other. The next group of substrates were whole maize grains (12.30%), rice husk (11.14%) while least growth rate was recorded on whole rice grains (9.67%), however they did not differ significantly from each other.

4.1.3 Biomass production of *Beauveria bassiana* : The data presented in table no. 13

Factor A: Substrate :

Among the different substrates evaluated, significantly highest biomass production (0.114gm) was recorded on broken wheat grains media, which was followed by whole wheat grains (0.101gm), broken rice grains (0.092gm), broken maize grains (0.088gm), broken sorghum grains (0.087gm), wheat bran (0.079gm), rice bran (0.072gm), whole rice grains (0.070), whole maize grains (0.063gm), whole sorghum grains (0.057gm), wheat husk (0.052gm), rice husk (0.032gm) and least biomass production was recorded in water soaked rice (0.024gm) and water soaked wheat (0.024gm) but they differed significantly from each other.

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrate revealed that significantly highest biomass production (0.071gm) was recorded on substrates containing nutrient and was lowest (0.066gm) on substrates without nutrient.

Factor C: Temperature :

Among the different temperatures evaluated, significantly biomass production (0.079gm) was recorded at 30^0C. This was followed by biomass production recorded at 25^0C (0.070gm) and at 35^0C (0.066gm) and least biomass production (0.057gm) was recorded at room temperature (25 ± 5 °C) but they differed significantly from each other.

Interactions :

The interaction of substrates with presence or absence of nutrient found to be significant and substrate with various temperature were found to

be non significant. Similarly interaction of nutrient and temperature was also found to be non significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature did not have any significant impact on the sporulation of entomopathogenic fungus.

Table no. 13 Influence of substrates (A), nutrient (B) and temperature (C) on biomass production of *Beauveria bassiana*

Mean biomass production					
Factor A	**Mean**	**Factor B**	**Mean**	**Factor C**	**Mean**
A_1	0.10	B_1	0.066	C_1	0.066
A_2	0.07	B_2	0.071	C_2	0.07
A_3	0.06			C_3	0.079
A_4	0.06			C_4	0.057
A_5	0.11				
A_6	0.09				
A_7	0.09				
A_8	0.09				
A_9	0.08				
A_{10}	0.07				
A_{11}	0.05				
A_{12}	0.03				
A_{13}	0.02				
A_{14}	0.02				
SEm ±	0.002	0.001		0.001	
CD at 5%	0.007	0.003		0.003	
Interaction A X B	SEm ±	0.003			
	CD at 5%	0.010			

4.1.4 Dry matter production of *Beauveria bassiana* : The data presented in table no. 14

Factor A: Substrate :

Among the different substrates evaluated, significantly highest dry matter production (0.632gm) was recorded on water soaked rice which was followed by water soaked wheat (0.543gm), whole rice grains (0.540gm), whole sorghum grains (0.519gm), broken sorghum grains (0.514gm), broken rice grains (0.506gm), rice bran (0.483gm), whole wheat grains (0.366gm), broken wheat grains (0.313gm), wheat bran (0.298gm), rice husk (0.269gm), whole maize grains (0.257gm), wheat husk (0.251gm) and least dry matter

production was recorded in broken maize (0.245gm) but they differed significantly from each other.

Factor B: Nutrient :

Evaluation of presence or absence of nutrient in the substrate was found to be non significant.

Table no. 14 Influence of substrates (A), nutrient (B) and temperature (C) on dry matter production of *Beauveria bassiana*

Mean dry matter production					
Factor A	**Mean**	**Factor B**	**Mean**	**Factor C**	**Mean**
A_1	0.366	B_1	0.411	C_1	0.402
A_2	0.540	B_2	0.408	C_2	0.413
A_3	0.257			C_3	0.420
A_4	0.519			C_4	0.403
A_5	0.313				
A_6	0.506				
A_7	0.245				
A_8	0.514				
A_9	0.298				
A_{10}	0.483				
A_{11}	0.251				
A_{12}	0.269				
A_{13}	0.543				
A_{14}	0.632				
SEm ±	0.003	0.001		0.002	
CD at 5%	0.009	NS		0.005	
Interaction A X B	SEm ±	0.005			
	CD at 5%	0.014			
Interaction A X C	SEm ±	0.007			
	CD at 5%	0.020			
Interaction B X C	SEm ±	0.003			
	CD at 5%	0.007			
Interaction A X B X C	SEm ±	0.010			
	CD at 5%	0.028			

Factor C: Temperature :

Among the different temperatures evaluated, significantly dry matter production (0.420gm) was recorded at 30^0C. This was followed by dry matter production recorded at 25^0C (0.413gm) and at 35^0C (0.403gm) and least dry matter production (0.402gm) was recorded at room temperature (25 ± 5 °C) but they differed significantly from each other.

Interactions :

The interaction of substrates with presence or absence of nutrient found to be significant and substrate with various temperature were also found to be significant. Similarly interaction of nutrient and temperature was also found to be significant.

Further, interaction of all the three factors *i.e.* substrates, nutrient and temperature impact on the sporulation of entomopathogenic fungus.

Table 15 Economics of mass production of *Beauveria bassiana* on/in different substrates

Treatment code	Media	Group	Substrates	Mean spore count (1×10^8spore/ml)	Cost of substrate /100g (Rs)	Cost of production of *B. bassiana* 1×10^8spore/ml (Rs.)
T_1	Solid Media	Whole grains	Wheat, *Triticum aestivum*	3.13 (1.90)	2.00	0.64
T_2			Rice, *Oryza sativa*	3.20 (1.92)	2.20	0.69
T_3			Maize, *Zea mays*	3.21 (1.93)	2.00	0.62
T_4			Sorghum, *Sorghum bicolour*	3.58 (2.01)	2.50	0.70
T_5		Broken grains	Wheat	4.04 (2.12)	2.00	0.50
T_6			Rice	4.03 (2.12)	2.20	0.55
T_7			Maize	2.90 (1.83)	2.20	0.76
T_8			Sorghum	2.58 (1.75)	2.50	0.97
T_9		Bran	Wheat	2.88 (1.82)	2.50	0.87
T_{10}			Rice	2.71 (1.78)	1.00	0.37
T_{11}		Husks	Wheat	3.93 (2.10)	1.50	0.38
T_{12}			Rice	1.65 (1.46)	1.20	0.73
T_{13}	Liquid Media	Water soaked	Wheat	2.25 (1.65)	2.00	0.89
T_{14}			Rice	2.67 (1.77)	2.20	0.82
			SEm ±	0.03	--	
			CD at 5%	0.08	--	

( ) Figures in parentheses are arcsin transformed values

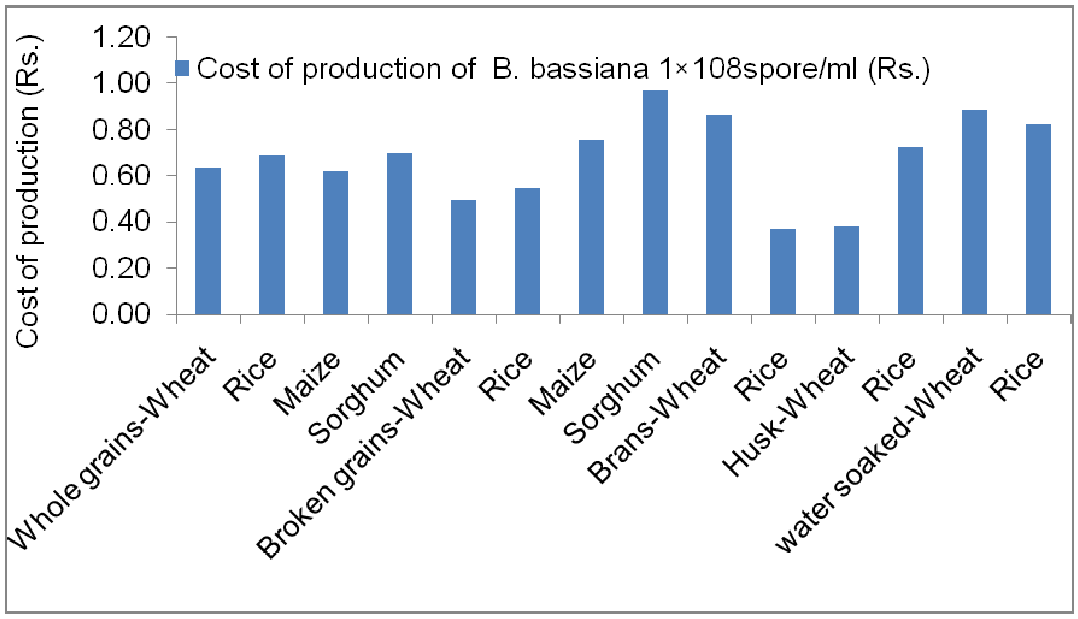


Fig.3: Economics of mass production of *Beauveria bassiana* on/in different substrate

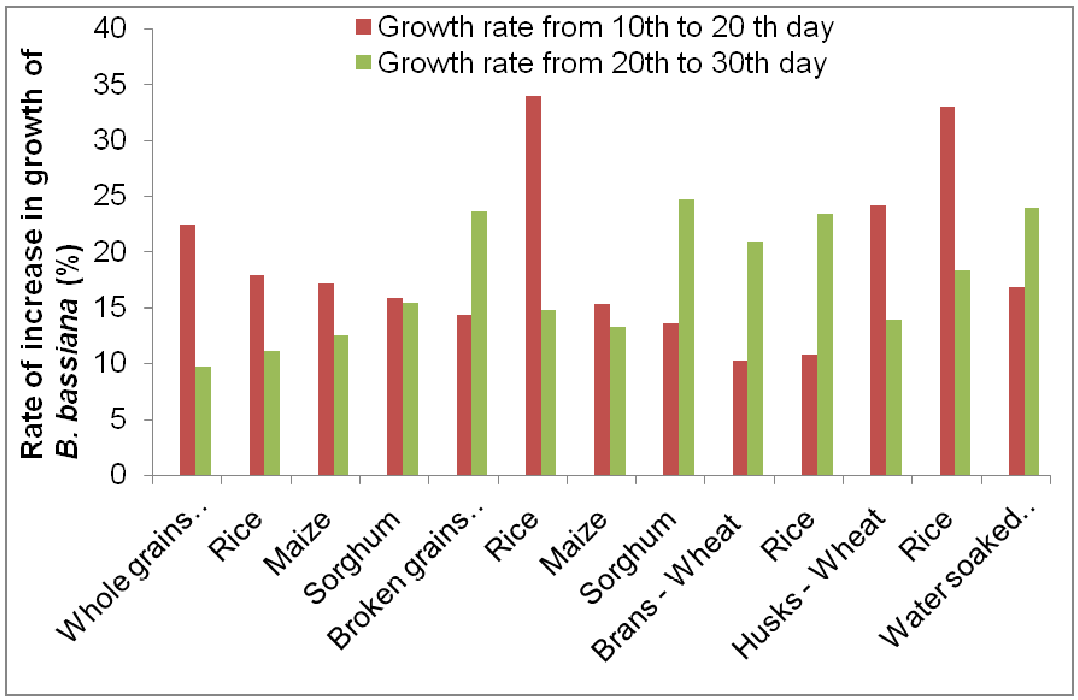


Fig. 4: Rate of increase in growth of *B. bassiana* at different days after inoculation

4.2 To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex :

4.2.1 Invitro studies on compatibility of *Beauveria bassiana* with some new generation insecticides:

An experiment was conducted in the laboratory to screen some of the recommended insecticides which are used in pigeonpea to control pigeonpea pod infesting insect pest complex, for their toxic effect on the growth of *B. bassiana*.

4.2.1.a Growth performance of *B.bassiana* in media treated with different insecticides :

Data on growth performance of *B. bassiana* in insecticide treated media are presented in table no. 16 and depicted in fig no. 5 and plate no. 5, 6, 7, 8 and 9.

4.2.1.a. (i) Two days after inoculation :

At two days after inoculation, the differences in the mean growth of *B.bassiana* on different media were significant. Among the treatments, rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (21.60 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (20.62 mm), but both were at par with each other. The next effective treatments were emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (16.00 mm) followed by triazophos 40%EC @ 300g *a.i.*/ha (T_7) (15.68 mm), indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (15.52 mm) and least growth was observed in flubendiamide 20%EC @ 25g *a.i.*/ha (T_5) (15.01 mm), but all were at par with each other. However, in control (*B.bassiana)* maximum growth (30.90 mm) was observed.

4.2.1.b. (ii) Four days after inoculation :

At fourth day after inoculation the differences in the mean growth of *B.bassiana* on different media were significant. Among the treatments, rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (27.10 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (26.70 mm) and emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (25.60 mm), but all

were at par with each other. The next effective treatments were triazophos 40%EC @ 300g *a.i.*/ha (T_7) (23.00 mm) followed by indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (21.70 mm), but both were at par with each other. The least effective treatment was flubendiamide 20EC @ 25g *a.i.*/ha (20.60 mm). However, in control maximum growth (39.72 mm) was observed.

4.2.1.a. (iii)Six days after inoculation :

At sixth day after inoculation the differences in the mean growth of *B.bassiana* on different media were significant. Among the treatments, rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (35.56 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (33.80 mm). The next effective treatments were emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (31.42 mm), followed triazophos 40%EC @ 300g *a.i.*/ha (T_7) (29.12 mm), but both were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (27.16 mm) while least effective treatment was flubendiamide 20EC @ 25 g *a.i.*/ha (24.28 mm), but they did not differ significantly from each other. However, in control maximum growth (50.42 mm) was observed.

4.2.1.a. (iv) Eight days after inoculation :

At eighth day after inoculation the differences in the mean growth of *B.bassiana* on different media were significant. Among the treatments, rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (50.36 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (47.38 mm), emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (39.98 mm) and triazophos 40%EC @ 300g *a.i.*/ha (T_7) (36.54 mm), but they did not differ significantly from each other. The next effective treatments were indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (34.88 mm) followed by flubendiamide 20EC @ 25 g *a.i.*/ha (33.62 mm), but both were at par with each other. However, in control maximum growth (71.76 mm) was observed.

4.2.1.a. (v) Ten days after inoculation :

At tenth day after innoculation the differences in the mean growth of *B.bassiana* on different media were significant. Among the treatments, rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (58.38 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (54.58), but they did not differ significantly from each other. The next effective treatments were emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (51.18 mm) followed by triazophos 40%EC @ 300g *a.i.*/ha (T_7) (50.38 mm), indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (50.22 mm) and flubendiamide 20EC @ 25 g *a.i.*/ha (49.20 mm), but all were at par with each other. However, in control maximum growth (84.74 mm) was observed.

4.2.1.a. (vi) Mean

On the overall basis the differences in the mean growth *B.bassiana* on different media were significant. Among the treatments rynaxpyr 20%SC @ 20g *a.i.*/ha (T_4) showed maximum growth (38.60 mm) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (T_3) (36.62), emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (T_6) (32.67 mm), triazophos 40%EC @ 300g *a.i.*/ha (T_7) (31.10 mm), indoxacarb 14.5%SC @ 30g *a.i.*/ha (T_2) (29.68 mm) while least effective treatment was flubendiamide 20EC @ 25 g *a.i.*/ha (28.77 mm), but they differed significant from each other. However, in control maximum growth (84.74 mm) was observed.

4.2.1.b Growth inhibition of *B.bassiana* in different insecticide treated media:

The data on effect of insecticide treated media on the growth inhibition of *B.bassiana* are presented in table 16 and depicted fig. 5

4.2.1.b. (i) Two days after inoculation :

All the treatments showed significant difference in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (30.14%) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (33.13%), but both were at par with each other. The next effective treatments were emamectin benzoate 5% SG @ 5.5g *a.i.*/ha, triazophos40%EC @ 300g

a.i./ha, indoxacarb 14.5%SC @ 30g *a.i.*/ha and flubendiamide 20EC @ 30g *a.i.*/ha showed growth inhibition percentage of 48.15%, 49.17%, 49.43% and 51.28% respectively, but all were at par with each other.

4.2.1.b. (ii) Four days after inoculation :

All the treatments showed significant differences in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (31.49%) and was found to be the most compatible insecticide among the other insecticides tested. The next effective insecticides were spinosad 45%SC @ 36.5g *a.i.*/ha (32.50%), emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (35.60%) and triazophos 40%EC @ 300g *a.i.*/ha (41.76%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 30g *a.i.*/ha (48.05%) and flubendiamide 20EC @ 30g *a.i.*/ha (45.05%), but they were at par with each other.

4.2.1.b. (iii) Six days after inoculation :

All the treatments showed significant differences in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (29.33%) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (32.80%), but both were at par with each other. The next effective treatments were emamectin benzoate5% SG @ 5.5g *a.i.*/ha (37.58%) and triazophos 40%EC @ 300g *a.i.*/ha (42.05%), but both were of them at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 30g *a.i.*/ha (45.95%) and flubendiamide 20EC @ 30g *a.i.*/ha (51.65%), but both were at par with each other.

4.2.1.b. (iv) Eight days after inoculation :

All the treatments showed significant differences in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (29.78%) and was found to be the most compatible insecticide among the other insecticides tested. The next effective treatments were spinosad 45%SC @ 36.5g *a.i.*/ha (33.96%) followed by emamectin benzoate 5% SG

@ 5.5g *a.i.*/ha (44.26%), but they were at par with each other. The next effective treatments were triazophos 40%EC @ 300g *a.i.*/ha (49.05%) and indoxacarb 14.5%SC @ 30g *a.i.*/ha (51.36%), but they were at par with each other. The highest growth inhibition in flubendiamide 20EC @ 30g *a.i.*/ha (53.13%).

4.2.1.b. (v) Ten days after inoculation :

All the treatments showed significant differences in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (31.01%) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (35.55%) but both differed significant from each other. The next effective treatments were emamectin benzoate 5% SG @ 5.5g *a.i.*/ha (39.55%), triazophos 40%EC @ 300g *a.i.*/ha (40.48%), indoxacarb 14.5%SC @ 30g *a.i.*/ha (40.67%) and flubendiamide 20EC @ 30g *a.i.*/ha (41.90%), but all were at par with each other.

4.2.1.b. (v) Mean :

All the treatments showed significant differences in growth inhibition of *B. bassiana* in different insecticide treated media. Among the insecticides tested, rynaxpyr 20%SC @ 20g *a.i.*/ha showed least growth inhibition (30.35%) followed by spinosad 45%SC @ 36.5g *a.i.*/ha (35.59 %), but both were at par with each other. The next effective treatments were emamectin benzoate5% SG @ 5.5g *a.i.*/ha (39.55%) and triazophos 40%EC @ 300g *a.i.*/ha (40.48%), but both were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 30g *a.i.*/ha (40.67%) and flubendiamide 20EC @ 30g *a.i.*/ha (41.90%), but both were at par with each other.

4.2.1.c Spore count and spore viability of *B.bassiana* spores in media mixed with some new generation insecticides:

Data on sporulation of *B. bassiana* and germination in insecticide treated media are presented in table no. 17. However, among all the treatments, highest mean spore count was recorded in *B. bassiana* (T_1) ($5.40x10^8$spores/ml) followed by *B. bassiana* + rynaxpyr (T_4) (4.20

x10^8spores/ml), but both were at par with each other. The next highest mean spore count was recorded in *B. bassiana* + spinosad (T_3) (4.00 x10^8spores/ml) followed by *B. bassiana* + emamectin benzoate (T_6) (3.60 x10^8spores/ml), *B. bassiana* + indoxacarb (T_2) (3.40 x10^8spores/ml), *B. bassiana* + triazophos (T_7) (3.40 x10^8spores/ml) while least mean spore count was recorded in *B. bassiana* + flubendamide (T_5) (3.60 x10^8spores/ml), but all were at par with each other.

Studies on germination of viable spores over control revealed that the highest spore germination was recorded in *B. bassiana* + rynaxpyr (T_4) (87.00%) followed by *B. bassiana* + spinosad (T_3) (83.00%), *B. bassiana* + emamectin benzoate (T_6) (82.00%), *B. bassiana* + indoxacarb (T_2) (77.67%), *B. bassiana* + triazophos (T_7) (73.67%) and *B. bassiana* + flubendamide (T_5) (61.67%), but all were at par with each other.

Table no.16 Invitro studies on compatibility *Beauveria bassiana* with some new generation insecticides

Tre. No.	Treatments	Performance of *B. bassiana* in different media (at DDAI)											
		Growth (mm)						Growth inhibition (%)					
		2	4	6	8	10	Mean	2	4	6	8	10	Mean
T_1	*Beauveria bassiana*	30.90	39.72	50.42	71.76	84.74	55.51	-	-	-	-	-	-
T_2	*B.bassiana*+ Indoxacarb	15.52	20.60	27.16	34.88	50.22	29.68	49.43 (44.56)	48.05 (43.88)	45.95 (42.67)	51.36 (45.78)	40.67 (39.62)	47.09 (43.33)
T_3	*B. bassiana* + Spinosad	20.62	26.72	33.80	47.38	54.58	36.62	33.13 (35.09)	32.50 (34.71)	32.80 (34.87)	33.96 (35.63)	35.55 (36.60)	33.59 (35.42)
T_4	*B. bassiana* + Rynaxpyr	21.60	27.08	35.56	50.36	58.38	38.60	30.14 (33.21)	31.49 (33.99)	29.33 (32.74)	29.78 (33.05)	31.01 (33.79)	30.35 (33.42)
T_5	*B.bassiana* +Flubendamide	15.01	21.72	24.28	33.62	49.20	28.77	51.28 (45.73)	45.05 (42.12)	51.65 (45.95)	53.13 (46.80)	41.90 (40.34)	48.60 (44.19)
T_6	*B.Bassiana* + EB	16.00	25.56	31.42	39.98	50.38	32.67	48.15 (43.93)	35.60 (36.63)	37.58 (37.79)	44.26 (41.70)	39.55 (38.96)	41.03 (39.84)
T_7	*B. bassiana* + Triazophos	15.68	22.96	29.12	36.54	51.18	31.10	49.17 (44.53)	41.76 (40.19)	42.05 (40.41)	49.05 (44.46)	40.48 (39.50)	44.50 (41.84)
	SEm±	0.82	0.78	0.85	0.68	0.89	0.29	1.82	1.60	1.32	0.67	0.79	0.99
	CD at 5%	2.40	2.28	2.48	1.98	2.59	0.86	5.34	4.70	3.89	1.97	2.34	2.92

Max. temp. 37± 2.2 °C, Min. temp. 22.45± 7.15°C, Morning RH (%) 52.5± 20.5, Evening RH (%) 22.5± 2.5,

DDAI =Different days after inoculation ( ) = Figures in parentheses are arc sin transformed values

Table no.17 Spore count and germination of *B.bassiana* spores in media mixed with some new generation insecticides

Treatment No.	Treatments	Dose	Mean spore counts ($1x10^8$ spores/ml)*	Germination of viable spores over control (%)**
T_1	*Beauveria bassiana*	1×10^8 spores/ml	5.40 (2.43)	---
T_2	*B.bassiana*+ Indoxacarb	Half dose of T_1+ 30g *a.i.*/ha	3.40 (1.97)	77.67 (64.58)
T_3	*B. bassiana* + Spinosad	Half dose of T_1 + 36.5g *a.i.*/ha	4.00 (2.12)	83.00 (70.84)
T_4	*B. bassiana* + Rynaxpyr	Half dose of T_1 +20g *a.i.*/ha	4.20 (2.17)	87.00 (73.38)
T_5	*B.bassiana* +Flubendamide	Half dose of T_1 +25g *a.i.*/ha	3.20 (1.92)	61.67 (51.89)
T_6	*B.Bassiana* + EB	Half dose of T_1 +5.5g *a.i.*/ha	3.60 (2.02)	82.00 (70.15)
T_7	*B. bassiana* + Triazophos	Half dose of + 300g *a.i.*/ha	3.40 (1.97)	73.67 (62.04)
	SEm±		0.11	5.38
	CD at 5%		NS	15.99

NS = Non Significant *( ) = Figures in parentheses square root transformed value **( ) = Figures in parentheses are arc sin transformed values

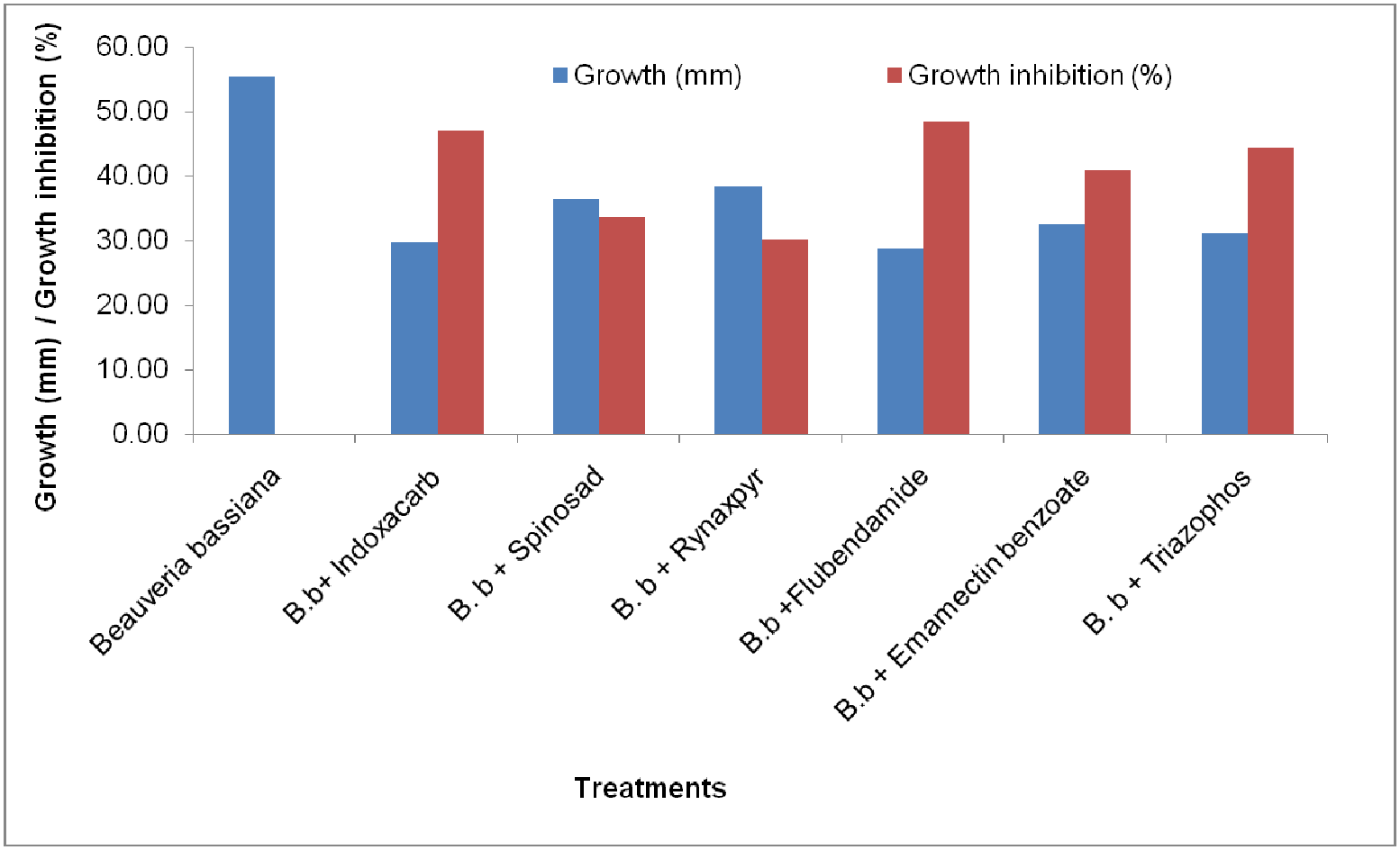


Fig. 5 Growth and growth inhibition of *B.bassiana* in media treated with different insecticides

4.2.2 Invivo studies on efficacy of *Beauveria bassiana* with some new generation insecticides against pod infesting insect pests :

The data on bioefficacy of *B. bassiana* and insecticides alone and their combination against immature stages of major pigeonpea pod infesting insect pest complex are presented in table 18 to 21

4.2.2.1 Efficacy of *B.bassiana* and insecticides alone and their combination against pigeonpea pod infesting insect pest complex :

4.2.2.1. (i) Gram pod borer, *Helicoverpa armigera* Hub.

Data presented in table no. 18

Pre- treatment:

Differences in the *Helicoverpa armigera* mean larval population per plant among different treatments were not significant, indicating more or less uniform distribution of the pest in the experimental field.

Mean of three sprayings :

Three days after spray :

Data presented in table 18 showed that at three days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.02 larvae / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.04 larvae / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.04 larvae / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.07 larvae / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.07 larvae / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.07 larvae / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.09 larvae / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.09 larvae / plant), *B. bassiana @* $1x10^8$ spores/ml (T_7) (0.11 larvae / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.11 larvae / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.13 larvae / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.13 larvae / plant), but all were at par with each other.

The next effective treatment was *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.22 larvae / plant). The highest larval population was recorded in control (0.49 larvae / plant).

Seven days after spray:

Data presented in table 18 showed that at seven days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.02 larvae / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.07 larvae / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.07 larvae / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.07 larvae / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.07 larvae / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.07 larvae / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.07 larvae / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.09 larvae / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.09 larvae / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.09 larvae / plant), but they were at par with each other. The next effective treatments were *B. bassiana* + triazophos 40%EC (T_{13}) (0.11 larvae / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.11 larvae / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.18 larvae / plant), but all were at par with each other. The highest larval population was recorded in control (0.49 larvae / plant).

Ten days after spray:

Data presented in table 18 showed that at ten days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.04 larvae / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.09 larvae / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.09 larvae / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.09 larvae / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.09 larvae /

plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.11 larvae / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.11 larvae / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.11 larvae / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.11 larvae / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.13 larvae / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.13 larvae / plant) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.13 larvae / plant), but all were at par with each other. The highest larval population was recorded in control (0.58 larvae / plant).

Overall mean:

Data presented in table 18 showed that on the basis of overall mean, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.03 larvae / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.07 larvae / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.07 larvae / plant), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.07 larvae / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.07 larvae / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.08 larvae / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.09 larvae / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.10 larvae / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.10 larvae / plant), but all were at par with each other. The next effective treatments were triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.11 larvae / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.13 larvae / plant) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.13 larvae / plant), but they were at par with each other. The highest larval population was recorded in control (0.52 larvae / plant).

4.2.2.1. (ii) Tur plume moth, *Exelastis atomosa* Wals.

Data presented in table no. 19

Pre- treatment:

Differences in the *Exelastis atomosa* mean larval population per 25 pods among different treatments were not significant, indicating more or less uniform distribution of the pest in the experimental field.

Mean of three sprayings:

Three days after spray:

Data presented in table 19 showed that at three days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.03 larvae / 25 pods) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.04 larvae / 25 pods), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.07 larvae /25 pods), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.07 larvae /25 pods), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.07 larvae /25 pods), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.09 larvae /25 pods), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.09 larvae /25 pods), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.09 larvae /25 pods), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.09 larvae /25 pods), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.09 larvae /25 pods), *B. bassiana* + triazophos 40%EC (T_{13}) (0.11 larvae / 25 pods) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.11 larvae / 25 pods), but they were all at par with each other. The highest larval population was recorded in control (0.66 larvae / plant).

Seven days after spray:

Data presented in table 19 showed that at seven days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.06 larvae / 25 pods) followed by treatments *B. bassiana* + spinosad

45% SC (T_9) (0.07 larvae / 25 pods), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.07 larvae /25 pods), *B. bassiana* + emamectin benzoate 5% (T_{12}) (0.09 larvae /25 pods), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.09 larvae /25 pods), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.09 larvae /25 pods), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.09 larvae /25 pods), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.09 larvae /25 pods), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.11 larvae /25 pods), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.11 larvae /25 pods), *B. bassiana* + triazophos 40%EC (T_{13}) (0.13 larvae / 25 pods) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.13 larvae / 25 pods), but they were all at par with each other. The highest larval population was recorded in control (0.71 larvae / plant).

Ten days after spray:

Data presented in table 19 showed that at ten days after spray, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.07 larvae / 25 pods) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.09 larvae / 25 pods), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.11 larvae /25 pods), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.11 larvae /25 pods), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.11 larvae /25 pods), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.13 larvae /25 pods), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.13 larvae /25 pods), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.16 larvae /25 pods), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.16 larvae /25 pods), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.18 larvae /25 pods), *B. bassiana* + triazophos 40%EC (T_{13}) (0.18 larvae / 25 pods) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.18 larvae / 25 pods) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.20 larvae / plant), but they were all at par with each other The highest larval population was recorded in control (0.87 larvae / plant).

Overall mean:

Data presented in table 19 showed that at on the basis of overall mean, the differences in the mean larval population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest larval population (0.05 larvae / 25 pods) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.07 larvae / 25 pods), but both were at par with each other. The next effective treatments were rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.08 larvae /25 pods), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.09 larvae /25 pods), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.09 larvae /25 pods), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.010 larvae /25 pods) and emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.010 larvae /25 pods), but they were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.11 larvae /25 pods), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.12 larvae /25 pods), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.13 larvae /25 pods), *B. bassiana* + triazophos 40%EC (T_{13}) (0.14 larvae / 25 pods) and *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.14 larvae / 25 pods), but they all were at par with each other. The highest larval population was recorded in control (0.87 larvae / plant).

4.2.2.1 (iii) Tur pod bug, *Clavigralla gibbosa* Spinola

Data presented in table no. 20

Pre- treatment:

Differences in the *Clavigralla gibbosa* mean bug population (nymph + adult) per plant among different treatments were not significant, indicating more or less uniform distribution of the pest in the experimental field.

Mean of three sprayings:

Three days after spray:

Data presented in table 20 showed that at three days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10})

was found to be most effective as it recorded lowest bug population (0.15 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.16 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.16 bugs / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.16 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.18 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.18 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.20 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.20 bugs / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.20 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.22 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.24 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.24 bugs / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.31 bugs / plant), but they were all at par with each other. The highest bug population was recorded in control (2.89 bugs / plant).

Seven days after spray:

Data presented in table 20 showed that at seven days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.12 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.13 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.13 bugs / plant), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.13 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.16 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.16 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.18 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.18 bugs / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.18 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.18 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.20 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.22 bugs / plant) and *B. bassiana* + flubendiamide 20%EC @ 1×10^4spores/ml + 25g *a.i.*/ha (T_{11}) (0.31 bugs / plant), but they were all at par with each other. The highest bug population was recorded in control (3.04 bugs / plant).

Ten days after spray:

Data presented in table 20 showed that at ten days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.21 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.22 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.24 bugs / plant), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.27 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.27 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.27 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.27 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.29 bugs / plant), *B. bassiana @* $1x10^8$ spores/ml (T_7) (0.20 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.31 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.33 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.33 bugs / plant) and *B. bassiana* + flubendiamide 20%EC @ 1×10^4spores/ml + 25g *a.i.*/ha (T_{11}) (0.33 bugs / plant), but they were all at par with each other. The highest bug population was recorded in control (3.38 bugs / plant).

Overall mean:

Data presented in table 20 showed that at on the basis of overall mean, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.16 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.17 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.18 bugs / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.19 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.20 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.20 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.21 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.22 bugs / plant), *B. bassiana @* $1x10^8$ spores/ml (T_7) (0.23 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.24 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.26

bugs / plant), but they were all at par with each other. The next effective treatments were *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.27 bugs / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.32 bugs / plant), but they did not differ significantly from each other. The highest bug population was recorded in control (3.10 bugs / plant).

4.2.2.1. (iv) Green stink bug, *N. viridula* Linn.

Data presented in table no. 21

Pre- treatment:

Differences in the *N. viridula* mean bug population (nymph + adult) per plant among different treatments were not significant, indicating more or less uniform distribution of the pest in the experimental field.

Mean of three sprayings:

Three days after spray:

Data presented in table 21 showed that at three days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.15 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.16 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.16 bugs / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.16 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.18 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.18 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.20 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.22 bugs / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.22 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.22 bugs / plant), *B. bassiana* + triazophos 40%EC *a.i.*/ha (T_{13}) (0.22 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.24 bugs / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.33 bugs / plant), but they were all at par with each other. The highest bug population was recorded in control (2.71 bugs / plant).

Seven days after spray:

Data presented in table 21 showed that at seven days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.13 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.16 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.16 bugs / plant), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.16 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.16 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.20 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.20 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.20 bugs / plant), *B. bassiana* (T_7) (0.20 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.22 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.22 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.24 bugs / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.29 bugs / plant), but they were all at par with each other. The highest larval population was recorded in control (3.02 bugs / plant).

Ten days after spray:

Data presented in table 21 showed that at ten days after spray, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.20 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.24 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.24 bugs / plant, *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.24 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.24 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.24 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.24 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.27 bugs / plant), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (0.27 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.27 bugs / plant), *B. bassiana* + triazophos 40%EC (T_{13}) (0.29 bugs / plant), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.29 bugs /

plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.31 bugs / plant), but they were all at par with each other. The highest bug population was recorded in control (2.84 bugs / plant).

Overall mean:

Data presented in table 21 showed that on the overall mean basis, the differences in the mean bug population among different treatments were significant. Among the treatments, *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest bug population (0.16 bugs / plant) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.19 bugs / plant), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.19 bugs / plant), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.19 bugs / plant), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.19 bugs / plant), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.21 bugs / plant), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.21 bugs / plant), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.23 bugs / plant), *B. bassiana* (T_7) (0.23 bugs / plant), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (0.24 bugs / plant) and *B. bassiana* + triazophos 40%EC (T_{13}) (0.24 bugs / plant), but they were at par with each other. The next effective treatments were *B. bassiana* + indoxacarb 14.5%SC @ 1×10^4spores/ml + 30g *a.i.*/ha (T_8) (0.26 bugs / plant) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.31 bugs / plant), but non significant differences were observed between them. The highest bug population was recorded in control (2.86 bugs / plant).

Table no. 18: Bioefficacy of *B. bassiana* and insecticides alone and their combination against Gram pod borer, *Helicoverpa armigera* infesting pigeonpea

Tr. code	Treatments	Dose	Mean *H. armigera* larval population /plant*				
			Pre treatment	Days after spraying			Mean
				3	7	10	
T_1	Indoxacarb 14.5SC	60g *a.i.*/ha	0.47 (0.98)	0.09 (0.77)	0.09 (0.77)	0.11 (0.78)	0.10 (0.77)
T_2	Spinosad 45SC	73g *a.i.*/ha	0.60 (1.05)	0.07 (0.75)	0.07 (0.75)	0.09 (0.77)	0.07 (0.75)
T_3	Rynaxypyr 20EC	40g *a.i.* /ha	0.67 (1.08)	0.04 (0.73)	0.07 (0.75)	0.09 (0.77)	0.07 (0.75)
T_4	Flubendiamide 20EC	50g *a.i.*/ha	0.67 (1.08)	0.07 (0.75)	0.07 (0.75)	0.11 (0.78)	0.08 (0.76)
T_5	Emamectin benzoate 5%SG	11g *a.i.*/ha	0.80 (1.14)	0.09 (0.77)	0.07 (0.75)	0.11 (0.78)	0.09 (0.77)
T_6	Triazophos 40EC	600g *a.i.*/ha	0.80 (1.14)	0.11 (0.78)	0.09 (0.77)	0.13 (0.79)	0.11 (0.78)
T_7	*Beauveria bassiana*	1×10^8spores/ml	0.80 (1.14)	0.11 (0.78)	0.09 (0.77)	0.11 (0.78)	0.10 (0.77)
T_8	*B.bassiana* + Indoxacarb	Half dose of T_7+T_1	0.93 (1.20)	0.13 (0.79)	0.11 (0.78)	0.13 (0.79)	0.13 (0.79)
T_9	*B.bassiana* + Spinosad	Half dose of T_7+T_2	0.80 (1.14)	0.04 (0.73)	0.07 (0.75)	0.09 (0.77)	0.07 (0.75)
T_{10}	*B.bassiana* + Rynaxpyr	Half dose of T_7+T_3	0.73 (1.11)	0.02 (0.72)	0.02 (0.72)	0.04 (0.73)	0.03 (0.73)
T_{11}	*B.bassiana* + Flubendamide	Half dose of T_7+T_4	0.60 (1.05)	0.22 (0.85)	0.18 (0.82)	0.27 (0.88)	0.22 (0.85)
T_{12}	*B.bassiana* + EB	Half dose of T_7+T_5	0.87 (1.17)	0.07 (0.75)	0.07 (0.75)	0.09 (0.77)	0.07 (0.75)
T_{13}	*B.bassiana* + Triazophos	Half dose of T_7+T_6	0.93 (1.20)	0.13 (0.79)	0.11 (0.78)	0.13 (0.79)	0.13 (0.79)
T_{14}	Control	-	0.67 (1.08)	0.49 (0.99)	0.49 (0.99)	0.58 (1.04)	0.52 (1.01)
	SEm±	-	0.08	0.02	0.02	0.04	0.01
	CD at 5%	-	NS	0.07	0.05	0.11	0.03

* Mean of 3 sprayings ( ) = Figures in parentheses square root transformed values

Table no. 19: Bioefficacy of *B. bassiana* and insecticides alone and their combination against Tur plume moth, *Exelastis atomosa* Wals. infesting pigeonpea

Tr. code	Treatments	Dose	Mean *E. atomosa* larval population / 25 pods*				
			Pre treatment	Days after spraying			
				3	7	10	Mean
T_1	Indoxacarb 14.5SC	60g *a.i.*/ha	0.73 (1.11)	0.09 (0.77)	0.09 (0.77)	0.16 (0.81)	0.11 (0.78)
T_2	Spinosad 45SC	73g *a.i.*/ha	0.60 (1.05)	0.07 (0.75)	0.09 (0.77)	0.11 (0.78)	0.09 (0.77)
T_3	Rynaxypyr 20EC	40g *a.i.* /ha	1.20 (1.30)	0.07 (0.75)	0.07 (0.75)	0.11 (0.78)	0.08 (0.76)
T_4	Flubendiamide 20EC	50g *a.i.*/ha	0.80 (1.14)	0.09 (0.77)	0.09 (0.77)	0.13 (0.79)	0.10 (0.77)
T_5	Emamectin benzoate 5%SG	11g *a.i.*/ha	1.00 (1.22)	0.09 (0.77)	0.09 (0.77)	0.13 (0.79)	0.10 (0.77)
T_6	Triazophos 40EC	600g *a.i.*/ha	0.53 (1.01)	0.09 (0.77)	0.11 (0.78)	0.18 (0.82)	0.13 (0.79)
T_7	*Beauveria bassiana*	1×10^8spores/ml	1.20 (1.30)	0.09 (0.77)	0.11 (0.78)	0.16 (0.81)	0.12 (0.79)
T_8	*B.bassiana* + Indoxacarb	Half dose of T_7+T_1	1.00 (1.22)	0.11 (0.78)	0.13 (0.19)	0.18 (0.82)	0.14 (0.80)
T_9	*B.bassiana* + Spinosad	Half dose of T_7+T_2	0.87 (1.17)	0.04 (0.73)	0.07 (0.75)	0.09 (0.77)	0.07 (0.75)
T_{10}	*B.bassiana* + Rynaxpyr	Half dose of T_7+T_3	1.07 (1.25)	0.03 (0.73)	0.06 (0.75)	0.07 (0.75)	0.05 (0.74)
T_{11}	*B.bassiana* + Flubendamide	Half dose of T_7+T_4	1.00 (1.22)	0.24 (0.86)	0.22 (0.85)	0.20 (0.84)	0.22 (0.85)
T_{12}	*B.bassiana* + EB	Half dose of T_7+T_5	1.00 (1.22)	0.07 (0.75)	0.09 (0.77)	0.11 (0.78)	0.09 (0.77)
T_{13}	*B.bassiana* + Triazophos	Half dose of T_7+T_6	1.20 (1.13)	0.11 (0.78)	0.13 (0.79)	0.18 (0.82)	0.14 (0.80)
T_{14}	Control	-	1.00 (1.22)	0.66 (1.08)	0.71 (1.10)	0.87 (1.17)	0.74 (1.11)
	SEm±	-	0.07	0.02	0.02	0.03	0.01
	CD at 5%	-	NS	0.06	0.06	0.09	0.04

* Mean of 3 sprayings ( ) = Figures in parentheses square root transformed values

Table no 20: Bioefficacy of *B. bassiana* and insecticides alone and their combination against Tur pod bug, *Clavigralla gibbosa* Spinola infesting pigeonpea

Tr. code	Treatments	Dose	Mean *C. gibbosa* bugs (nymph + adult) population / plant*				
			Pre treatment	Days after spraying			
				3	7	10	Mean
T_1	Indoxacarb 14.5SC	60g a.i./ha	6.20 (2.59)	0.20 (0.84)	0.18 (0.82)	0.29 (0.89)	0.22 (0.85)
T_2	Spinosad 45SC	73g a.i./ha	5.47 (2.44)	0.18 (0.82)	0.16 (0.81)	0.27 (0.88)	0.22 (0.85)
T_3	Rynaxypyr 20EC	40g a.i./ha	5.53 (2.46)	0.16 (0.81)	0.13 (0.79)	0.24 (0.86)	0.18 (0.82)
T_4	Flubendiamide 20EC	50g a.i./ha	6.07 (2.56)	0.18 (0.82)	0.16 (0.81)	0.27 (0.88)	0.20 (0.84)
T_5	Emamectin benzoate 5%SG	11g a.i./ha	5.47 (2.44)	0.20 (0.84)	0.18 (0.82)	0.27 (0.88)	0.21 (0.84)
T_6	Triazophos 40EC	600g a.i./ha	5.67 (2.48)	0.22 (0.85)	0.18 (0.82)	0.33 (0.91)	0.24 (0.86)
T_7	*Beauveria bassiana*	1×10^8 spores/ml	5.67 (2.48)	0.20 (0.84)	0.18 (0.82)	0.31 (0.90)	0.23 (0.85)
T_8	*B.bassiana* + Indoxacarb	Half dose of T_7+T_1	5.40 (2.43)	0.24 (0.86)	0.22 (0.85)	0.33 (0.91)	0.27 (0.88)
T_9	*B.bassiana*+ Spinosad	Half dose of T_7+T_2	5.60 (2.47)	0.16 (0.81)	0.13 (0.79)	0.22 (0.85)	0.17 (0.82)
T_{10}	*B.bassiana*+ Rynaxpyr	Half dose of T_7+T_3	5.60 (2.47)	0.15 (0.81)	0.12 (0.79)	0.21 (0.84)	0.16 (0.81)
T_{11}	*B.bassiana* +Flubendamide	Half dose of T_7+T_4	5.60 (2.47)	0.31 (0.90)	0.31 (0.90)	0.33 (0.91)	0.32 (0.91)
T_{12}	*B.bassiana*+EB	Half dose of T_7+T_5	5.60 (2.47)	0.16 (0.81)	0.13 (0.79)	0.27 (0.88)	0.19 (0.83)
T_{13}	*B.bassiana+* Triazophos	Half dose of T_7+T_6	5.40 (2.43)	0.24 (0.86)	0.20 (0.84)	0.33 (0.91)	0.26 (0.87)
T_{14}	Control	-	5.60 (2.47)	2.89 (1.84)	3.04 (1.88)	3.38 (1.97)	3.10 (1.90)
	SEm±	-	0.03	0.06	0.06	0.07	0.09
	CD at 5%	-	NS	0.17	0.17	0.21	0.27

* Mean of 3 sprayings ( ) = Figures in parentheses square root transformed value

Table no. 21 Bioefficacy of *B. bassiana* and insecticides alone and their combination against Green stink bug, *Nezara viridula* Linn infesting pigeonpea

Tr. code	Treatments	Dose	Mean *N. viridula* bugs population / plant				
			Pre treatment	Days after spraying			
				3	7	10	Mean
T_1	Indoxacarb 14.5SC	60g a.i./ha	4.73 (2.29)	0.22 (0.85)	0.20 (0.84)	0.27 (0.88)	0.23 (0.85)
T_2	Spinosad 45SC	73g a.i./ha	4.87 (2.32)	0.18 (0.82)	0.16 (0.81)	0.24 (0.86)	0.19 (0.83)
T_3	Rynaxypyr 20EC	40g *a.i.* /ha	4.80 (2.30)	0.16 (0.81)	0.16 (0.81)	0.24 (0.86)	0.19 (0.83)
T_4	Flubendiamide 20EC	50g *a.i.*/ha	5.87 (2.52)	0.18 (0.82)	0.20 (0.84)	0.24 (0.86)	0.21 (0.84)
T_5	Emamectin benzoate 5%SG	11g *a.i.*/ha	5.53 (2.46)	0.20 (0.84)	0.20 (0.84)	0.24 (0.86)	0.21 (0.84)
T_6	Triazophos 40EC	600g *a.i.*/ha	5.20 (2.39)	0.22 (0.85)	0.22 (0.85)	0.27 (0.88)	0.24 (0.86)
T_7	*Beauveria bassiana*	1×10^8spores/ml	5.80 (2.51)	0.22 (0.85)	0.20 (0.84)	0.27 (0.88)	0.23 (0.85)
T_8	*B.bassiana* + Indoxacarb	Half dose of T_7+T_1	5.53 (2.46)	0.24 (0.86)	0.24 (0.86)	0.29 (0.89)	0.26 (0.87)
T_9	*B.bassiana* + Spinosad	Half dose of T_7+T_2	5.47 (2.44)	0.16 (0.81)	0.16 (0.81)	0.24 (0.86)	0.19 (0.83)
T_{10}	*B.bassiana* + Rynaxpyr	Half dose of T_7+T_3	5.73 (2.50)	0.15 (0.81)	0.13 (0.79)	0.20 (0.84)	0.16 (0.81)
T_{11}	*B.bassiana*+Flubendamide	Half dose of T_7+T_4	5.33 (2.41)	0.33 (0.91)	0.29 (0.89)	0.31 (0.90)	0.31 (0.90)
T_{12}	*B.bassiana* + EB	Half dose of T_7+T_5	5.87 (2.52)	0.16 (0.81)	0.16 (0.81)	0.24 (0.86)	0.19 (0.83)
T_{13}	*B.bassiana* + Triazophos	Half dose of T_7+T_6	6.07 (2.56)	0.22 (0.85)	0.22 (0.85)	0.29 (0.89)	0.24 (0.86)
T_{14}	Control	-	5.53 (2.46)	2.71 (1.79)	3.02 (1.88)	2.84 (1.83)	2.86 (1.83)
	SEm±	-	0.06	0.05	0.05	0.07	0.01
	CD at 5%	-	NS	0.14	0.15	0.19	0.04

* Mean of 3 sprayings ( ) = Figures in parentheses square root transformed values

4.2.2 Invivo studies on efficscy of B*eauveria bassiana* with some new generation insecticides against pod infesting insect pests :

Data on pod and grain damage due to pest complex *viz*., gram pod borer, tur plume moth, tur pod bug and pod fly are presented in table 22

4.2.2.2 Efficacy of *B. bassiana* and insecticides alone and their combination on pigeonpea pod and grain damage by pod infesting insect pest complex :

Gram pod borer:

Pod damage:

All the treatments significantly reduced the pod damage by gram pod borer as compared to control (9.29%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest pod damage (1.66%) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (2.29%), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (2.71%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (2.71%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (3.12%), flubediamide 20%EC 50g *a.i.*/ha (T_4) (3.33%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (3.33%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (3.75%), *B. bassiana* @ $1x10^8$ spores/ml (T_7) (4.37%) and triazophos 40%EC @ 600g a.i./ha (T_6) (4.79%), but both of them were at par with each other. The least effective treatments were *B. bassiana* + indoxacarb 14.5%SC (T_8) (4.79%) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (5.41%), but they did not differ significantly with each other.

Grain damage :

All the treatments significantly reduced the grain damage by gram pod borer as compared to control (5.09%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest grain damage (0.42%) followed by

treatments *B. bassiana* + spinosad 45% SC (T_9) (0.63%), rynaxpyr 20EC (T_3) (0.73%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.78%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.86%), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.94%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.99%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (1.10%), *B. bassiana* @ $1x10^8$ *a.i.*/ha (T_7) (1.20%), triazophos 40%EC @ 600g a.i./ha (T_6) (1.30%), *B. bassiana* + triazophos 40%EC (T_{13}) (1.30), *B.b* + indoxacarb 14.5%SC (T_8) (1.30%) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (1.52%), but they did not differ significantly from each other.

Tur plume moth:

Pod damage:

All the treatments significantly reduced the pod damage by plume moth as compared to control (6.71%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest pod damage (0.84%) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (1.25%), but both were at par with each other. The next effective treatments were rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (1.87%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (1.87%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (2.08%), flubediamide 20%EC @ 50g *a.i.*/ha (T_4) (2.29%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (2.29%), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (2.50%) and *B. bassiana* @ $1x10^8$ spores/ml (T_7) (2.50%), but all were at par with each other. The least effective treatments were triazophos 40%EC @ 600g *a.i.*/ha (T_6) (2.91%), *B. bassiana* + triazophos 40%EC (T_{13}) (3.12%) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (4.58%), but they did not differ significantly with each other.

Grain damage:

All the treatments significantly reduced the grain damage by plume moth as compared to control (3.23%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it

recorded lowest grain damage (0.21%) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.31%), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.46%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.47%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.57%), flubendiamide 20%EC 50g *a.i.*/ha (T_4) (0.57%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.57%), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.63%) and *B. bassiana* @ $1x10^8$ 1×10^8spores/ml (T_7) (0.63%), but all were at par with each other. The least effective treatments were of triazophos 40%EC @ 600g a.i./ha (T_6) (0.78%), *B.b* + triazophos 45%EC (T_{13}) (0.79%) and *B.b* + flubendiamide 20%EC (T_{11}) (1.52%), and, but all were at par with each other.

Tur pod bug

Pod damage:

All the treatments significantly reduced the pod damage by pod bug as compared to control (8.79%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest pod damage (0.84%) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (1.25%), but both were at par with each other. The next effective treatments were *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (2.08%), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (2.29%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (2.71%), flubediamide 20%EC 50g *a.i.*/ha (T_4) (2.71%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (2.71%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (3.12%) and *B. bassiana* @ $1x10^8$spores/ml (T_7) (3.645) but both were at par with each other. The least effective treatments were triazophos 40%EC @ 600g *a.i.*/ha (T_6) (4.58%), *B. bassiana* + triazophos 40%EC (T_{13}) (4.79%), *B. bassiana* + indoxacarb 14.5%SC (T_8) (5.00%) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (7.08%), but all were at par with each other.

Grain damage:

All the treatments significantly reduced the grain damage by pod bug as compared to control (4.37%). Among the treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) was found to be most effective as it recorded lowest grain damage (0.21%) followed by treatments *B. bassiana* + spinosad 45% SC (T_9) (0.36%), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.57%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.57%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.68%), flubediamide 20%EC 50g *a.i.*/ha (T_4) (0.68%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.68%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.79%), *B. bassiana* (T_7) (0.94%), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (1.15%) and *B. bassiana* + triazophos 45%EC (T_{13}) (1.21%), but they did not differ significantly with each other. The least effective treatments were *B. bassiana* + indoxacarb 14.5%SC (T_8) (1.38%) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (1.88%), but both were at par with each other.

Pod fly:

Pod damage:

All the treatments significantly reduced the pod damage by pod fly as compared to control (8.46%). Among the treatments, triazophos 40%EC @ 600g *a.i.*/ha (T_6) was found to be most effective as it recorded lowest pod damage (0.50%) followed by treatment *B. bassiana* + rynaxpyr 20%EC (T_{10}) (0.63%), but both were at par with each other. The next effective treatments were *B. bassiana* + spinosad 45% SC (T_9) (1.46%), *B.b* + emamectin benzoate 5% SG (T_{12}) (1.46%), *B. bassiana* + indoxacarb 14.5%SC (T_8) (1.66%) and spinosad 45% SC @ 73g *a.i.*/ha (T_2) (1.87%), but all were at par with each other. The next effective treatments were indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (2.50%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (2.50%), *B. bassiana* + flubendiamide 20%EC (T_{11}) (2.50%), *B. bassiana* + triazophos 40%EC (T_{13}) (2.50%) and rynaxpyr

20EC @ 40g *a.i.*/ha (T_3) (3.12%), but they did not differ significant with each other. The least effective treatments were flubendiamide 20%EC (T_4) (3.75%) and *B. bassiana* 1×10^8spores/ml *a.i.*/ha (T_7) (5.21%), and they were at par with each other.

Grain damage:

All the treatments significantly reduced the grain damage by pod fly as compared to control (5.06%). Among the treatments triazophos 40%EC @ 600g *a.i.*/ha (T_6) was found to be most effective as it recorded lowest grain damage (0.10%) followed by treatments *B. bassiana* + rynaxpyr 20%EC (T_{10}) (0.16%), *B. bassiana* + spinosad 45% SC (T_9) (0.37%), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (0.37%), *B. bassiana* + indoxacarb 14.5%SC (T_8) (0.41%), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (0.47%), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (0.63%), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (0.63%), *B. bassiana* + flubendiamide 20%EC (T_{11}) (0.63%) and *B. bassiana* + triazophos 40%EC (T_{13}) (0.63%), but all were at par with each other. The least effective treatments were rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (0.78%), flubendiamide 20EC 50 g *a.i.*/ha (T_4) (0.99%) and *B. bassiana* 1×10^8spores/ml (T_7) (1.30%), and they were at par with each other.

4.2.2.3 Efficacy of *B. bassiana* and insecticides alone and their combinations on pigeonpea grain yield:

The yield of net plot area of each plot was recorded and converted into kg/ha. All the treatments registered significantly highest grain yields as compared to the control (307.31 kg/ha). The highest grain yield was recorded in *B. bassiana* + rynaxpyr 20%EC (T_{10}) treated plots (1080.40 kg/ha) followed by *B. bassiana* + spinosad 45% SC (T_9) (1046.90 kg/ha), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (990.15 kg/ha), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (894.14 kg/ha), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (825.82 kg/ha), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (761.40 kg/ha), flubediamide 20%EC 50g *a.i.*/ha (T_4) (719.20 kg/ha), indoxacarb 14.5%SC @ 60g

a.i./ha (T_1) (667.20 kg/ha), *B. bassiana* @ $1x10^8$ *a.i.*/ha (T_7) (646.51 kg/ha), but they did not differ significantly from each other. The next effective treatments were triazophos 40%EC @ 600g a.i./ha (T_6) (635.61 kg/ha) followed by *B. bassiana* + triazophos 45%EC (T_{13}), but both were at par with each other. The next effective treatments were *B. bassiana* + indoxacarb 14.5%SC (T_8) (601.29 kg/ha) and *B. bassiana* + flubendiamide 20%EC (T_{11}) (599.03 kg/ha), but both were at par each with other. (Table 23)

4.2.2.4 Economics of Treatments:

4.2.2.4. (i) Increase in yield over control:

Among the different treatments, highest increase in yield over control was registered with *B. bassiana* + rynaxpyr 20%EC (T_{10}) treated plots (773.20 kg/ha), this was followed by *B. bassiana* + spinosad 45% SC (T_9) (739.70 kg/ha), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (683.00 kg/ha), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (587.00 kg/ha), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (518.70 kg/ha), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (454.20 kg/ha), flubendiamide 20%EC 50g *a.i.*/ha (T_4) (412.00 kg/ha), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (360.04 kg/ha), *B. bassiana* @ $1x10^8$ *a.i.*/ha (T_7) (339.00 kg/ha), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (328.50 kg/ha), *B.b* + triazophos 40%EC (T_{13}) (318.20 kg/ha), *B. bassiana* + indoxacarb 14.5%SC (T_8) (294.10 kg/ha) and lowest in *B.b* + flubendiamide 20%EC (T_{11}) (291.90 kg/ha), respectively (Table 23).

4.2.2.4. (ii) Net profit:

Among the different treatments highest net profit was registered in case of *B. bassiana* + spinosad 45% SC (T_9) (Rs. 39245.88/ha) followed by *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (Rs. 38349.72/ha), *B. bassiana* + rynaxpyr 20%EC (T_{10}) (Rs. 37822.26/ha), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (Rs. 22239.56/ha), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (Rs. 20988.92/ha), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (Rs. 18224.76/ha), *B. bassiana* @ $1x10^8$spores/ml (T_7) (Rs. 17549.38kg/ha), indoxacarb 14.5%SC @

60g *a.i.*/ha (T_1) (Rs. 17234.48/ha), *B. bassiana* + triazophos 40%EC (T_{13}) (Rs. 16657.30/ha), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (Rs. 16295.06/ha), *B. bassiana* + indoxacarb 14.5%SC (T_8) (Rs. 14658.06/ha), flubendiamide 20%EC 50g *a.i.*/ha (T_4) (Rs. 11488.48/ha) and lowest in *B. bassiana* + flubendiamide 20%EC (T_{11}) (Rs. 10032.94/ha), respectively (Table no. 23).

4.2.2.4. (iii) Cost benefit ratio:

Among the different treatments, highest cost benefit ratio was obtained in *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (1:9.60), followed by *B. bassiana* + spinosad 45% SC (T_9) (1:5.93), *B. bassiana* + triazophos 40%EC (T_{13}) (1:5.43), *B. bassiana* @ $1x10^8$spores/ml (T_7) (5.06), *B. bassiana* + indoxacarb 14.5%SC (T_8) (1:4.10), triazophos 40%EC @ 600g *a.i.*/ha (T_6) (1:4.01), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (1:3.75), *B. bassiana* + rynaxpyr 20%EC (T_{10}) (1:3.74), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (1:3.39), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (1:1.88), *B. bassiana* + flubendiamide 20%EC (T_{11}) (1:1.24), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (1:1.00), and lowest in flubediamide 20%EC 50g *a.i.*/ha (T_4) (1:0.83), respectively (Table 23).

Table no. 22 Bioefficacy of *Beauveria bassiana* and insecticides alone and their combination on pod and grain damage by pigeonpea pod borer complex

Tre. No.	Treatments	Dose	Percent damage by*							
			Pod borer		Tur plume moth		Pod bug		Pod fly	
			Pod	Grain	Pod	Grain	Pod	Grain	Pod	Grain
T_1	Indoxacarb 14.5SC	60g *a.i.*/ha	3.75 (11.16)	1.10 (6.02)	2.50 (9.10)	0.63 (4.55)	3.12 (10.17)	0.79 (5.10)	2.50 (9.10)	0.63 (4.55)
T_2	Spinosad 45SC	73g *a.i.*/ha	3.12 (10.17)	0.86 (5.32)	2.08 (8.27)	0.57 (4.31)	2.71 (9.46)	0.68 (4.72)	1.87 (7.85)	0.47 (3.93)
T_3	Rynaxypyr 20EC	40g *a.i.*/ha	2.71 (9.46)	0.73 (4.91)	1.87 (7.85)	0.46 (3.87)	2.29 (8.68)	0.57 (4.35)	3.12 (10.17)	0.78 (5.08)
T_4	Flubendiamide 20EC	50g *a.i.*/ha	3.33 (10.50)	0.94 (5.55)	2.29 (8.68)	0.57 (4.33)	2.71 (9.46)	0.68 (4.72)	3.75 (11.13)	0.99 (5.71)
T_5	Emamectin benzoate 5%SG	11g *a.i.*/ha	3.33 (10.50)	0.99 (5.70)	2.29 (8.68)	0.57 (4.33)	2.71 (9.46)	0.68 (4.72)	2.50 (9.10)	0.62 (4.53)
T_6	Triazophos 40EC	600g a.i./ha	4.79 (12.63)	1.31 (6.56)	2.91 (9.81)	0.78 (5.06)	4.58 (12.33)	1.16 (6.16)	0.50 (4.05)	0.10 (1.81)
T_7	*Beauveria bassiana*	1×10^{8} spores/ml	4.37 (12.06)	1.20 (6.27)	2.50 (9.10)	0.63 (4.53)	3.65 (11.01)	0.94 (5.56)	5.21 (13.18)	1.30 (6.55)
T_8	*B.bassiana* + Indoxacarb	Half dose of T_7+T_1	4.79 (12.63)	1.31 (6.57)	3.33 (10.50)	0.84 (5.25)	5.00 (12.90)	1.38 (6.71)	1.66 (7.37)	0.41 (3.63)
T_9	*B. bassiana* + Spinosad	Half dose of T_7+T_2	2.29 (8.68)	0.63 (4.57)	1.25 (6.41)	0.31 (3.21)	1.25 (6.41)	0.36 (3.44)	1.46 (6.89)	0.37 (3.45)
T_{10}	*B. bassiana* + Rynaxpyr	Half dose of T_7+T_3	1.66 (7.37)	0.42 (3.68)	0.84 (5.17)	0.21 (2.59)	0.84 (5.17)	0.21 (2.56)	0.63 (4.55)	0.16 (2.29)
T_{11}	*B. bassiana* + Flubendamide	Half dose of T_7+T_4	5.41 (13.45)	1.52 (7.08)	4.58 (12.31)	1.52 (7.08)	7.08 (15.43)	1.88 (7.88)	2.50 (9.10)	0.63 (4.55)
T_{12}	*B. bassiana* + Emamectin	Half dose of T_7+T_5	2.71 (9.46)	0.78 (5.08)	1.87 (7.85)	0.47 (3.92)	2.08 (8.28)	0.57 (4.32)	1.46 (6.89)	0.37 (3.45)

	benzoate									
T_{13}	*B. bassiana* + Triazophos	Half dose of T_7+T_6	4.79 (12.63)	1.30 (6.54)	3.12 (10.18)	0.79 (5.09)	4.79 (12.63)	1.21 (6.33)	2.50 (9.10)	0.63 (4.55)
T_{14}	Control	-	9.29 (17.74)	5.09 (13.01)	6.71 (15.01)	3.23 (10.35)	8.79 (17.24)	4.37 (12.04)	8.46 (16.91)	5.06 (12.96)
Mean			2.18 (5.85)	0.79 (3.35)	1.55 (4.87)	0.53 (2.71)	8.09 (5.60)	0.70 (3.10)	2.72 (8.96)	0.89 (4.79)
SEm±			0.23	0.20	0.30	0.16	0.24	0.19	0.25	0.21
CD at 5%			0.69	0.58	0.89	0.46	0.70	0.57	0.74	0.62

( ) = Figures in parentheses are arc sin transformed values

Table no. 23: Economics of *Beauveria bassiana* and newer insecticides alone and their combinations against pigeonpea pod infesting insect pest complex

Tre. no.	Treatments	Dose	Grain yield (kg/ha)	Increase in yield over control (Kg/ha)	Cost of treatment (Rs)*	Cost of increased yield over control @ Rs 6200/quintal	Net profit (Rs/ha)	Cost benefit ratio
T_1	Indoxacarb 14.5SC	60g *a.i.*/ha	667.2	360.04	5088	22322	17234	1:3.39
T_2	Spinosad 45SC	73g *a.i.*/ha	825.82	518.66	11168	32157	20989	1:1.88
T^3	Rynaxypyr 20EC	40g *a.i.*/ha	894.14	586.98	18168	36393	18225	1:1.00
T_4	Flubendiamide 20EC	50g *a.i.*/ha	719.2	412.04	14058	25546	11488	1:0.82
T_5	Emamectin benzoate 5%SG	11g *a.i.*/ha	761.4	454.24	5923.3	28163	22240	1:3.75
T_6	Triazophos 40EC	600g *a.i.*/ha	635.61	328.45	4068	20364	16296	1:4.01
T_7	*Beauveria bassiana* (*B. b.*)	1×10^8 spores/ml	646.51	338.99	3468	21017	17549	1:5.06
T_8	*B.b* + Indoxacarb	Half dose of T_7+T_1	601.29	294.13	3578	18236	14658	1:4.1
T_9	*B.b* + Spinosad	Half dose of T_7+T_2	1046.9	739.74	6618	45864	39246	1:5.93
T_{10}	*B.b* + Rynaxpyr	Half dose of T_7+T_3	1080.4	773.23	10118	47940	37822	1:3.74
T_{11}	*B.b* +Flubendamide	Half dose of T_7+T_4	599.03	291.87	8063	18096	10033	1:1.24
T_{12}	*B.b* + Emamectin benzoate	Half dose of T_7+T_5	990.15	682.99	3995.7	42345	38350	1:9.6
T_{13}	*B.b* + Triazophos	Half dose of T_7+T_6	625.31	318.15	3068	19725	16657	1:5.43
T_{14}	Control	---	307.16	---	---	---	---	---
	SEm ±		4.53					
	CD at 5%		13.18					

B.bassiana – Rs 700/litre, Rynaxypyr – Rs 28,000/ litre, Flubendiamde – Rs 16,920/ litre, Emamectin benzoate –Rs 6,902/kg, Indoxacarb 14.5SC –3000/ litre, Spinosad 45SC –20,000/ litre ,Triazophos 40EC –Rs 600/ litre,

Labour cost –Rs 228 /per day (Two labour are required for spraying 1 ha pigeonpea in one day)

4.3. To study the population dynamics of pigeonpea pod borer complex

4.3.1. Green stink bug, *Nezara viridula* Linn (Hemiptera: Pentatomidae):

First appearance of the green stink bug was observed on 5th October *i.e.*, during 40th SW (01/10/2014 to 07/10/2014) on pigeonpea. The number of green stink bug (both nymph and adult) was worked out as weekly average per plant and the data are presented in Table no. 24 and depicted in fig. 6

From the fig. 6, it is seen that green stink bug population appeared from 40th SW (01/10/2014 to 07/10/2014) and was available upto 2nd SW (08/01/2015 to 14/01/2015). Green stink bug population attained its peak (2.00 bugs per plant) during 48th SW (26/11/2014 to 02/12/2014), when maximum and minimum temperature was 29.36 and 10.17°C respectively, whereas morning and evening relative humidity was 85.17 and 24.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.72 hrs, 2.07 km/hr, 9.15 mm, 7.24 mm and 2.74 mm, respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 25)

Minimum temperature, evening relative humidity, morning and evening vapour pressure showed significant negative correlation (r = -0.52, -0.60, -0.59 and -0.65, respectively) with green stink bug (nymph and adult) population.

The regression equations being:

$\hat{Y} = 1.60-0.04x$ ($R^2 = 0.27$)

$\hat{Y} = 1.88-0.02x$ ($R^2 = 0.37$)

$\hat{Y} = 1.80-0.07x$ ($R^2 = 0.35$) and

$\hat{Y} = 1.88-0.08x$ ($R^2 = 0.42$), respectively.

From the above equations, it may be expressed that with every unit increase in minimum temperature, evening relative humidity, morning and evening vapour pressure there was a decrease of 0.04, 0.02, 0.07 and 0.08 green stink bug (nymph and adult) per plant (Fig. 7, 8, 9 and 10), respectively.

Correlation studies further revealed that maximum temperature, rainfall, morning relative humidity, wind speed, evaporation and rainy days showed a negative correlation (r = -0.11, -0.33, -0.35, -0.29, -0.18, and -0.30, respectively) with green stink bug population, but statistically found to be non significant.

Sunshine showed positive correlation (r = 0.19) with green stink bug population, but statistically found to be non significant.

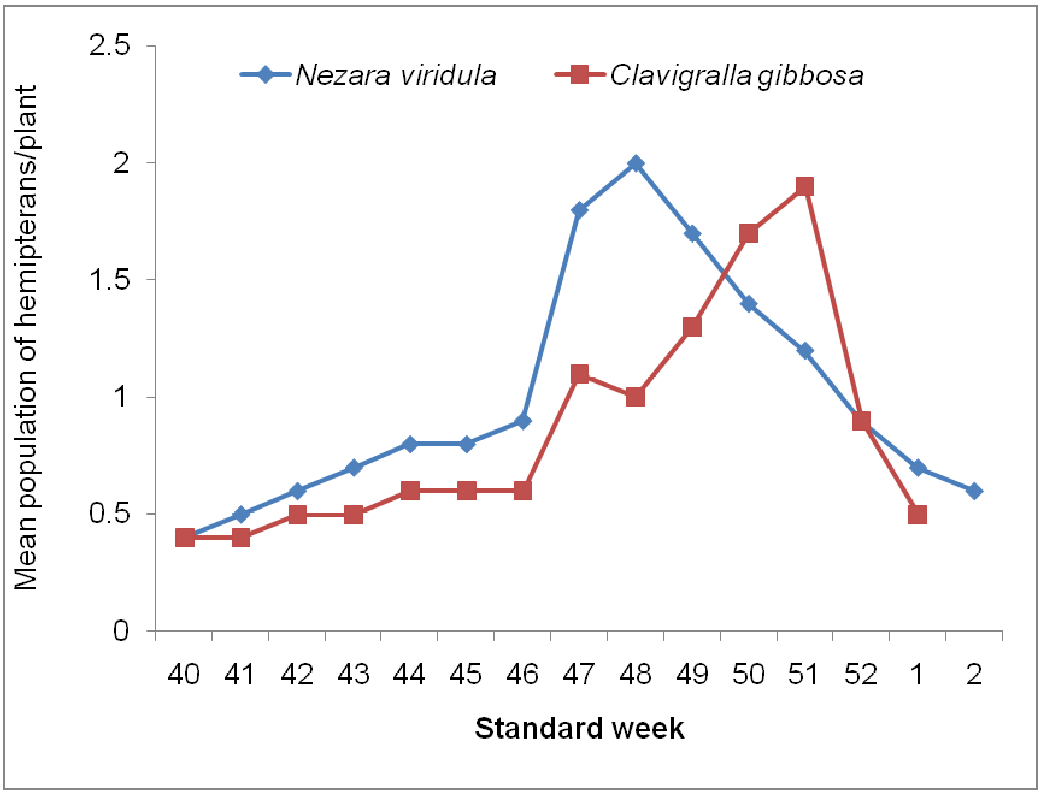


Fig. 6 Incidence of Hemipteran (nymph and adult) on pigeonpea

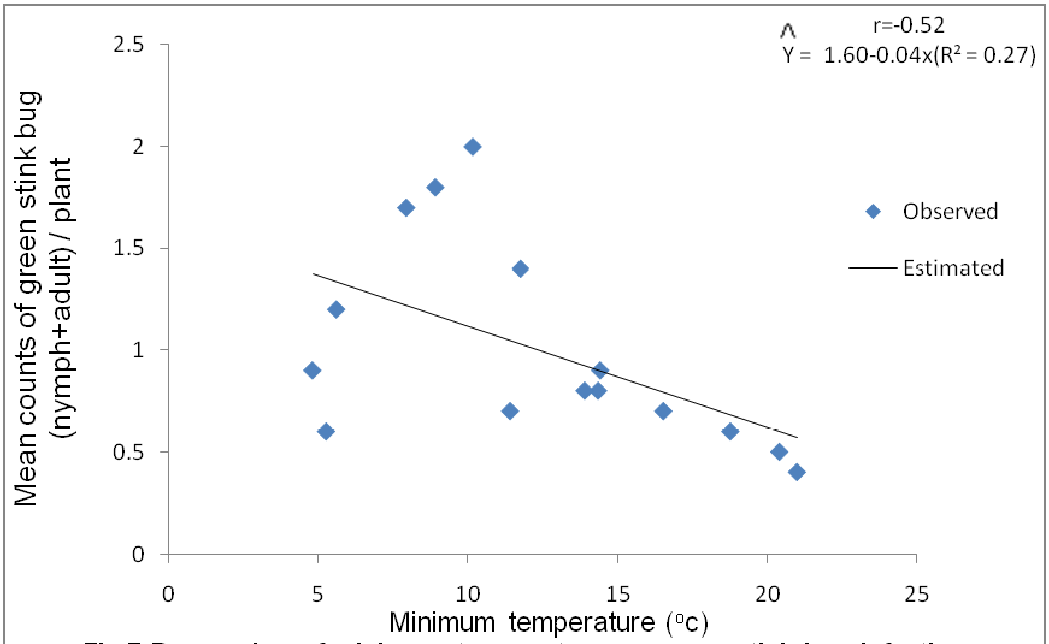


Fig.7 Regression of minimum temperature on green stink bug infesting pigeonpea

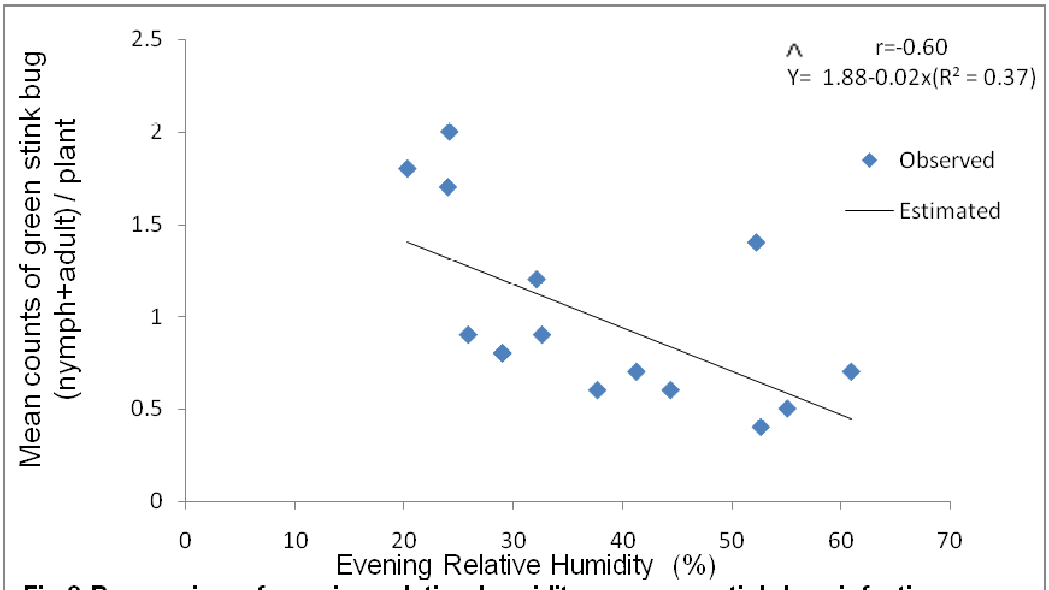


Fig.8 Regression of evening relative humidity on green stink bug infesting pigeonpea

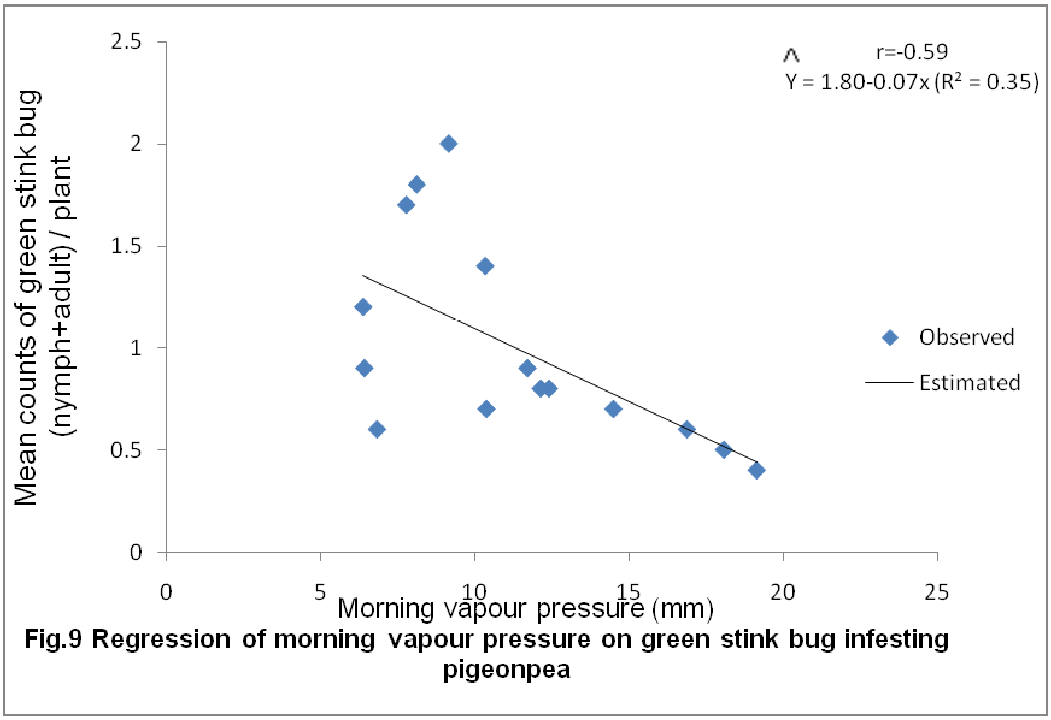


Fig.9 Regression of morning vapour pressure on green stink bug infesting pigeonpea

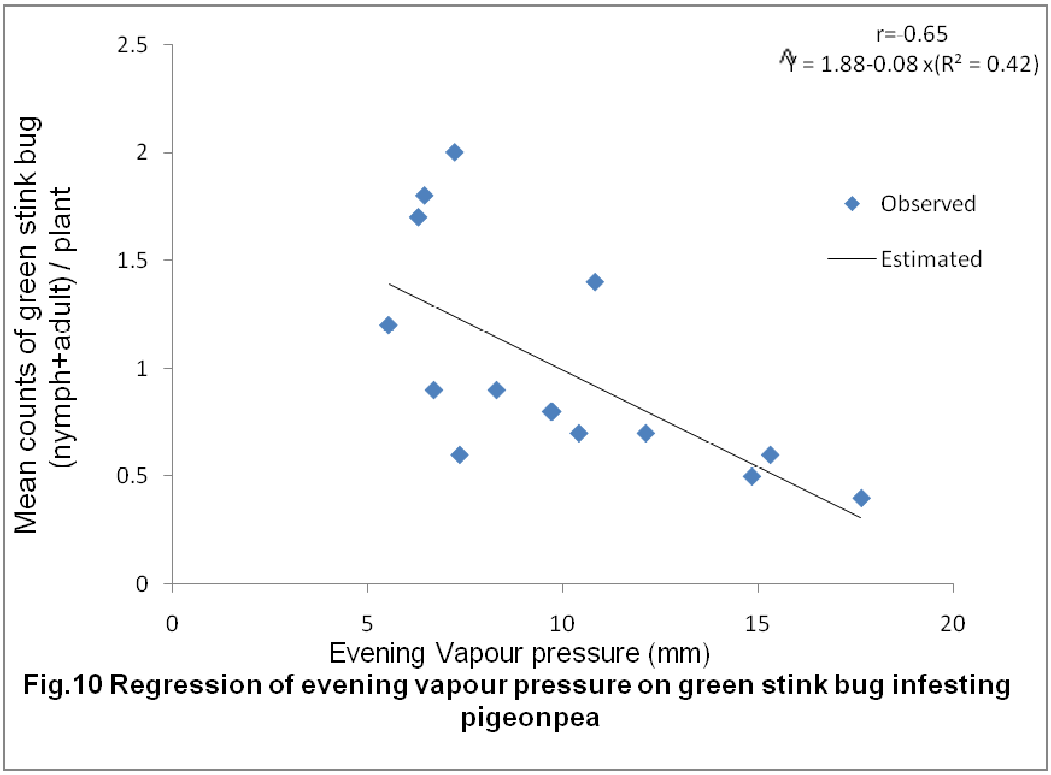


Fig.10 Regression of evening vapour pressure on green stink bug infesting pigeonpea

4.3.2. Pod bug, *Clavigralla gibbosa* Spinola (Hemiptera:Coreidae):

4.3.2. (i) Nymph and adult:

First appearance of the pod bug was observed on 5th October *i.e.*, during 40th SW (01/10/2014 to 07/10/2014) on pigeonpea. The number of pod bug (nymph and adult) was worked out as weekly average per plant and the data are presented in Table 24 and depicted fig. 6

From the fig. 6, it is seen that pod bug population appeared from 40th SW (01/10/2014 to 07/10/2014) and was available upto 1st SW (01/01/2015 to 07/01/2015). Pod bug population attained its peak (1.90 bugs/plant) during 51st SW (17/12/2014 to 23/12/2014), when maximum and minimum temperature was 22.20 and 5.61°C respectively, whereas morning and evening relative humidity was 86.14 and 32.14% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 7.58 hrs, 2.15 km/hr, 6.37 mm, 5.55 mm and 1.84 mm respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 25)

Maximum and minimum temperature and morning and evening vapour pressure showed significant negative correlation (r = -0.54, -0.72, -0.71 and -0.62, respectively) with pod bug nymph and adult population.

The regression equations being:

$\hat{Y} = 2.90-0.07x$ ($R^2 = 0.30$)

$\hat{Y} = 1.73-0.06x$ ($R^2 = 0.51$)

$\hat{Y} = 1.83-0.08x$ ($R^2 = 0.51$) and

$\hat{Y} = 1.68-0.08x$ ($R^2 = 0.39$), respectively.

From the above equations it may be expressed that with every unit increase in maximum and minimum temperature and morning and evening vapour pressure there was a decrease of 0.07, 0.06, 0.08 and 0.08 pod bug (nymph and adult) per plant (Fig. 11, 12, 13 and 14,

respectively).

Evaporation showed positive correlation (r =0.49) with pod bug nymph and adult population, but statistically found to be non significant.

Correlation studies further revealed that sunshine, rainfall, morning relative humidity, evening relative humidity, wind speed and rainy days showed negative correlation (r = -0.06, -0.33, -0.11, -0.29, -0.24 and -0.26, respectively) with pod bug population, but statistically found to be non significant.

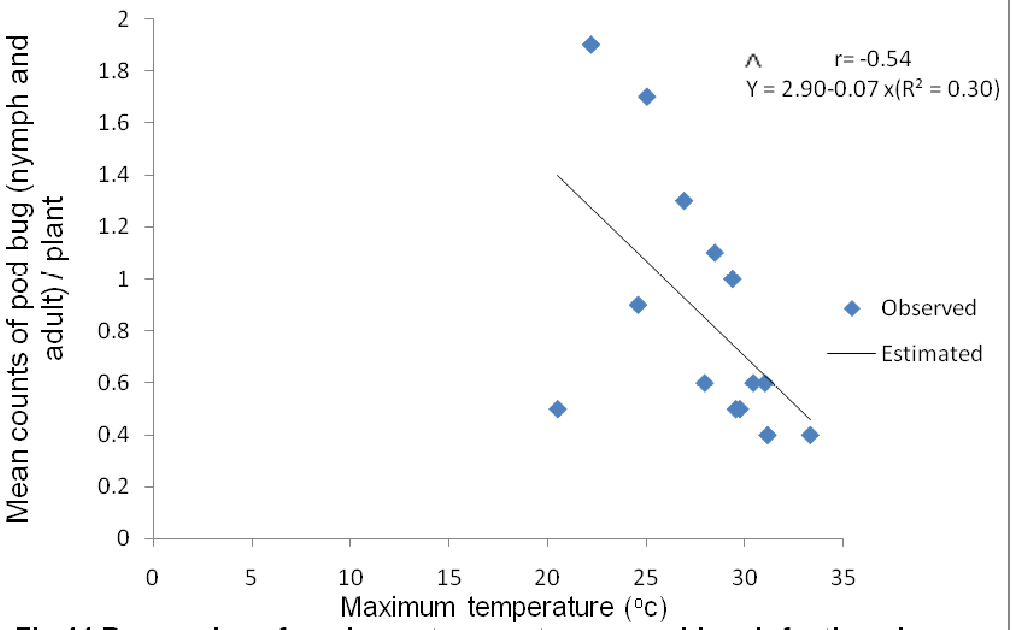


Fig.11 Regression of maximum temperature on pod bug infesting pigeonpea

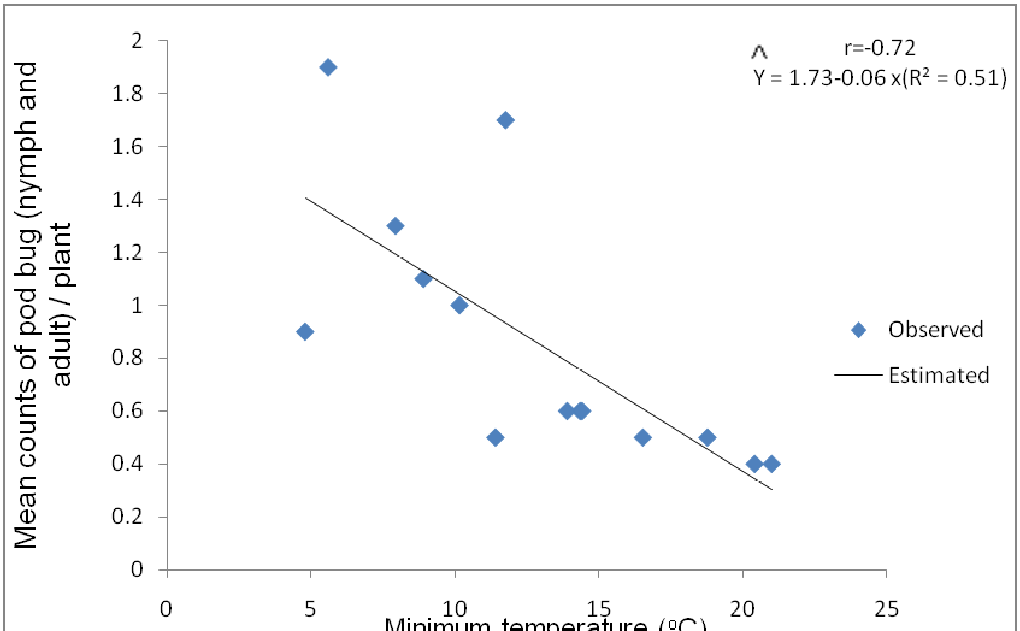


Fig.12 Regression of minimum temperature on pod bug infesting pigeonpea

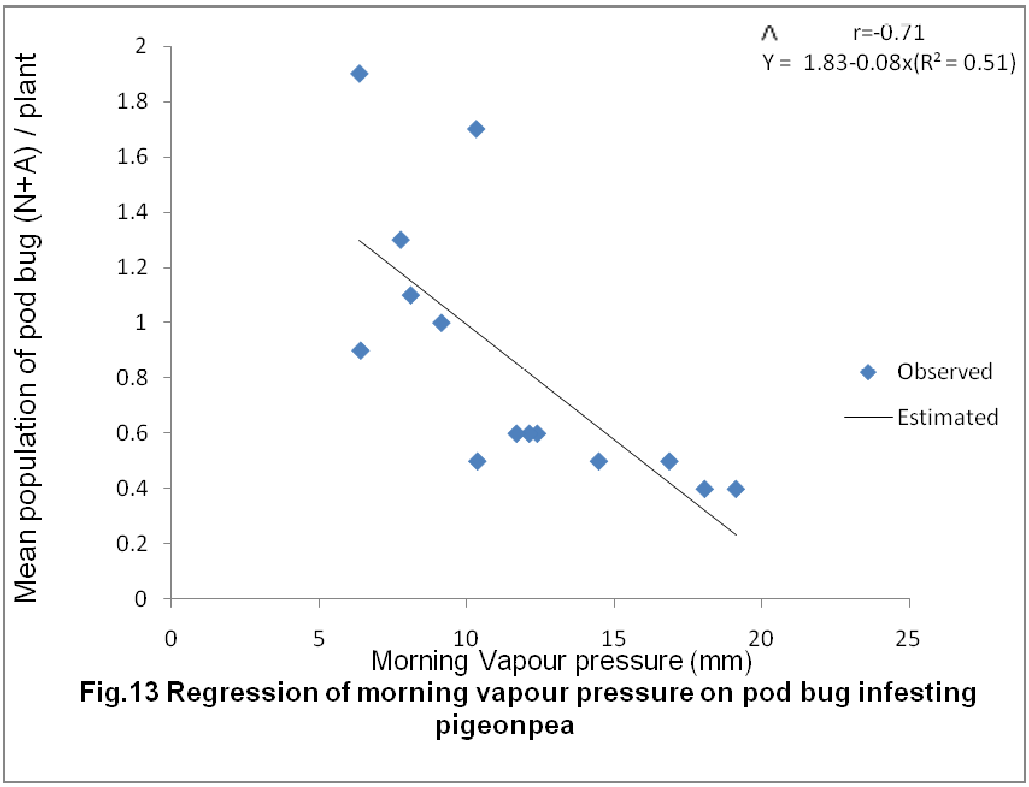


Fig.13 Regression of morning vapour pressure on pod bug infesting pigeonpea

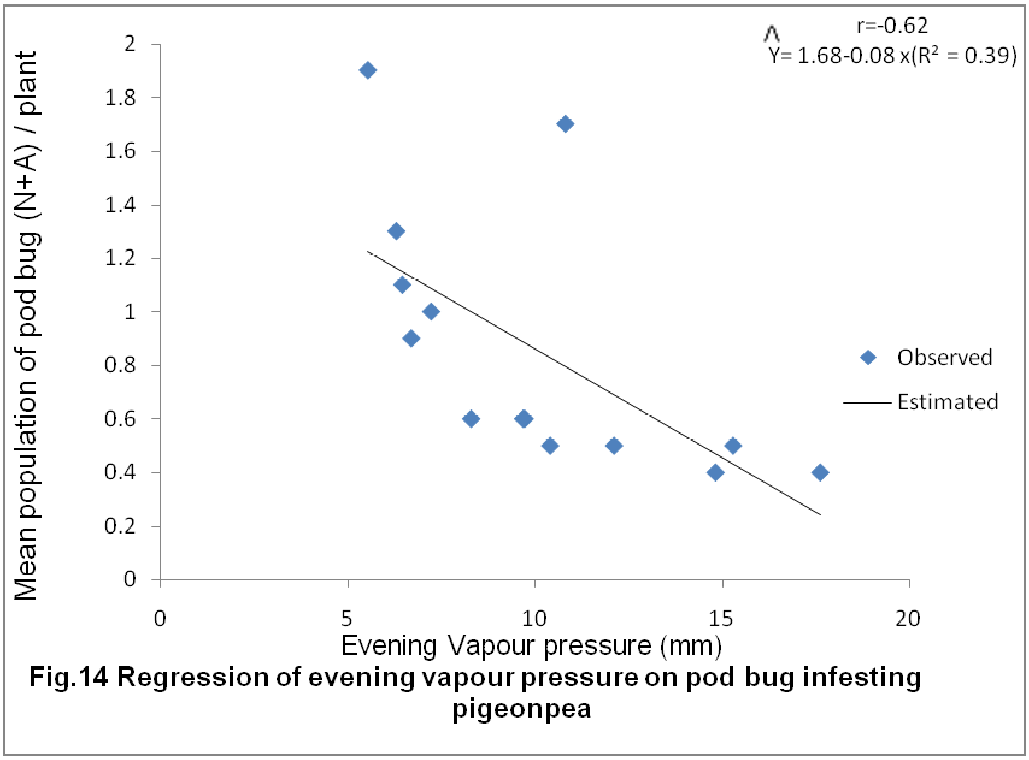


Fig.14 Regression of evening vapour pressure on pod bug infesting pigeonpea

Table no.24 Incidence of Hemipteran insects infesting pigeonpea at Jabalpur during 2014-15

SW	Mean population of Hemipterans (nymph and adult)/plant	
	Nezara viridula	***Clavigralla gibbosa***
40	0.4	0.4
41	0.5	0.4
42	0.6	0.5
43	0.7	0.5
44	0.8	0.6
45	0.8	0.6
46	0.9	0.6
47	1.8	1.1
48	2.0	1.0
49	1.7	1.3
50	1.4	1.7
51	1.2	1.9
52	0.9	0.9
1	0.7	0.5
2	0.6	

Table no.25 Correlation (r) and regression coefficient (byx) of abiotic factors on Hemipteran insects (nymph + adult) infesting Pigeonpea.

Weather factors	Green stink bug		Pod bug	
	r	byx	r	byx
Max. temperature ˚C	-0.11 NS	-	-0.54**	-0.07
Min. temperature ˚C	-0.52**	-0.04	-0.72*	-0.06
Sunshine (hrs)	0.19 NS	-	-0.06 NS	-
Rainfall (mm)	-0.33 NS	-	-0.33 NS	-
Morning RH (%)	-0.35 NS	-	-0.11 NS	-
Evening RH (%)	-0.60**	-0.02	-0.29 NS	-
Wind speed (km/ hr)	-0.29 NS	-	-0.24 NS	-
Morn. Vapour pressure (mm)	-0.59**	-0.07	-0.71*	-0.08
Even. Vapour pressure (mm)	-0.65*	-0.08	-0.62*	-0.08
Evaporation (mm)	-0.18 NS	-	0.49 NS	
Rainy days (nos.)	-0.30 NS	-	-0.26 NS	-

NS = Non significant * Significant at 5% ** Significant at 1%

4.3.3. Gram pod borer, *Helicoverpa armigera* Hub. (Lepidoptera: Noctuidae):

4.3.3. (i) Eggs:

First appearance of the pod borer eggs was observed on 10th November *i.e.*, during 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of pod borer eggs was worked out as weekly average per 10 cm twig and the data are presented in Table no. 26 and depicted in fig. 15

From the fig. 15, it is seen that pod borer egg population appeared from 45th SW (05/11/2014-1 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/11/2014). Egg population attained its peak (0.75 eggs/10cm twig) during 49th SW (3/12/2014 to 9/12/2014), when maximum and minimum temperature was 26.91 and 7.49°C respectively, whereas morning and evening relative humidity was 88.00 and 24.00%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.67 hrs, 2.45 km/hr, 7.77 mm, 6.31 mm and 2.75 mm, respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 27)

Sunshine and morning relative humidity showed positive correlation (r = 0.17 and 0.12, respectively) with pod borer egg population, but statistically found to be non significant.

Further, maximum and minimum temperature, rainfall, evening relative humidity, wind velocity, morning and evening vapour pressure, evaporation and rainy days showed negative correlation (r = -0.31, -0.38, -0.01, -0.20, -0.18, -0.48, -0.51, -0.22 and -0.01, respectively) with pod borer egg population, but statistically found to be non significant.

4.3.3. (ii) Larvae:

First appearance of the pod borer larvae was observed on 10th

November *i.e.*, during 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of pod borer larvae was worked out as weekly average per/plant and the data are presented in Table no. 26 and depicted fig. 15

From the fig. 15, it is seen that pod borer larval population, appeared from 45th SW (05/11/2014-1 to 11/11/2014) and was available upto 2nd SW (8/1/2015 to 14/1/2015). Larval population attained its peak (1.80 larvae/plant) during 48th SW (26/11/2014 to 2/12/2014), when maximum and minimum temperature was 29.36 and 10.17°C respectively, whereas morning and evening relative humidity was 85.17 and 24.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.72 hrs, 2.07 km/hr, 9.15 mm, 7.24 mm and 2.74 mm, respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 27)

Maximum temperature showed significant positive correlation (r = 0.66) with pod borer larval population.

The regression equation being:

$\hat{Y} = -1.96+0.10x$ ($R^2 = 0.44$)

From the above equation it may be expressed that with every unit increase in maximum temperature there was an increase of 0.10 larvae per plant (fig. 16).

Morning relative humidity showed significant negaitive correlation (r = -0.68) with pod borer larval population.

The regression equation being:

$\hat{Y} = 13.28-0.14x$ ($R^2 = 0.47$)

From the above equation it may be expressed that with every unit increase in morning relative humidity there was a decrease of 0.14 larvae per plant (fig. 17).

Correlation studies revealed that minimum temperature,

sunshine, morning vapour pressure and evaporation showed positive correlation (r = 0.16, 0.45, 0.05 and 0.50, respectively) with pod borer larval population, but statistically found to be non significant.

Correlation studies further revealed that rainfall, evening relative humidity, wind velocity, evening vapour pressure and rainy days showed negative correlation (r = -0.47, -0.65, -0.59, -0.32 and -0.40, respectively) with pod borer larval population, but statistically found to be non significant.

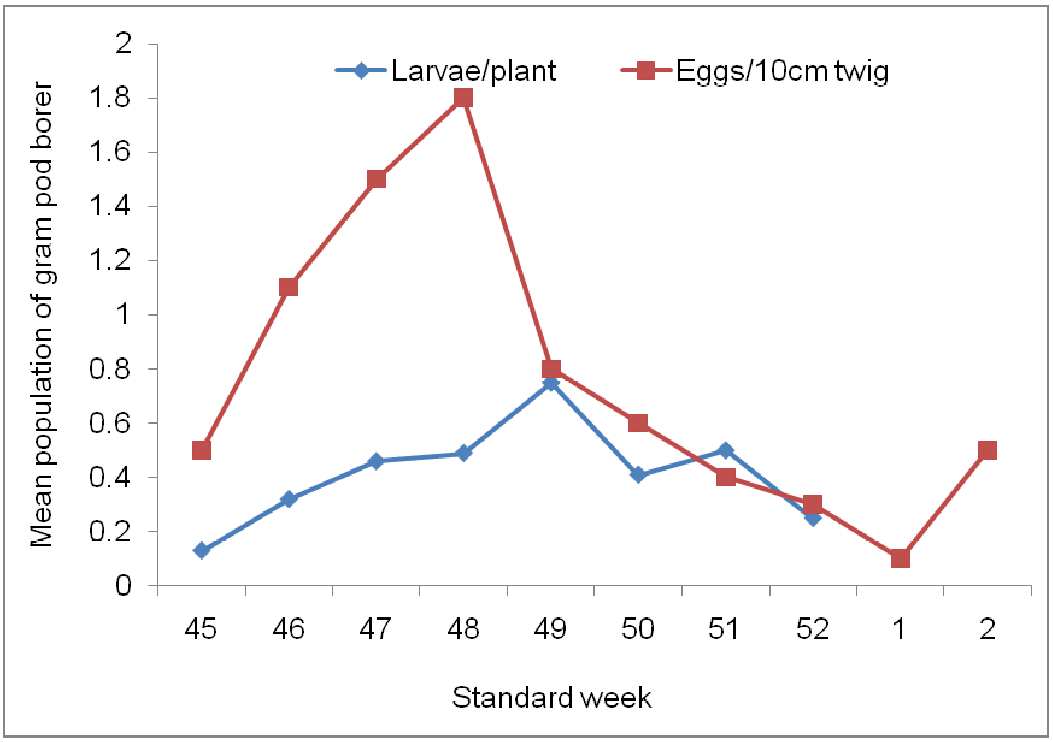


Fig. 15 Incidence of gram pod borer on pigeopea

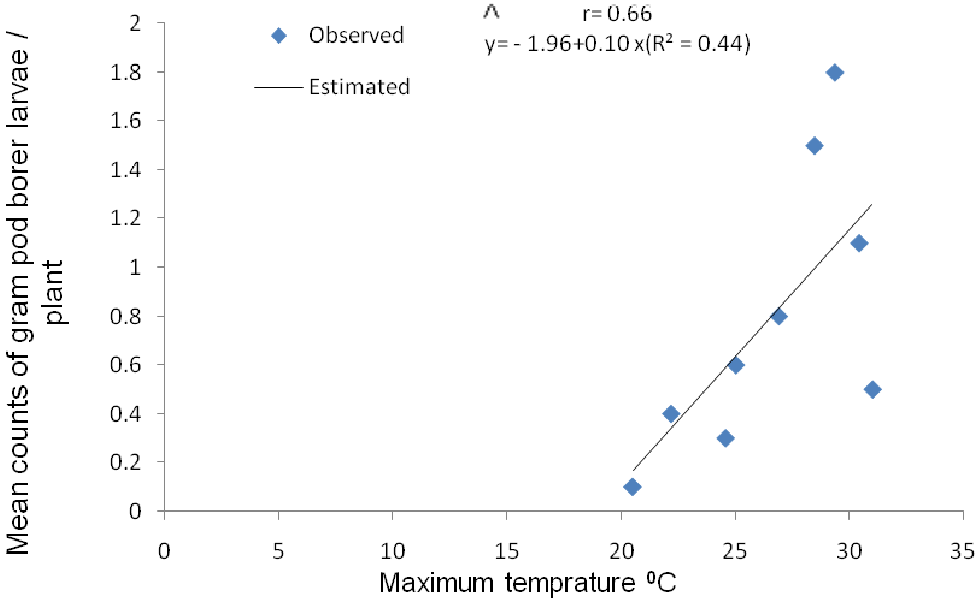


Fig.16 Regression of maximum temparature on gram pod borer larvae infesting pigeonpea

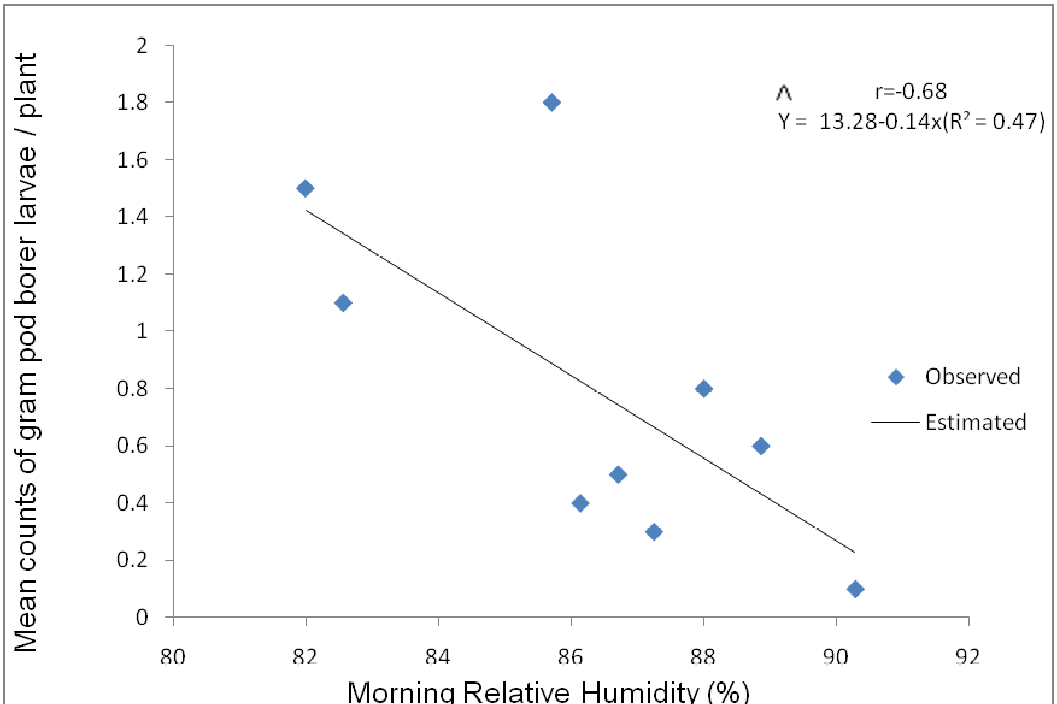


Fig.17 Regression of morning relative humidity on gram pod borer infesting pigeonpea

4.3.4. Red gram plume moth, *Exelastis atomosa* Walsingham (Lepidoptera: Pterophoridae):

4.3.4. (i) Larvae:

First appearance of the plume moth larvae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of plume moth larvae was worked out as weekly average /25pods and the data are presented in Table no. 26 and depicted fig. 18

From the fig.18, it is seen that plume moth larvae population appeared from 45th SW (05/11/2014 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/12/2014). Larval population attained its peak (0.95 larvae/25pods) during 48th SW (26/11/2014 to 2/12/2014), when maximum and minimum temperature was 29.36 and 10.17°C respectively, whereas morning and evening relative humidity was 85.17 and 24.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.72 hrs, 2.07 km/hr, 9.15 mm, 7.24 mm and 2.74, mm respectively. There was no rainfall received during this week.

Second peak was attained (0.99 larvae/25pods) during 51st (17/12/2014 to 23/12/2014), when maximum and minimum temperature was 22.20 and 5.61°C respectively, whereas morning and evening relative humidity was 86.14 and 32.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.52 hrs, 2.08 km/hr, 6.37 mm, 5.55 mm and 1.84 mm, respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 27)

Rainfall, and rainy days exhibited positive correlation (r = 0.13 and 0.13, respectively) with red gram plume moth larval population, but statistically found to be non significant.

Maximum and minimum temperature, morning and evening relative humidity, wind speed, sunshine, morning and evening vapour pressure and evaporation showed a negative correlation (r = -0.43,-0.40, -0.17, -0.04, -0.52, -0.03, -0.52, -0.48 and -0.54, respectively) with red gram plume moth larval population, but statistically found to be non significant.

4.3.4. (ii) Pupae:

First appearance of the plume moth pupae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of red gram plume moth pupae was worked out as weekly average /25pods and the data are presented in Table no. 26 and depicted fig.18

From the fig. 18, it is seen that red gram plume moth pupal population appeared from 45th SW (05/11/2014 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/12/2014). Pupal population attained its peak (0.83 pupae/25 pods) during 48th SW (26/11/2014 to 2/12/2014), when maximum and minimum temperature was 29.36 and 10.17^{o}C respectively, whereas morning and evening relative humidity was 85.17 and 24.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.72 hrs, 2.07 km/hr, 9.15 mm, 7.24 mm and 2.74 mm, respectively. There was no rainfall received during this week.

Second peak was attained (0.75 pupae/25pods) during 51st (17/12/2014 to 23/12/2014), when maximum and minimum temperature was 22.20 and 5.61^{o}C respectively, whereas morning and evening relative humidity was 86.14 and 32.14%, respectively.

Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.52 hrs, 2.08 km/hr, 6.37 mm, 5.55 mm and 1.84 mm respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 27)

Morning relative humidity, sunshine, rainfall and rainy days exhibited positive correlation (r = 0.05, 0.02, 0.16, and 0.16, respectively) with red gram plume moth population, but statistically found to be non significant.

Maximum and minimum temperature, evening relative humidity, wind speed, morning and evening vapour pressure and evaporation showed a negative correlation (r = -0.44, -0.43, -0.003, -0.41, -0.53, -0.45 and -0.50, respectively) with red gram plume moth population, but statistically found to be non significant.

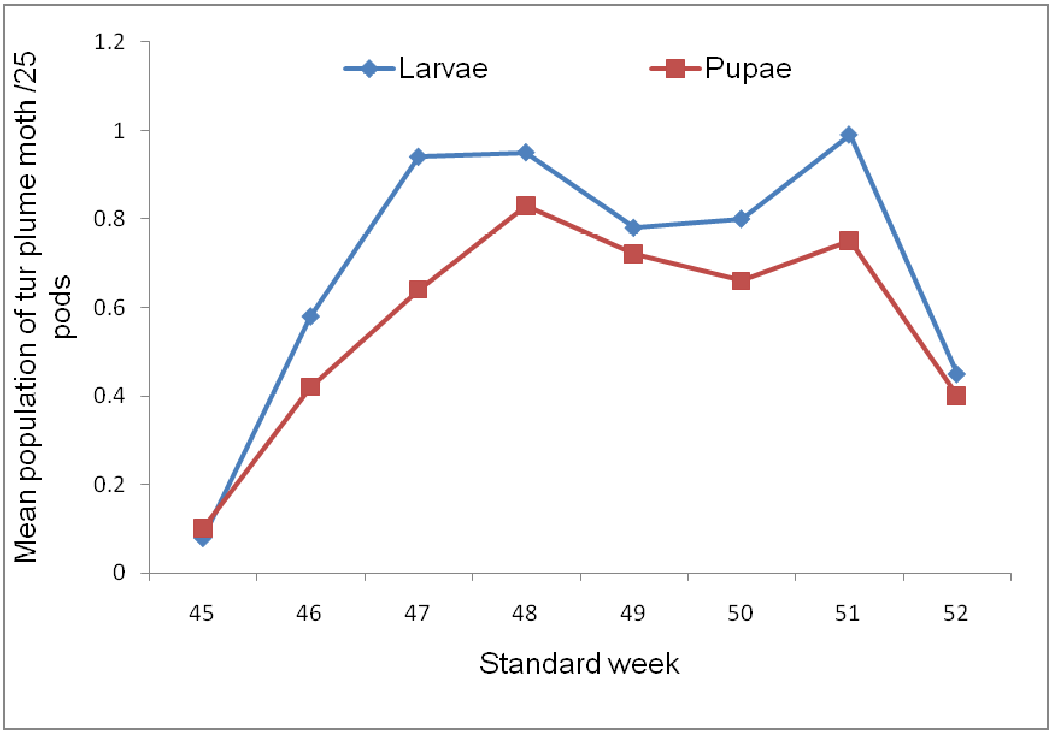


Fig.18 Incidence of tur plume moth on pigeonpea

Table no.26 Incidence of plume moth and pod borer infesting pigeonpea at Jabalpur during 2014-15

SW	Mean population of lepidopteron pests			
	Gram pod borer		Plume moth (per 25 pods)	
	Eggs/10 cm twig	Larvae/plant	Larvae	Pupae
45	0.13	0.5	0.08	0.1
46	0.32	1.1	0.58	0.42
47	0.46	1.5	0.94	0.64
48	0.49	1.8	0.95	0.83
49	0.75	0.8	0.78	0.72
50	0.41	0.6	0.8	0.66
51	0.5	0.4	0.99	0.75
52	0.25	0.3	0.45	0.4
1		0.1		
2		0.5		

Table no.27 Correlation (r) and regression coefficient (byx) of abiotic factors on lepidopterean insect pests infesting pigeonpea.

Weather factors	Gram pod borer			Plume moth	
	Eggs	Larvae		Larvae	Pupae
	r	r	byx	r	r
Max. temperature ˚C	-0.31 NS	0.66**	0.10	-0.43 NS	-0.44 NS
Min. temperature ˚C	-0.38 NS	0.16 NS	-	-0.40 NS	-0.43 NS
Morning RH (%)	0.17 NS	0.45 NS	-	-0.17 NS	0.05 NS
Evening RH (%)	-0.01 NS	-0.47 NS	-	-0.04 NS	-0.003 NS
Wind speed (km/ hr)	0.12 NS	-0.68**	-0.14	-0.52 NS	-0.41 NS
Sunshine (hrs)	-0.20 NS	-0.65 NS	-	-0.03 NS	0.02 NS
Rainfall (mm)	-0.18 NS	-0.59 NS	-	0.13 NS	0.16 NS
Rainy days (nos.)	-0.48 NS	0.05 NS	-	0.13 NS	0.16 NS
Morn. Vapour pressure (mm)	-0.51 NS	-0.32 NS	-	-0.52 NS	-0.53 NS
Even. Vapour pressure (mm)	-0.22 NS	0.50 NS	-	-0.48 NS	-0.45 NS
Evaporation (mm)	-0.01 NS	-0.40 NS	-	-0.54 NS	-0.50 NS

*Significant at 5% **Significant at 1%* NS = Non significant

4.3.5. Pod fly, *Melanagromyza obtusa* Malloch (Diptera: Agromyzidae):

4.3.5. (i) Eggs:

First appearance of the pod fly eggs was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of pod fly eggs was worked out as weekly

average per 25 pods and the data are presented in Table no. 28 and depicted fig. 19

From the fig. 19, it is seen that pod fly egg population appeared from 45th SW (05/11/2014 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/12/2014). Egg population attained its peak (4.66 eggs/25 pods) during 49th SW (3/12/2014 to 9/12/2014), when maximum and minimum temperature was 26.91 and 7.49^{o}C respectively, whereas morning and evening relative humidity was 88.00 and 24.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.67 hrs, 2.45 km/hr, 7.77 mm, 6.31 mm and 2.75 mm respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 29)

Morning and evening relative humidity, rainfall and rainy days exhibited positive correlation (r = 0.26, 0.18, 0.28 and 0.28, respectively) with pod fly egg population, but statistically found to be non significant.

Maximum and minimum temperature, wind velocity, sunshine, morning and evening vapour pressure and evaporation showed a negative correlation (r = -0.64, -0.61, -0.34, -0.04, -0.68, -0.42 and -0.69, respectively) with pod fly egg population, but statistically found to be non significant.

4.3.5. (ii) Maggots:

First appearance of the pod fly maggot was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of pod fly maggot was worked out as weekly average per 25 pods and the data are presented in Table no. 28 and depicted fig.19

From the fig. 19, it is seen that pod fly maggot population appeared from 45th SW (05/11/2014 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/12/2014). Maggot population attained its peak (6.75 maggot/25 pods) during 49th SW (3/12/2014 to

9/12/2014), when maximum and minimum temperature was 26.91 and 7.49°C respectively, whereas morning and evening relative humidity was 88.00 and 24.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.67 hrs, 2.45 km/hr, 7.77 mm, 6.31 mm and 2.75 mm respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 29)

Morning relative humidity, sunshine, rainfall, and rainy days exhibited positive correlation (r = 0.33, 0.07, 0.21 and 0.21, respectively) with pod fly maggot population, but statistically found to be non significant.

Maximum and minimum temperature, evening relative humidity, wind velocity, morning and evening vapour pressure and evaporation showed a negative correlation (r = -0.21, -0.27, -0.01, -0.05, -0.34, -0.24 and -0.21, respectively) with pod fly maggot population, but statistically found to be non significant.

4.3.5. (iii) Pupae:

First appearance of the pod fly pupae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea. The number of pod fly pupae was worked out as weekly average per 25 pods and the data are presented in Table no. 28 and depicted fig. 19

From the fig. 19, it is seen that pod fly pupal population appeared from 45th SW (05/11/2014 to 11/11/2014) and was available upto 52nd SW (24/12/2014 to 31/12/2014). Pupal population attained its peak (3.33 pupae/25 pods) during 49th SW (3/12/2014 to 9/12/2014), when maximum and minimum temperature was 26.91 and 7.49°C respectively, whereas morning and evening relative humidity was 88.00 and 24.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.67 hrs, 2.45 km/hr, 7.77 mm, 6.31 mm and 2.75 mm respectively. There was no rainfall received during this week.

Second peak was attained (2.37 pupae/25pods) during 51st (17/12/2014 to 23/12/2014), when maximum and minimum temperature was 22.20 and 5.61°C respectively, whereas morning and evening relative humidity was 86.14 and 32.14%, respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.52 hrs, 2.08 km/hr, 6.37 mm, 5.55 mm and 1.84 mm respectively. There was no rainfall received during this week.

Correlation studies: (Table no. 29)

Morning relative humidity, sunshine, rainfall and rainy days exhibited positive correlation (r = 0.40, 0.30, 0.05 and 0.05, respectively) with pod fly pupal population, but statistically found to be non significant.

Maximum and minimum temperature, evening relative humidity, wind speed, morning and evening vapour pressure and evaporation showed a negative correlation (r = -0.48, -0.62, -0.02, -0.32, -0.66, -0.49 and -0.40, respectively) with pod fly pupal population, but statistically found to be non significant.

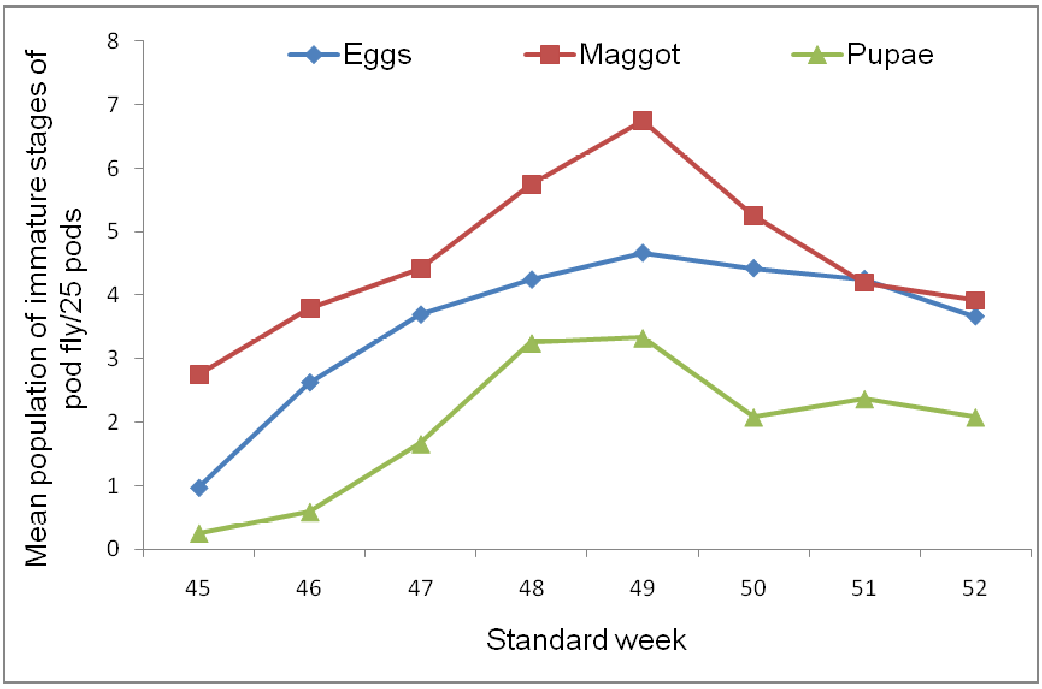


Fig.19 Incidence of pod fly on pigeonpea

Table no.28 Incidence of pod fly infesting pigeonpea at Jabalpur during 2014-15

SW	Mean population of immature stages of pod fly /25pods		
	Eggs	Maggots	Pupae
45	0.96	2.75	0.25
46	2.62	3.79	0.59
47	3.69	4.42	1.66
48	4.24	5.74	3.25
49	4.66	6.75	3.33
50	4.42	5.25	2.08
51	4.25	4.2	2.37
52	3.66	3.92	2.08

Table no.29 Correlation (r) and regression coefficient (byx) of abiotic factors on pod fly infesting Pigeonpea.

Weather factors	Pod fly		
	Eggs	Maggot	Pupae
	r	r	R
Max. temperature ˚C	-0.64 NS	-0.21 NS	-0.48 NS
Min. temperature ˚C	-0.61 NS	-0.27 NS	-0.62 NS
Morning RH (%)	0.26 NS	0.33 NS	0.40 NS
Evening RH (%)	0.18 NS	-0.01 NS	-0.02 NS
Wind speed (km/ hr)	-0.34 NS	-0.05 NS	-0.32 NS
Sunshine (hrs)	-0.04 NS	0.07 NS	0.30 NS
Rainfall (mm)	0.28 NS	0.21 NS	0.05 NS
Rainy days (nos.)	0.28 NS	0.21 NS	0.05 NS
Morn. Vapour pressure (mm)	-0.68 NS	-0.34 NS	-0.66 NS
Even. Vapour pressure (mm)	-0.42 NS	-0.24 NS	-0.49 NS
Evaporation (mm)	-0.69 NS	-0.21 NS	-0.40 NS

NS=Non significant

DISCUSSION

The findings of the experiment on "Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex" is described in this chapter under respective objective.

5.1 To study the influence of nutrient and temperature on mass production of *Beauveria bassiana* on local substrates:

In the present study, several naturally available substrates were tested for mass production of *Beauveria bassiana*, impact of nutrient and temperature on mass production of *Beauveria bassiana.* The success of microbial control of insect pests depends not only on the isolation, characterization and pathogenicity, but also on the successful mass production of the microbial agents in the laboratory. Large-scale availability of the pathogen is a primary requirement in the bio-control programme. For a successful integrated pest management programme, the agents like the entomopathogenic fungi should be amenable to easy and cheap mass multiplication.

5.1.1. Spore count of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest spore count (4.04×10^8 spore/ml) was observed on broken grains wheat which was better than all the substrates followed by broken rice grains (4.03×10^8 spore/ml). The lowest spore count was recorded in rice husk (1.65×10^8spore/ml).

In accordance with the present findings Sahayaraj and Namasivayam (2008) reported that wheat was found to be the best solid substrate for spore production.

In contrast to the present findings, Rao et al (2005), Sachin et al (2011), Kaur and Joshi (2014) and Smriti et al., (2015) reported that rice was found to be the best solid substrate for spore production.

In contrast to the present findings, Rajanikanth et al., (2010 and 2011) and Rishi et al., (2013) reported that sorghum was found to be the best solid substrate for spore production.

In contrast to the present findings, Parmod and Saroj (2004) reported that among the solid media, wheat bran and maize bran resulted in the greatest fungal sporulation.

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest spore count (3.21×10^8 spore/ml) was observed on with nutrient media and lowest spore count was recorded in without nutrient (2.89×10^8spore/ml).

In accordance with present findings Mazumder et al., (1995) and Parmod and Saroj (2004) also reported that supplemented with dextrose to be the most suitable medium for mass production of *Beauveria bassiana.*

In contrast to the present findings, Gangwar (2013) reported that addition of 1 per cent sucrose increased the growth and sporulation of *B. bassiana* in sorghum and barnyard millet. However, population of *B. bassiana* was significantly reduced in sorghum and barnyard millet grains when amended with 2 per cent sucrose.

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that highest conidial counts (3.39×10^8spores/ml) were recorded at 30^0C followed by 25^0C (3.13×10^8 spores/ml) and 35^0C (3.06×10^8 spores/ml) and least

spore count (2.64 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

In accordance with present findings James et al., (1998), Shimazu (2004), Patel and Kanaujia (2004) and David et al., (2008) also reported that temperature 30^0C most suitable temperature for mass production of *Beauveria bassiana*.

In contrast to the present findings, Sivasankaran et al., (1998), Elanchezhyan et al., (2007), David et al., (2008) and Rishi et al., (2013) reported 25^0C most suitable temperature for mass production of *Beauveria bassiana.*

In accordance with present findings, Patel and Kanaujia (2004), Shimazu (2004) and Elanchezhyan et al., (2007) reported that reduction in growth and sporulation of the fungus when temperature was increasing.

5.1.2. Spore viability of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest viable spore count (3.70 × 10^8 spores/ml) was recorded on broken rice grains was better than all the substrates. The lowest spore count was recorded in rice husk (1.54×10^8spore/ml).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest viable spore count (2.95 × 10^8 spore/ml) was observed on with nutrient media and lowest spore count was recorded in without nutrient (2.62×10^8spore/ml).

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that

highest spore viability (3.06 × 10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore counts recorded at 25^0C (2.91 × 10^8 spores/ml) and at 35^0C (2.69 × 10^8 spores/ml) while least viable spore count (1.77 × 10^8spores/ml) was recorded at room temperature (25 ± 5°C), and they differed significantly from each other.

In contrast to the present findings, Patel and Kanaujia (2004) reported that *Beauveria bassiana* and *Metarhizium anisopliae* cultured at 15, 20, 25, 30 and 35^0C using PDA medium showed maximum biomass, radial growth, conidial-count and viability at 25^0C in case of *B.bassiana* followed by 30^0C whereas the most favourable temperature for growth and germination of *M. anisopliae* was 30^0C followed by 25^0C. There was a significant reduction in growth and sporulation of the fungus when temperature was either raised to 35^0C or reduced to 20 and 15^0C.

5.1.3 Biomass production of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest biomass production (0.114gm) was recorded on broken wheat grains media, which was followed by whole wheat grains (0.101gm) and least biomass production was recorded in water soaked rice (0.024gm) and water soaked wheat (0.024gm).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest biomass production (0.071gm) was recorded on substrates containing nutrient and was lowest (0.066gm) on substrates without nutrient.

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that biomass production (0.079gm) was recorded at 30^0C. This was followed by biomass production recorded at 25^0C (0.070gm) and at 35^0C (0.066gm) and least biomass production (0.057gm) was recorded at room temperature (25 ± 5 °C).

In contrast to the present findings, Ficiu et al., (2013) reported that wheat which was selected for the production of fungal biomass.

In contrast to the present findings, Sivasankaran et al., (1998) evaluated among the 5 different temperature conditions tested biomass production greater at 25^0C.

In contrast to the present findings, Abraham et al., (2003) reported that the various concentrations (0.5, 1, 2, 3, 4, 5 and 6%) of sugarcane molasses, the 3-6% molasses was found to be highly suitable for the biomass production of *B. bassiana*.

In contrast to the present findings, Patel and Kanaujia (2004) reported that *Beauveria bassiana* and *Metarhizium anisopliae* cultured at 15, 20, 25, 30 and 35^0C using PDA medium showed maximum biomass at 25^0C in case of *B.bassiana* followed by 30^0C.

4.1.4 Dry matter production of *Beauveria bassiana* : The data presented in table no. 14

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest dry matter production (0.632gm) was recorded on water soaked rice which was followed by water soaked wheat (0.543gm) and least dry matter production was recorded in broken maize (0.245gm).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated of presence or absence of nutrient in the substrate was found to be non significant.

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that dry matter production (0.420gm) was recorded at 30^0C. This was followed by dry matter production recorded at 25^0C (0.413gm) and at 35^0C (0.403gm) and least dry matter production (0.402gm) was recorded at room temperature (25 ± 5 °C).

In contrast to the present findings, Abraham et al., (2003) reported rice was recorded the maximum ($0.67x10^{10}$ g/100 ml) mycelial dry weight of the fungus.

5.2. To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex

5.2.1 Invitro studies on compatibility of *Beauveria bassiana* with some new generation insecticides:

The effect of insecticides on the mycelia growth of *B. bassiana* was conducted in invitro. All the treatment showed significant inhibition over control. Among insecticides tested rynaxypyr 20SG @ 20g ai/ha (half recommended dose) was found more compatible with least growth inhibition percentage (30.35%) and significant differ over other five insecticides spinosad 36.5g *a.i.*/ha, emamectin benzoate @ 5.5g *a.i.*/ha, triazophos @ 30g *a.i.*/ha, indoxacarb @ 30g *a.i.*/ha and flubendiamide @ 30g *a.i.*/ha showed growth inhibition percentage of 33.59%, 41.21%, 44.32%, 47.09% and 48.60% respectively.

In contrast to the present findings Ying Sheng and Ming Guang (2002) reported that negative effects of the pesticides on the germination of *B. bassiana* conidia increased with the increasing pesticide concentrations. Triazophos 20% EC compatable with *B. bassiana*.

In contrast to the present findings, Yue Zhang (2011) reported that inhibition of some isolates of *B. bassiana* by 1% emamectin benzoate was significantly reduced after diluted by 10 times.

In contrast to the present findings, Amutha et al., (2010) reported that except profenophos, indoxacarb and methyldemeton, the rest of the insecticides tested can be safely used along with the entomopathogenic fungi *B. bassiana*. Also reported that relatively less toxic to *B. bassiana*, while, spinosad (45% SC), econeem (1%), quinalphos (25 EC), acetamprid (20%), endosulfan (35 EC) and thiodicarb (75 WP) were slightly toxic. Imidacloprid (17.80% SL) and triazophos (40 EC) were moderately toxic and profenofos (50 EC), indoxacarb (14.5 % EC) and methyldemeton were highly toxic.

In contrast to the present findings, Muhammad et al., (2010) reported that tracer was found safe to conidial germination and growth of the fungi.

In contrast to the present findings, Nithin (2014) reported that emamectin benzoate 5 SG was found to be the most compatible with least inhibition percentage followed by flubendiamide 20SC and rynaxypyr 20SC.

Although the different insecticides tested in the present investigations inhibited the growth of *B. bassiana* in poisoned media invitro, the combined use of the fungus and insecticides cannot be completely ruled out. All the insecticides tested in this study have been combined at half recommended dose with entomopathogenic fungi for obtaining better control of pod borer in chickpea considering this it is worth exploring the effect of these insecticides at sublethal dose with fungus for an enhance result over pest control.

5.2.2 Invivo studies on efficacy of *B. bassiana* with some new generation insecticides against pod infesting insect pests:

All the chemicals proved their superiority over control in reducing the pest population, pod and grain damage by different treatments and grain yield obtained from them. It is clear that all the treatments effectively reduced the damage and registered higher grain yield than control.

Treatment *Beauveria bassiana* + rynaxpyr 20%EC (T_{10}) treated plots folloerd by *B. bassiana* + spinosad 45% SC (T_9) and *B. bassiana*

+ emamectin benzoate 5% SG (T_{12}) proved to be the most effective treatments not only in reducing the damage due to pod borer complex, but also recorded higher grain yields (1080.39, 1046.90 and 990.15 kg/ha, respectively). The least effective treatment was *B. bassiana* + flubendiamide 20%EC (T_{11}) (599.03 kg/ha).

In accordance with present findings Singh et al., (2008), Das et al., (2009), Landge (2009), Ajagol et al., (2014) and Kapasi et al., (2014) that reported rynaxpyr 20%EC was the most effective treatments in reducing damage due to pod borer complex and obtained higher yields, while Srinivasan and Durairaj (2007), Ambulker (2008), Babariya et al., (2010), Babu and Mallikarjun (2012), Gopali et al., (2012), Sreekanth and Seshamahalakshmi (2012), Vinayaka et al., (2013), Kapasi et al., (2014) and Sambath et al., (2015) reported that other treatments were effective in reducing damage due to pod borer complex and obtained higher yields.

Economics of treatments:

Maximum grain yield was registered over control in *Beauveria bassiana* + rynaxpyr 20%EC (T_{10}) treated plots (773.20 kg/ha), this was followed by *B. bassiana* + spinosad 45% SC (T_9) (739.70 kg/ha), *B. bassiana* + emamectin benzoate 5% SG (T_{12}) (683.00 kg/ha), rynaxpyr 20EC @ 40g *a.i.*/ha (T_3) (587.00 kg/ha), spinosad 45% SC @ 73g *a.i.*/ha (T_2) (518.70 kg/ha), emamectin benzoate 5% SG @ 11g *a.i.*/ha (T_5) (454.20 kg/ha), flubediamide 20%EC 50g *a.i.*/ha (T_4) (412.00 kg/ha), indoxacarb 14.5%SC @ 60g *a.i.*/ha (T_1) (360.04 kg/ha), *B. bassiana* @ $1x10^8$ *a.i.*/ha (T_7) (339.00 kg/ha), triazophos 45%EC @ 60ml *a.i.*/ha (T_6) (328.50 kg/ha), *B. bassiana* + triazophos 45%EC (T_{13}) (318.20 kg/ha), *B. bassiana* + indoxacarb 14.5%SC (T_8) (294.10 kg/ha) and lowest in *B. bassiana* + flubendiamide 20%EC (T_{11}) (291.90 kg/ha), respectively (Table 21).

Thus, the quantity of grains saved per hectare in applying different insecticide ranged from 291.87 kg/ha (*B. bassiana* + flubendiamide 20%EC) to 773.23 kg/ha (*B. bassiana* + rynaxpyr 20%EC) taking into

account the prevailing market price of pigeonpea at Rs. 6200/- per quintal, the cost of grain saved ranged from Rs. 18095.94 per ha. (*B. bassiana* + flubendiamide 20%EC) to Rs. 47940.26 per hectare (*B. bassiana* + rynaxpyr 20%EC). The cost benefit ratio worked out ranged from 1:0.82 (flubediamide 20%EC 50g *a.i.*/ha) to 1:9.59 (*B. bassiana* + emamectin benzoate 5% SG).

It showed that's spraying of *B. bassiana* + emamectin benzoate 5% SG on pigeonpea crop gave maximum cost benefit ratio (1:9.59) which was obviously due to its effectiveness as compared to other treatments. The second highest cost benefit ratio obtained from *B. bassiana* + spinosad 45% SC combination. The data from the lab studies was validating the result which was recorded in the field. The compatibility between the bio pesticide and chemical pesticide can be effectively manipulated from the control of pest population in IPM programs.

Besides pest population, there may be a number of factors like field location, soil type, variety of the crop, fertilizer used, irrigation available etc., which may determine the pigeonpea grain yield at a time. Further the losses in terms of rupees and the benefit accrued due to use of insecticides may depend on market price of yield, insecticides and labour cost, which are likely to vary from year to year and place to place. These in further are all responsible for variation in losses caused due to pest incidence and the benefit obtained by pest control.

5.3 To study the population dynamics of major insects on pigeonpea:

Observations of different major insect pests were recorded on pigeonpea are described below:

5.3.1. Green stink bug, *Nezara viridula* Linn (Hemiptera: Pentatomidae):

The green stink bug (nymph and adult), *N.viridula* was first recorded during the first week of October *i.e.,* on 5th October (40th SW). The activity of the pest continued from 5th October to second week of January. The peak population of the pest was observed during 40th SW and 52nd SW. During this period maximum and minimum temperature

was 33.30 and 21.01°C respectively, whereas morning and evening relative humidity was 85.57 and 52.71% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 9.42 hrs, 2.28 km/hr, 19.14 mm, 17.64 mm and 4.14 mm respectively. There was 0.71 mm rainfall received during this week.

Correlations between various abiotic factors and stink bug population exhibited significant influence of minimum temperature, evening RH, morning vapor pressure and evening vapor pressure pest population had significant negative impact on pest population.

In accordance with the present findings Pandey and Das (2014) reported that population of different Hemiptaran insects was observed from 36th standard week (first week of September 2012) to 5th standard week (last week of January to first week of February 2013). The abiotic factors also affected the population built up of the insect pests. Green stink bug population exhibited significant correlation with wind speed.

5.3.2. Pod bug, *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae):

The pod bug (nymph and adult), *C.gibbosa* was first recorded during the first week of October *i.e.,* on 5th October (40th SW). The activity of the pest continued from 40th SW to 1st SW. During this period maximum and minimum temperature was 33.30 and 21.01°C respectively, whereas morning and evening relative humidity was 85.57 and 52.71% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 9.42 hrs, 2.28 km/hr, 19.14 mm, 17.64 mm and 4.14 mm respectively. There was 0.71 mm rainfall received during this week.

Correlations between various abiotic factors and pod bug nymph and adult population exhibited that maximum and minimum temperature, morning vapor pressure and evening vapor pressure pest population had significant negative impact on pest population.

In the present findings maximum and minimum temperature showed negative effect on pest population but were non significant.

In contrast to the present findings, Misra and Dash (2001) studied the seasonal activity of *C. gibbosa* on pigeonpea. The results revealed that all the stages (eggs, nymphs and adults) appeared simultaneously during the 46th standard week.

In contrast to the present findigs, Kaushik *et al.,* (2008) reported maximum and minimum temperature to exhibit positive impact on the pest population.

In contrast to the present findigs, Rana et al., (2008) reported that *H. armigera, E. atomosa, C. gibbosa* and *M. obtusa* were noticed from the flowering to the podding stage of pigeonpea crop *i.e.* from December to February.

In accordance with the present findings, Akhilesh and Paras (2005) reported that all the meteorological parameters showed non-significant effects (whether positive or negative) on pests of pigeon pea. Pod bug population showed a negative relationship with rainfall and a positive relationship with wind velocity and sunshine hours.

5.2.3. Tur plume moth, *Exelastis atomosa* Walsingham (Lepidoptera: Pterophoridae):

The larva of plume moth, *E.atomosa* was first recorded during the 45th SW. The activity of the pest continued from 45th SW to 52th. The peak population of the pest was observed during 45th SW. During this period maximum and minimum temperature ranged from 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlations between various abiotic factors and tur plume moth larval population exhibited no significant impact on the pest population**.**

In the present findings Akhilesh Kumar and Paras Nath (2005) reported that in case of plume moth (*Exelastis atomosa*), the maximum minimum and average temperatures, minimum relative humidity, water evaporation and

sunshine hours had positive effects on the population build up of the pest, while the rainfall, wind velocity, and maximum and average relative humidities showed negative effects.

Maximum temperature exhibited negative impact (though non significant) on pest population, which contradicts with the findings of Reddy *et al.,* (2001) and Kaushik *et al.,* (2008). They reported positive impact on the pest population. Further, minimum temperature showed negative impact on the pest population, which confirms the findings of Reddy *et al.,* (2001), Deshmukh *et al.,* (2005), and Kaushik *et al.,* (2008).

Morning relative humidity, exhibited negative impact on the pest population and are in accordance with those of Deshmukh *et al.,* (2005) , but contradicts the findings Reddy *et al.,* (2001) and Kaushik *et al.,* (2008). They reported positive correlation of morning relative humidity on pest population.

Evening relative humidity had negative effect on pest population, which is in conformity with the findings of Kaushik *et al.,* (2008).

Wind speed had negative influence on pest population. The present findings confirm the findings of Reddy *et al.,* (2001) and Kaushik *et al.,* (2008).

Evening vapour pressure exhibited negative impact on pest population, which confirms the findings of Reddy *et al.,* (2001) and Landge (2009).

5.2.4. Gram pod borer, *Helicoverpa armigera* Hub. (Lepidoptera: Noctuidae):

Eggs:

Gram pod borer eggs were first recorded in the second week of November 45th SW. The activity of the pest continued from 45th SW to 52th SW. During this period maximum and minimum temperature was 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation between various abiotic factors and pod borer egg

population were found to be non significant.

The present findings revealed controversy with the findings of Deshmukh *et al.* (2005) and Landge (2009). In which they reported that none of the weather parametere showed any effect on the population build up of pod borer eggs.

In the present findings Ambulker, (2008) observed that first appearance of *Helicoverpa armigera* eggs and larvae during 41st and 42nd standard week respectively.

Larva:

Pod borer larvae were first recorded in the first week of November *i.e.* 5th November (45th SW). The activity of the pest continued from first week of November to second week of January. During this period maximum and minimum temperature was 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was mm rainfall received during this week.

Correlations between various abiotic factors and pod borer larvae population exhibited significant positive impact of maximum temperature and morning relative humidity showed negative impact on pest population.

Present findings contradict the findings of Ram *et al.,* (2003). They reported that, minimum temperature had significant negative while maximum temperature and sunshine had positive influence on larval population. Further, Landge (2009) reported that maximum and minimum temperature, sunshine, evening vapour pressure and evaporation showed significant positive influence on pod borer larval population.

In the present findings Ambulker, (2008) observed that first appearance of *Helicoverpa armigera* eggs and larvae during 41st and 42nd standard week respectively.

In the present findings Dwivedi et al., (2014) reported that the maximum population of Gram pod borer was recorded on 44th Standard Week on maximum temperature of 33.0^{0}C, minimum 18.20^{0}C and R.H. 71.70%.

5.2.5. Pod fly, *Melanagromyza obtusa* Malloch (Diptera: Agromyzidae):

Eggs:

Pod fly eggs were first recorded in the second week of November *i.e.* 10th November (45th SW). The activity of the pest continued from second week of November to last week of December. During this period maximum and minimum temperature ranged from 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation between various abiotic factors and pod fly egg population were found to be non significant.

Present findings contradicts the findings, of Landge (2009) reported that maximum and minimum temperature, sunshine and evaporation exhibited significant positive correlation, whereas morning and evening relative humidity and evening vapour pressure exhibited significant negative influence on pod fly egg population.

In present findings, Akhilesh Kumar and Paras Nath (2005) they reported that in case of podfly (*Melanagromyza obtusa*), rainfall, wind velocity, minimum and average temperatures and relative humidity had negative effects, while maximum temperature, relative humidity, water evaporation and sunshine hours showed non-significant positive effects on the population build up.

In present findings, Rathore (2011) observed first appearance of gram pod borer, *H. armigera*; pod bug, *C. gibbosa* during 47th standard week and pod fly, *M. obtusa* during 52nd standard week.

Maggots:

Pod fly maggots were first recorded in the second week of November *i.e.* 10th November (45th SW). The activity of the pest continued from second week of November to last week of December. During this period when maximum and minimum temperature 31.01 and 13.91°C respectively, where as morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation between various abiotic factors and pod fly maggot population were found to be non significant.

In present findigs Yadav et al., (2011) reported that pod fly *M. obtusa* (Malloch) maggots in pigeonpea pods were first observed in the first week of October (90-100 days old crop) and peaked up to 47th week i.e. first week of November when crop was 100 to 125 days old and thereafter population declined to zero level with maturity in the first week of December, thus the pest remained active for nearly two months. The maggot population started building up when the maximum temperature dropped below 32 ºC and attained the peak when it further declined. The present findings suggest that maximum temperature below 30ºC and minimum temperature between 8.1-17.0ºC and average relative humidity around 60-70% is conducive for population build up of the pest. Correlation between maggot population and rainfall for current, one, two and three weeks before was found significant and negative, indicating adverse effect of rainfall.

Present findings contradict the findings of Das and Katyar (1998) they reported that maximum maggot population were observed during 5th SW in PP.

Pupae:

Pod fly pupae were first recorded in the second week of November *i.e.* 10th November (45th SW). The activity of the pest continued from second week of November to last week of December.

During this period maximum and minimum temperature ranged from 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively.Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation between various abiotic factors and pod fly pupal population were found to be non significant.

The present findings contradict the findings of Mahalle (2008), reported that morning relative humidity was negatively associated with the pupal population. Further Landge (2009) reported that maximum and minimum temperature and evaporation exhibited significant positive influence while, morning and evening relative humidity exhibited significant negative influence on pod fly pupal population.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1. Summary

The present investigation entitled, “Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex”. Was carried out in the experimental field of Department of Entomology, Live Stock Farm, Adhartal, JNKVV, Jabalpur (M.P.) during *Kharif* 2014-15. The laboratory studies were conducted in the Entomology Laboratory, College of Agriculture, JNKVV,Jabalpur.

The experiment was conducted with the following objectives :

1. Influence of temperature and nutrient on mass production of *Beauveria bassiana* on local substrates
2. To study the bioefficacy and compatibility of *B. bassiana* with new generation insecticides against pigeonpea pod borer complex

2.1 Invitro studies on compatibility of *B. bassiana* with new generation insecticides

2.2 Invivo studies on efficacy of *B. bassiana* with some new generation insecticides against pod infesting insect pests

3. To study the population dynamics of pigeonpea pod borer complex

6.1.1 To study the influence of nutrient and temperature on mass production of *B. bassiana* on local substrates :

6.1.1.a. Spore count of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest spore count (4.04×10^8 spore/ml) was

observed on broken grains wheat which was better than all the substrates followed by broken rice grains (4.03 × 10^8 spore/ml). The lowest spore count was recorded in rice husk (1.65×10^8spore/ml).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest spore count (3.21 × 10^8 spore/ml) was observed on with nutrient media and lowest spore count was recorded in without nutrient (2.89×10^8spore/ml).

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that highest conidial counts (3.39 × 10^8spores/ml) were recorded at 30^0C followed by 25^0C (3.13 × 10^8 spores/ml) and 35^0C (3.06 × 10^8 spores/ml) and least spore count (2.64 × 10^8spores/ml) was recorded at room temperature (25 ± 5 °C).

6.1.1.b. Spore viability of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest viable spore count (3.70 × 10^8 spores/ml) was recorded on broken rice grains was better than all the substrates. The lowest spore count was recorded in rice husk (1.54×10^8spore/ml).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest viable spore count

(2.95 × 10^8 spore/ml) was observed on with nutrient media and lowest spore count was recorded in without nutrient (2.62×10^8spore/ml).

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that highest spore viability (3.06 × 10^8 spores/ml) was recorded at 30^0C. This was followed by viable spore counts recorded at 25^0C (2.91 × 10^8 spores/ml) and at 35^0C (2.69 × 10^8 spores/ml) while least viable spore count (1.77 × 10^8spores/ml) was recorded at room temperature (25 ± 5°C), and they differed significantly from each other.

5.1.3 Biomass production of *Beauveria bassiana*

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest biomass production (0.114gm) was recorded on broken wheat grains media, which was followed by whole wheat grains (0.101gm) and least biomass production was recorded in water soaked rice (0.024gm) and water soaked wheat (0.024gm).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated highest biomass production (0.071gm) was recorded on substrates containing nutrient and was lowest (0.066gm) on substrates without nutrient.

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that biomass production (0.079gm) was recorded at 30^0C. This was followed by biomass production recorded at 25^0C (0.070gm) and at 35^0C (0.066gm) and

least biomass production (0.057gm) was recorded at room temperature (25 ± 5 °C).

4.1.4 Dry matter production of *Beauveria bassiana* :

Factor A: Substrate :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates like whole grains of rice, sorghum, maize, wheat, broken grains of rice, sorghum, maize, wheat, wheat bran, rice bran, wheat husk, rice husk, wheat and rice soaked water. The results indicated that out of different substrates evaluated, highest dry matter production (0.632gm) was recorded on water soaked rice which was followed by water soaked wheat (0.543gm) and least dry matter production was recorded in broken maize (0.245gm).

Factor B: Nutrient :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates with presence or absence of nutrient in the substrate. The results indicated that substrates evaluated of presence or absence of nutrient in the substrate was found to be non significant.

Factor C: Temperature :

The fungus *Beauveria bassiana* was mass multiplied on locally available substrates at various temperatures. The results indicated that dry matter production (0.420gm) was recorded at 30^0C. This was followed by dry matter production recorded at 25^0C (0.413gm) and at 35^0C (0.403gm) and least dry matter production (0.402gm) was recorded at room temperature (25 ± 5 °C).

6.1.2 To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex

6.1.2.1 Invitro studies on compatibility of *Beauveria bassiana* with some new generation insecticides:

The effect of insecticides on the mycelial growth of *B.bassiana* was conducted *invitro* among the insecticides tested, rynaxpyr showed least growth inhibition found to be the most compatible insecticide among the other

insecticides tested. Out of other five insecticides, spinosad, emamectin benzoate, triazophos, indoxacarb found compatible with insecticide but least compatible with flubendiamide.

Although the different insecticides tested in the present investigations inhibited the growth of *B. bassiana* in poisoned media *invitro*, the combined use of the fungus and insecticides cannot be completely ruled out. All the insecticides tested in this study have been combined at half recommended dose with entomopathogenic fungi for obtaining better control of pod borer in chickpea considering this it is worth exploring the effect of these insecticides at sublethal dose with fungus for an enhance result over pest control.

6.1.2.2 *Invivo* study the efficacy of insecticides against pod infesting insect pests.

On the basis of the effectiveness of different treatments against pod borer complex and the grain yield obtained, it can be said that *Beauveria bassiana* + rynaxpyr 20%EC @ 1×10^4spores/ml + 20g a.i./ha (T_{10}) was found to be the most effective as it recorded lowest grain damage (0.21%) followed by *B.b* + spinosad 45% SC @ 1×10^4spores/ml + 36.5g a.i./ha (T_9) (0.36%) proved to be the most effective treatments, not only in reducing the damage due to pod borer complex but also recorded higher grain yields (1080.39 and 1046.90 kg / ha, respectively) and in case of pod fly triazophos 45%EC @ 60g *a.i.*/ha (T_6) was found to be most effective as it recorded lowest pod damage (0.50%) followed by *Beauveria bassiana* + rynaxpyr 20%EC @ 1×10^4spores/ml + 20g a.i./ha (T_{10}) (0.63%).

6.1.3 To study the population dynamics of major insect pests of pigeonpea :

6.1.3.1 Green stink bug :

The green stink bug (nymph and adult), *N.viridula* was first recorded during the first week of October *i.e.,* on 5th October (40th SW). The activity of the pest continued from 5th October to second week of January. The peak population of the pest was observed during 40th SW and 52nd SW. During this period maximum and

minimum temperature was 33.30 and 21.01°C respectively, whereas morning and evening relative humidity was 85.57 and 52.71% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 9.42 hrs, 2.28 km/hr, 19.14 mm, 17.64 mm and 4.14 mm respectively. There was 0.71 mm rainfall received during this week.

Correlations between various abiotic factors and stink bug population exhibited significant influence of minimum temperature, evening RH, morning vapor pressure and evening vapor pressure pest population had significant negative impact on pest population.

6.1.3.2. Pod bug :

Eggs:

First appearance of the pod bug eggs was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation studies revealed that none of the abiotic factors included in the study did not exhibit any significant influence on the pod bug eggs population.

Nymph and adult:

First appearance of the pod bug was observed on 5th October *i.e.*, during 40th SW (01/10/2014 to 07/10/2014) on pigeonpea, when maximum and minimum temperature was 33.30 and 21.01°C respectively, whereas morning and evening relative humidity was 85.57 and 52.71% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 9.42 hrs, 2.28 km/hr, 19.14 mm, 17.64 mm and 4.14 mm respectively. There was 0.71 mm rainfall received during this week.

Correlation studies revealed that maximum and minimum temperature and morning and evening vapour pressure showed negative correlation on nymph and adult population.

6.1.3.3 Gram pod borer :

Eggs:

First appearance of the pod borer eggs was observed on 10th November *i.e.*, during 45th SW (05/11/2014 to 11/11/2014) on pigeonpea when maximum and minimum temperature was 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no mm rainfall received during this week.

Correlation studies revealed that none of the abiotic factors included in the study did not exhibit any significant influence on the pod borer population.

Larvae:

First appearance of the pod borer larvae was observed on 10th November *i.e.*, during 45th SW (05/11/2014 to 11/11/2014) on pigeonpea, when maximum and minimum temperature was 31.01 and 13.91^{o}C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation studies revealed that maximum temperature showed positive and morning relative humidity showed negaitive correlation on pod borer larvae population.

6.1.3.4 Tur plume moth :

Larvae:

First appearance of the plume moth larvae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on

Pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation studies revealed that none of the abiotic factors included in the study did not exhibit any significant influence on the plume moth population

Pupae :

First appearance of the plume moth pupae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on Pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Correlation studies revealed that none of the abiotic factors included in the study did not exhibit any significant influence on the plume moth population

6.1.3.5. Pod fly :

Eggs :

First appearance of the pod fly eggs was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on Pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Maggot :

First appearance of the pod fly maggot was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on Pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no rainfall received during this week.

Pupae :

First appearance of the pod fly pupae was observed on 10th November *i.e.* during the 45th SW (05/11/2014 to 11/11/2014) on Pigeonpea, when maximum and minimum temperature ranged from 31.01 and 13.91°C respectively, whereas morning and evening relative humidity was 86.71 and 29.00% respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 8.17 hrs, 2.6 km/hr, 12.13 mm, 9.70 mm and 3.4 mm respectively. There was no mm rainfall received during this week.

Correlation studies revealed that none of the abiotic factors included in the study did not exhibit any significant influence on the pod fly population

6.2 Conclusion :

Broken wheat grains were found to be the best substrate for mass production of *B. bassiana* as it produced maximum spore production in minimum time followed by broken rice, but in case of viability of spore broken rice grains was recorded maximum viable spores, highest biomass production was recorded on broken wheat grains media and highest dry matter production was recorded on water soaked rice and substrate with nutrient for mass production of *B. bassiana* as it produced maximum spore, viable spore, biomass and dry matter production and best temperature was found at 30^0C.

All the chemical insecticides and biopesticides proved their superiority over control in reducing the pod and grain damage and increasing the grain yield.

On the basis of the effectiveness of different treatments against pod borer complex on grain damage and grain yield revealed that among chemicals rynaxypyr 20%SC and in case of pod fly triazophos 40%EC is effective treatments.

Insecticide *B.b* + emamectin benzoate maximum cost benefit ratio (1:9.60).

Invitro studies in compatibility of *B. bassiana* with chemicals show that rynaxypyr 20%SC was most compatible with least growth inhibition percentage.

The first group insects to appear on the crop were pod bug, gram pod borer, pod fly, green stink bug and red gram plume moth respectively. These appeared when the crop age was reproductive stage and remained available upto the maturity of the crop. These pests were the major key pests which caused colossal yield losses.

Green stink bug :

Green stink bug was first observed in the 40th SW. Minimum temperature, evening relative humidity, morning and evening vapour pressure exhibited negative effect on green stink bug (nymph + adult) population.

Pod bug :

Pod bug (nymph + adult) was first observed in the 40th SW. Maximum and minimum temperature and morning and evening vapour pressure showed negative effect on nymph and adult population.

Gram pod borer :

Gram pod borer larva was first observed in the 45th SW. Maximum temperature showed positive and morning relative humidity showed negative effect on pod borer larvae population.

Tur plume moth :

Plume moth larva and pupa was first observed in the 45th SW. All the abiotic factors (included in the study) did not exhibit any impact on plume moth larval population.

Pod fly :

Pod fly population was first observed in the 45th SW. All the abiotic factors (included in the study) did not exhibit any significant influence on pod fly maggot population.

6.3. Suggestions for further work :

Detail studies on economically cheap and easily available nutrient sources like, cereals, bran, husks, stalks and other agricultural wastes and by products alone and their combinations should be tested for mass production of entomopathogenic fungi.

In view of the changing climatic conditions, the studies on insect pest population should be carried out on pigeonpea. It is necessary to identify the status of various insect pests of pigeonpea and has become very essential to concentrate or focus on their status and reasons for their unavailability on in low quantum in the pigeonpea agro ecosystem.

Further, the present work sufficiently gives an indication that the biopesticides and chemicals have been found to be very promising. This work should be further continued so as to study the efficacy of biopesticides and insecticides against the major insect pests and their impact on potent parasite/s and predator/s so that they can be incorporated in the Integrated Pest Management modules.

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*= Unpublished

Appendix - I

Weekly meteorological data of Experimental field of Department of Entomology, Live Stock Farm, Adhartal, J.N.K.V.V., Jabalur (M.P.) 2014-15

SW	Date		Temperature (^{O}C)		Sunshine (hrs)	Rainfall (mm)	Relative humidity (%)		Wind speed (km/hr)	Vapour pressure (mm)		Evaporation (mm)	Rainy days
	From	To	Max.	Min.			Morn.	Even.		Morn.	Even.		
40	01/10/2014	07/10/2014	33.3	21.01	9.42	0.71	85.57	52.71	2.28	19.14	17.64	4.14	1
41	08/10/2014	14/10/2014	31.14	20.42	7.15	5.22	87.71	55.14	4.74	18.08	14.84	3.17	2
42	15/10/2014	21/10/2014	29.74	18.78	7.94	0	90.57	44.42	2.32	16.88	15.31	2.85	0
43	22/10/2014	28/10/2014	29.53	16.54	6.28	0	89	41.29	1.68	14.49	12.13	2.58	0
44	29/10/2014	04/11/2014	27.96	14.36	8.64	0	86.86	29	1.55	12.4	9.74	2.85	0
45	05/11/2014	11/11/2014	31.01	13.91	8.17	0	86.71	29	2.6	12.13	9.7	3.4	0
46	12/11/2014	18/11/2014	30.42	14.43	5.98	0	82.57	25.86	2.45	11.7	8.31	2.92	0
47	19/11/2014	25/11/2014	28.47	8.92	8.6	0	82	20.29	1.82	8.11	6.47	2.37	0
48	26/11/2014	02/12/2014	29.36	10.17	8.78	0	85.71	24.14	2.07	9.15	7.24	2.74	0
49	03/12/2014	09/12/2014	26.91	7.95	8.67	0	88	24	2.45	7.77	6.31	2.75	0
50	10/12/2014	16/12/2014	25.03	11.77	4.41	0.68	88.86	52.29	2.6	10.33	10.83	1.7	1
51	17/12/2014	23/12/2014	22.2	5.61	7.58	0	86.14	32.14	2.15	6.37	5.55	1.84	0
52	24/12/2014	31/12/2014	24.58	4.81	8.52	0	87.25	32.63	2.08	6.41	6.71	1.98	0
1	01/01/2015	07/01/2015	20.51	11.42	3.7	5.38	90.28	61	3.58	10.37	10.42	1.12	4
2	08/01/2015	15/01/2015	22.14	5.27	8.47	0	87	37.71	2.1	6.82	7.37	1.45	0

Appendix - II

1. To study the influence of nutrient and temperature on mass production of *Beauveria bassiana* on local substrates :

1.1 Spore count at different days after inoculation

ANOVA 1: 10 DAI

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.609		
Factor A	0.06	0.18	13	11.099	0.854	9.52
Error (a)			26	2.332	0.09	
Factor B	0.02	0.06	1	0.595	0.595	6.565
Int A X B	0.09	NS	13	0.835	0.064	0.708
Error (b)			28	2.537	0.091	
Factor C	0.02	0.06	3	3.611	1.204	36.377
Int A X C	0.07	NS	39	0.924	0.024	0.716
Int B X C	0.03	NS	3	0.119	0.04	1.195
Int A X B X C	0.11	NS	39	0.543	0.014	0.421
Error (c)			168	5.559	0.033	
Total			335	28.761		

ANOVA 2: 20 DAI

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.901		
Factor A	0.06	0.18	13	9.918	0.763	8.758
Error (a)			26	2.265	0.087	
Factor B	0.03	0.07	1	0.86	0.86	8.227
Int A X B	0.09	NS	13	0.969	0.075	0.713
Error (b)			28	2.926	0.105	
Factor C	0.02	0.06	3	2.038	0.679	17.843
Int A X C	0.08	NS	39	1.911	0.049	1.287
Int B X C	0.03	NS	3	0.005	0.002	0.045
Int A X B X C	0.11	NS	39	0.682	0.017	0.459
Error (c)			168	6.395	0.038	
Total			335	28.868		

ANOVA 3: 30 DAI

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.239		
Factor A	0.05	0.15	13	13.504	1.039	16.374
Error (a)			26	1.649	0.063	
Factor B	0.02	0.05	1	0.6	0.6	15.122
Int A X B	0.06	NS	13	0.52	0.04	1.008
Error (b)			28	1.112	0.04	

Factor C	0.02	0.06	3	0.874	0.291	8.309
Int A X C	0.08	0.21	39	2.416	0.062	1.767
Int B X C	0.03	NS	3	0.022	0.007	0.212
Int A X B X C	0.11	NS	39	0.902	0.023	0.66
Error (c)			168	5.889	0.035	
Total			335	27.729		

ANOVA 4: Mean

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	5.313		
Factor A	0.03	0.08	13	11.028	0.848	51.709
Error (a)			26	0.427	0.016	
Factor B	0.005	0.014	1	0.668	0.668	170.053
Int A X B	0.02	0.05	13	0.65	0.05	12.736
Error (b)			28	0.11	0.004	
Factor C	0.008	0.021	3	1.984	0.661	132.943
Int A X C	0.03	0.08	39	1.261	0.032	6.5
Int B X C	0.01	NS	3	0.014	0.005	0.97
Int A X B X C	0.04	NS	39	0.494	0.013	2.548
Error (c)			168	0.836	0.005	
Total			335	22.784		

Rate of increase in growth %

ANOVA 5: 10 to 20 DAI

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.118		
Factor A	13	9,405.10	723.469	642.474
Error (a)	26	29.278	1.126	
SEm ±	0.22			
CD at 5%	0.63			

ANOVA 6: 20 to 30 DAI

Source	D.F.	SS	MSS	F. Cal.
Replication	2	3.473		
Factor A	13	5,357.67	412.128	632.09
Error(a)	26	16.952	0.652	
SEm ±	0.17			
CD at 5%	0.48			

1.2 Viable spore count at different days after inoculation

ANOVA 7: 10 DAI

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.419		
Factor A	0.05	0.15	13	9.208	0.708	10.532
Error (a)			26	1.748	0.067	
Factor B	0.01	0.04	1	1.431	1.431	43.766

Int A X B	0.05	NS	13	0.457	0.035	1.076
Error (b)			28	0.916	0.033	
Factor C	0.02	0.06	3	2.63	0.877	25.049
Int A X C	0.08	NS	39	1.095	0.028	0.802
Int B X C	0.03	0.08	3	0.341	0.114	3.252
Int A X B X C	0.11	NS	39	1.083	0.028	0.794
Error (c)			168	5.879	0.035	
Total			335	25.207		

ANOVA 8: 20 DAI

Source	**SEm ±**	**CD at 5%**	**D.F.**	**SS**	**MSS**	**F. Cal.**
Replication			2	0.668		
Factor A	0.05	0.14	13	8.494	0.653	11.358
Error (a)			26	1.496	0.058	
Factor B	0.02	0.06	1	1.599	1.599	26.092
Int A X B	0.07	NS	13	0.441	0.034	0.553
Error (b)			28	1.715	0.061	
Factor C	0.02	0.06	3	1.07	0.357	8.934
Int A X C	0.08	NS	39	1.456	0.037	0.936
Int B X C	0.03	NS	3	0.085	0.028	0.708
Int A X B X C	0.12	NS	39	0.762	0.02	0.49
Error (c)			168	6.704	0.04	
Total			335	24.489		

ANOVA 9: 30 DAI

Source	**SEm ±**	**CD at 5%**	**D.F.**	**SS**	**MSS**	**F. Cal.**
Replication			2	0.367		
Factor A	0.05	0.15	13	11.861	0.912	15.236
Error (a)			26	1.557	0.06	
Factor B	0.02	NS	1	0.075	0.075	1.557
Int A X B	0.06	NS	13	0.851	0.065	1.367
Error (b)			28	1.341	0.048	
Factor C	0.02	0.06	3	0.822	0.274	8.018
Int A X C	0.08	0.21	39	2.298	0.059	1.724
Int B X C	0.03	NS	3	0.042	0.014	0.406
Int A X B X C	0.11	NS	39	0.907	0.023	0.68
Error (c)			168	5.742	0.034	
Total			335	25.862		

ANOVA 10: Mean

Source	**SEm ±**	**CD at 5%**	**D.F.**	**SS**	**MSS**	**F. Cal.**
Replication			2	6.744		
Factor A	0.03	0.08	13	9.425	0.725	44.04
Error (a)			26	0.428	0.016	
Factor B	0.01	0.03	1	0.802	0.802	59
Int A X B	0.03	0.10	13	0.399	0.031	2.256
Error (b)			28	0.381	0.014	
Factor C	0.01	0.03	3	1.388	0.463	69.787

Int A X C	0.03	0.09	39	1.037	0.027	4.01
Int B X C	0.01	0.04	3	0.072	0.024	3.636
Int A X B X C	0.05	0.13	39	0.574	0.015	2.22
Error (c)			168	1.114	0.007	
Total			335	22.363		

1.3 Biomass production of *Beauveria bassiana*

ANOVA 11

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.001		
Factor A	0.002	0.007	13	0.246	0.019	130.538
Error (a)			26	0.004	0	
Factor B	0.001	0.003	1	0.002	0.002	16.246
Int A X B	0.003	0.010	13	0.005	0	2.645
Error (b)			28	0.004	0	
Factor C	0.001	0.003	3	0.021	0.007	56.724
Int A X C	0.005	NS	39	0.007	0	1.42
Int B X C	0.002	NS	3	0	0	0.9
Int A X B X C	0.006	NS	39	0.006	0	1.136
Error (c)			168	0.021	0	
Total			335	0.316		

1.4 Dry matter production of *Beauveria bassiana*

ANOVA 12

Source	SEm ±	CD at 5%	D.F.	SS	MSS	F. Cal.
Replication			2	0.003		
Factor A	0.003	0.009	13	5.777	0.444	1,931.62
Error (a)			26	0.006	0	
Factor B	0.001	NS	1	0.001	0.001	2.097
Int A X B	0.005	0.014	13	0.046	0.004	12.646
Error (b)			28	0.008	0	
Factor C	0.002	0.005	3	0.018	0.006	20.48
Int A X C	0.007	0.020	39	0.048	0.001	4.102
Int B X C	0.003	0.007	3	0.005	0.002	5.879
Int A X B X C	0.010	0.028	39	0.022	0.001	1.861
Error (c)			168	0.05	0	
Total			335	5.984		

2. To study the bioefficacy and compatibility of *B. bassiana* with new generation insecticides against pigeonpea pod borer complex

2.1 Invitro studies on compatibility of *B. bassiana* with some new insecticides

A. Growth of *B.bassiana* (mm)

ANOVA 13: 2 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	991.355	165.226	48.562
Error	28	95.266	3.402	
Total	34	1,086.62		
SEm ±	0.82			
C.D. at 5%	2.42			

ANOVA 14: 4 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	1,230.20	205.033	66.571
Error	28	86.237	3.08	
Total	34	1,316.44		
SEm ±	0.78			
C.D. at 5%	2.28			

ANOVA 15: 6 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	2,191.31	365.218	100.435
Error	28	101.818	3.636	
Total	34	2,293.13		
SEm ±	0.85			
C.D. at 5%	2.48			

ANOVA 16: 8 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	5,395.78	899.296	386.848
Error	28	65.091	2.325	
Total	34	5,460.87		
SEm ±	0.68			
C.D. at 5%	1.98			

ANOVA 17: 10 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	4,799.10	799.85	201.355
Error	28	111.225	3.972	
Total	34	4,910.33		
SEm ±	0.89			
C.D. at 5%	2.59			

ANOVA 18: Mean

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	2,571.24	428.539	969.226
Error	28	12.38	0.442	
Total	34	2,583.62		

SEm ±	0.29			
C.D. at 5%	0.86			

A. Growth inhibition (%)

ANOVA 19: 2 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	757.74	151.548	9.143
Error	24	397.79	16.575	
Total	29	1,155.53		
SEm ±	1.82			
C.D. at 5%	5.34			

ANOVA 20: 4 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	415.329	83.066	6.467
Error	24	308.249	12.844	
Total	29	723.578		
SEm ±	1.60			
C.D. at 5%	4.70			

ANOVA 21: 6 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	606.564	121.313	13.808
Error	24	210.854	8.786	
Total	29	817.419		
SEm ±	1.32			
C.D. at 5%	3.89			

ANOVA 22: 8 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	802.783	160.557	70.927
Error	24	54.329	2.264	
Total	29	857.112		
SEm ±	0.67			
C.D. at 5%	1.97			

ANOVA 23: 10 DAI

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	154.5	30.9	9.727
Error	24	76.244	3.177	
Total	29	230.744		
SEm ±	0.79			
C.D. at 5%	2.34			

ANOVA 24: Mean

Source	D.F.	SS	MSS	F. Cal.
Treatment	5	480.443	96.089	19.429
Error	24	118.695	4.946	

Total	29	599.138		
SEm ±	0.99			
C.D. at 5%	2.92			

B. Mean spore counts

ANOVA 28:

Source	D.F.	SS	MSS	F. Cal.
Treatment	6	0.92	0.153	2.267
Error	28	1.895	0.068	
Total	34	2.815		
SEm ±	0.11			
C.D. at 5%	NS			

C. Germination of viable spore over control (%)

ANOVA 29:

Source	D.F.	SS	MSS	F. Cal.
Replication	4	2,324.03		
Treatment	5	2,030.57	406.114	2.802
Error	20	2,899.13	144.957	
SEm ±	5.38			
C.D. at 5%	15.99			

2.2 Invivo studies on efficacy of *B. bassiana* with some new generation insecticides against pod infesting insect pests

2.2.1 Efficacy of *B. bassiana* and insecticides alone and their combination against pigeonpea pod infesting insect pest complex

Gram pod borer

ANOVA 30: Pre treatment

Source	D.F.	SS	MSS	F. Cal.
Replication	2.00	0.00		
Treatment	13.00	0.14	0.01	0.54
Error	26.00	0.50	0.02	
Total	41.00	0.63		
SEm ±	0.08			
C.D. at 5%	NS			

ANOVA 31: Three days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.045		
Treatment	13	0.181	0.014	9.267
Error	26	0.039	0.002	

Total	41	0.265		
SEm ±	0.02			
C.D. at 5%	0.07			

ANOVA 32: Seven days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.02		
Treatment	13	0.164	0.013	15.076
Error	26	0.022	0.001	
Total	41	0.205		
SEm ±	0.02			
C.D. at 5%	0.05			

ANOVA 33: Ten days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.108		
Treatment	13	0.193	0.015	3.621
Error	26	0.107	0.004	
Total	41	0.407		
SEm ±	0.04			
C.D. at 5%	0.11			

ANOVA 34: Overall mean days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.005		
Treatment	13	0.177	0.014	36.928
Error	26	0.01	0	
Total	41	0.192		
SEm ±	0.01			
C.D. at 5%	0.03			

Tur plume moth

ANOVA 35: Pre treatment

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.014		
Treatment	13	0.315	0.024	1.516
Error	26	0.415	0.016	
Total	41	0.743		
SEm ±	0.07			
C.D. at 5%	NS			

ANOVA 36: Three days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.032		
Treatment	13	0.294	0.023	16.851
Error	26	0.035	0.001	
Total	41	0.361		
SEm ±	0.02			

C.D. at 5%	0.06			

ANOVA 37: Seven days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.022		
Treatment	13	0.307	0.024	17.967
Error	26	0.034	0.001	
Total	41	0.364		
SEm ±	0.02			
C.D. at 5%	0.06			

ANOVA 38: Ten days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.082		
Treatment	13	0.381	0.029	10.18
Error	26	0.075	0.003	
Total	41	0.537		
SEm ±	0.03			
C.D. at 5%	0.09			

ANOVA 39: Overall mean days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.009		
Treatment	13	0.325	0.025	55.858
Error	26	0.012	0	
Total	41	0.345		
SEm ±	0.01			
C.D. at 5%	0.04			

Tur pod bug

ANOVA 40: Pre treatment

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.005		
Treatment	13	0.083	0.006	1.879
Error	26	0.088	0.003	
Total	41	0.176		
SEm ±	0.03			
C.D. at 5%	NS			

ANOVA 41: Three days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.058		
Treatment	13	2.688	0.207	19.485
Error	26	0.276	0.011	
Total	41	3.023		
SEm ±	0.06			
C.D. at 5%	0.17			

ANOVA 42: Seven days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.079		
Treatment	13	3.02	0.232	22.895
Error	26	0.264	0.01	
Total	41	3.363		
SEm ±	0.06			
C.D. at 5%	0.17			

ANOVA 43: Ten days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.588		
Treatment	13	3.013	0.232	15.197
Error	26	0.396	0.015	
Total	41	3.998		
SEm ±	0.07			
C.D. at 5%	0.21			

ANOVA 44: Overall mean days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.001		
Treatment	13	1.326	0.102	3.974
Error	26	0.667	0.026	
Total	41	1.994		
SEm ±	0.09			
C.D. at 5%	0.27			

Green stink bug

ANOVA 45: Pre treatment

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.031		
Treatment	13	0.299	0.023	1.969
Error	26	0.304	0.012	
Total	41	0.634		
SEm ±	0.06			
C.D. at 5%	NS			

ANOVA 46: Three days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.124		
Treatment	13	2.462	0.189	27.065
Error	26	0.182	0.007	
Total	41	2.767		
SEm ±	0.05			
C.D. at 5%	0.14			

ANOVA 47: Seven days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.115		
Treatment	13	2.916	0.224	29.247
Error	26	0.199	0.008	
Total	41	3.23		
SEm ±	0.05			
C.D. at 5%	0.15			

ANOVA 48: Ten days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.47		
Treatment	13	2.35	0.181	14.009
Error	26	0.336	0.013	
Total	41	3.155		
SEm ±	0.07			
C.D. at 5%	0.19			

ANOVA 49: Overall mean days after spray

Source	D.F.	SS	MSS	F. Cal.
Replication	2	0.01		
Treatment	13	2.717	0.209	353.84
Error	26	0.015	0.001	
Total	41	2.742		
SEm ±	0.01			
C.D. at 5%	0.04			

2.2.2 Efficacy of *B. bassiana* and insecticides alone and their combination against pigeonpea pod infesting insect pest complex Per cent damage by pod fly

ANOVA 50: Pod damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	1.53		
Treatments	13	429.37	33.028	171.72
Error	26	5.001	0.192	
SEm ±	0.25			
C.D. at 5%	0.74			

ANOVA 52: Grain damage :

Source	D.F.	SS	MSS	F. cal.
Replications	**2**	**0.685**		
Treatments	**13**	**275.437**	**21.187**	**153.302**
Error	**26**	**3.593**	**0.138**	
SEm ±	**0.21**			
C.D. at 5%	**0.62**			

Per cent damage by red gram plume moth :

ANOVA 53 : Pod damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	2.866		
Treatments	13	226.74	17.442	61.454
Error	26	7.379	0.284	
SEm ±	0.3			
C.D. at 5%	0.89			

ANOVA 54: Grain damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	0.921		
Treatments	13	138.505	10.654	137.777
Error	26	2.011	0.077	
SEm ±	0.16			
C.D. at 5%	0.47			

Per cent damage by gram pod borer :

ANOVA 55: Pod damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	2.757		
Treatments	13	251.084	19.314	113.965
Error	26	4.406	0.169	
SEm ±	0.23			
C.D. at 5%	0.69			

ANOVA 56: Grain damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	0.966		
Treatments	13	183.012	14.078	116.34
Error	26	3.146	0.121	
SEm ±	0.2			
C.D. at 5%	0.58			

Per cent damage by pod bug :

ANOVA 57: Pod damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	7.005		
Treatments	13	420.673	32.359	185.611
Error	26	4.533	0.174	
SEm ±	0.24			
C.D. at 5%	0.7			

ANOVA 58: Grain damage :

Source	D.F.	SS	MSS	F. cal.
Replications	2	1.848		
Treatments	13	204.842	15.757	136.892
Error	26	2.993	0.115	
SEm ±	0.19			
C.D. at 5%	0.57			

ANOVA 59: Grain yield :

Source	D.F.	SS	MSS	F. cal.
Replications	2	26.73	13.36	0.22
Treatments	13	1707248	131327	2130.96
Error	26	1602.33	61.63	
SEm ±	4.53			
C.D. at 5%	13.18			

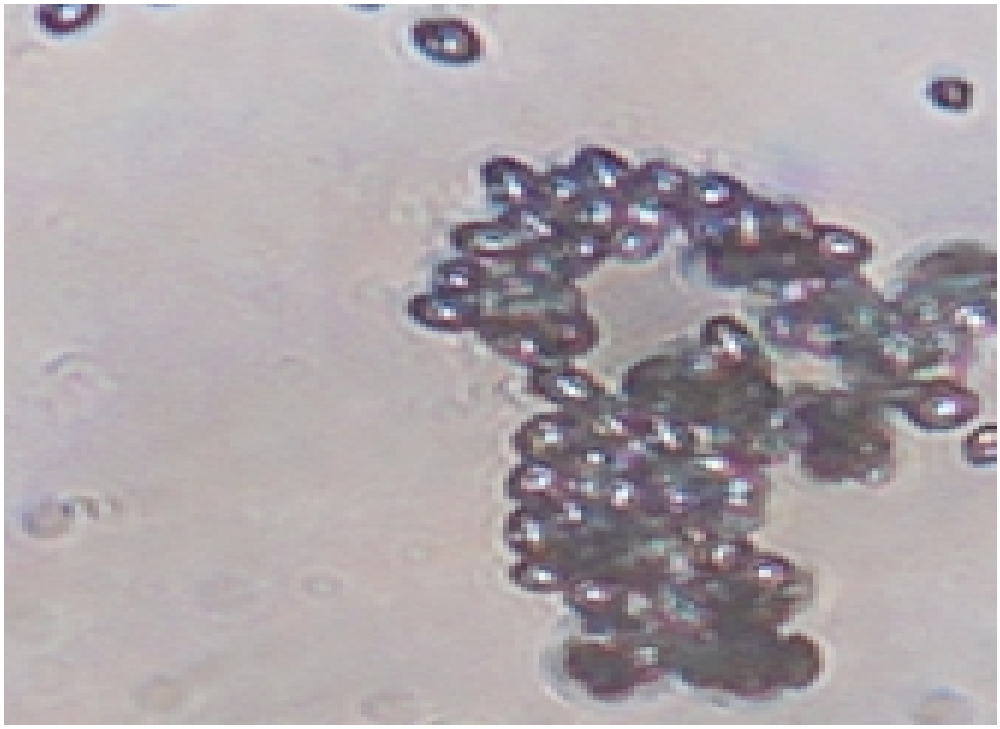


Plate 1: Conidia of *Beauveria bassiana*

Plate 2: Mycelia of B. bassiana

Plate 3: Methodology for growing *B.bassiana* on different substrates (a to e)

(a) Overnight soaking of substrates in distilled water

(b) At drying of substrates

(c) Autoclaving

(d) Inoculating *B.bassiana* in the substrates

(e) Incubation of fungus on different substrates in BOD

Plate 4: Establishment of *Beauveria bassiana* on whole grains and broken grains (30 days after inoculation)

Whole grains

Rice

Sorghum

Maize

Wheat

Establishment of *Beauveria bassiana* on different substrates (30 days after inoculation)

Broken grain

Rice

Sorghum

Wheat

Maize

Establishment of *Beauveria bassiana* on different substrates (30 days after inoculation)

Bran

Wheat

Rice

Husk

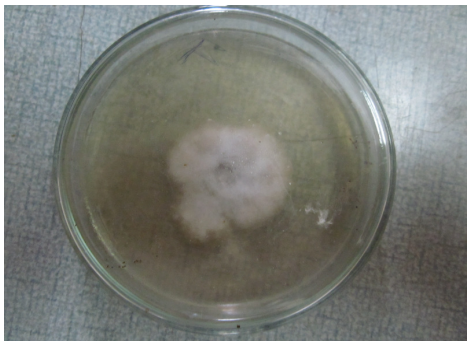
Wheat

Rice

Incubation of fungus in soaked water

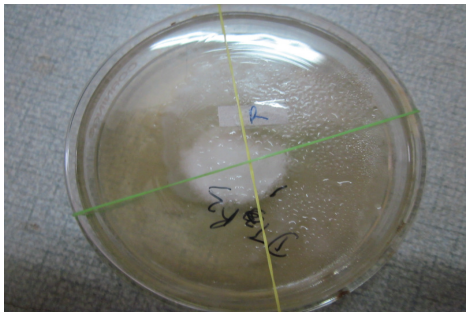
Wheat

Rice



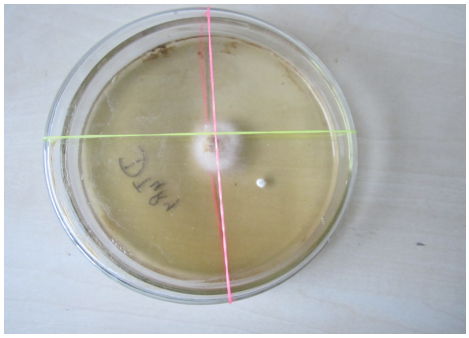
Rynaxpyr

Spinosad

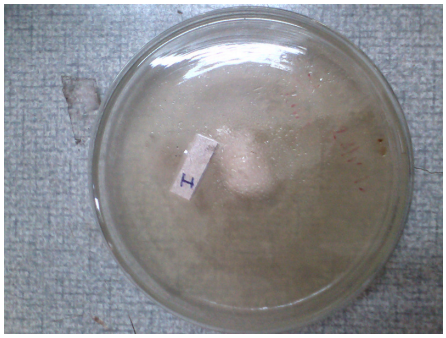


Emamectin benzoate

Triazophos



Indoxacarb

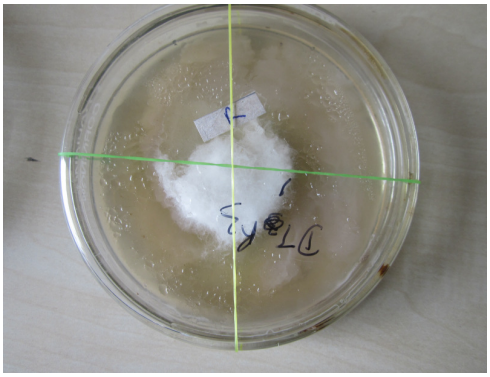


Flubendiamide

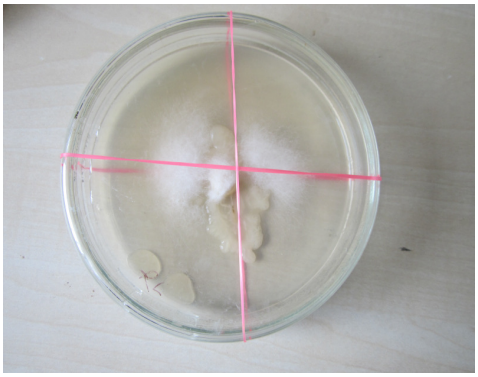
Plate 5: Mycelial growth of *B. bassiana* on different media (2 days after inoculation)

Rynaxpyr

Spinosad



Emamectin benzoate



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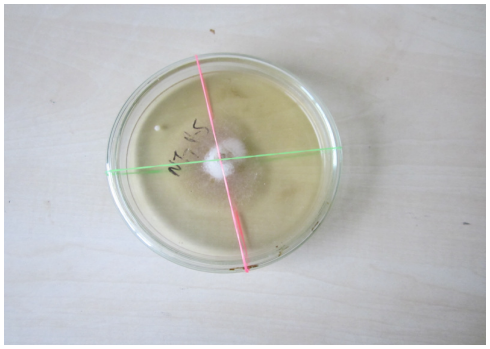

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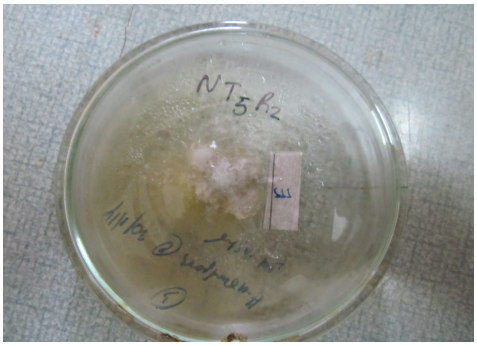
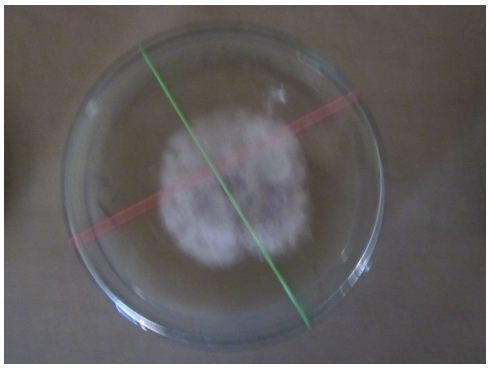
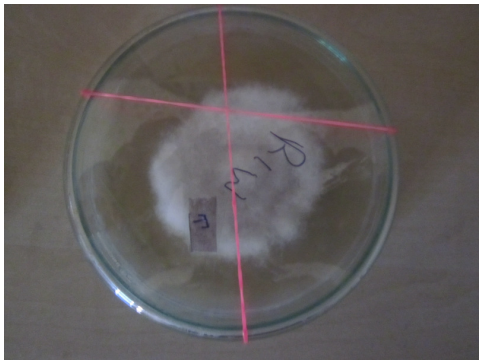


Flubendiamide

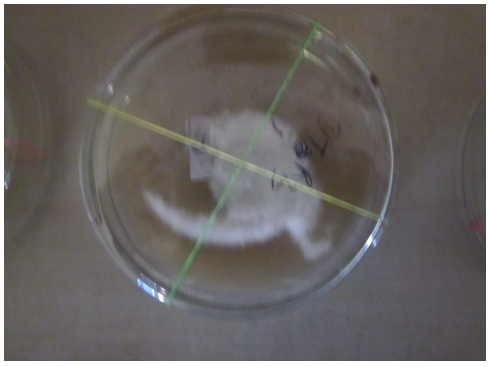
Plate 6: Mycelial growth of *B.bassiana* on different media (4 days after inoculation)



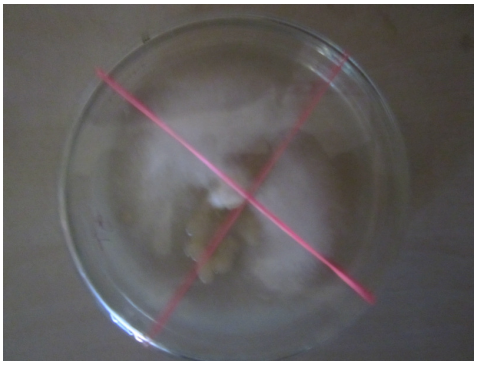
Rynaxpyr



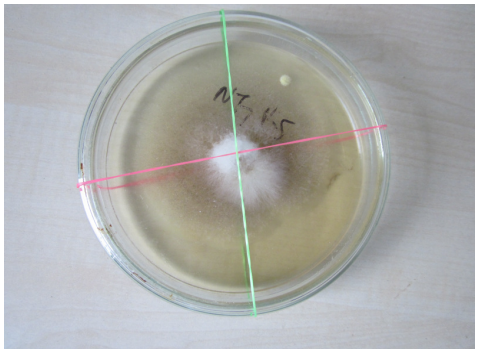
Spinosad



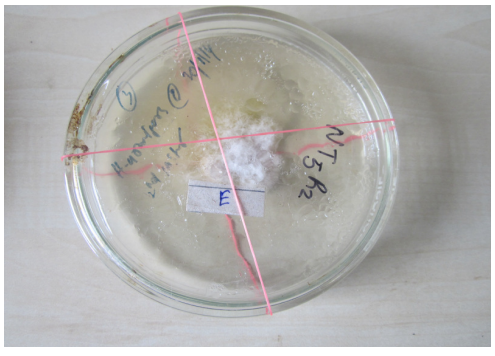
Emamectin benzoate



Triazophos

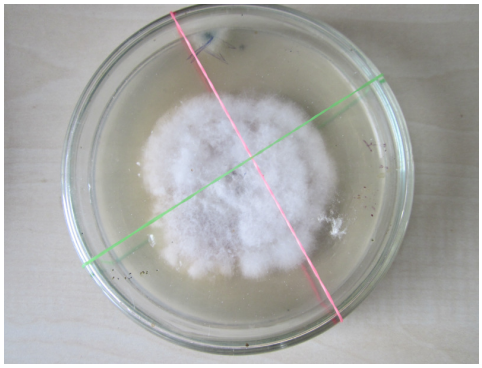


Indoxacarb



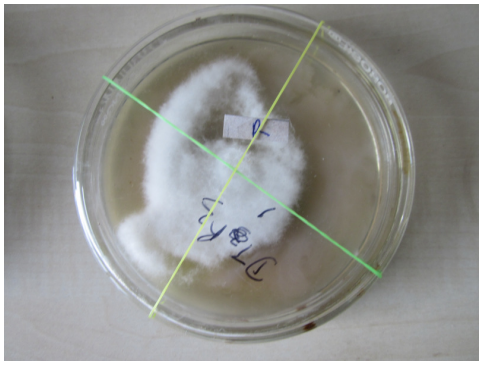
Flubendiamide

Plate 7: Mycelial growth of *B.bassiana* on different media (6 days after inoculation)

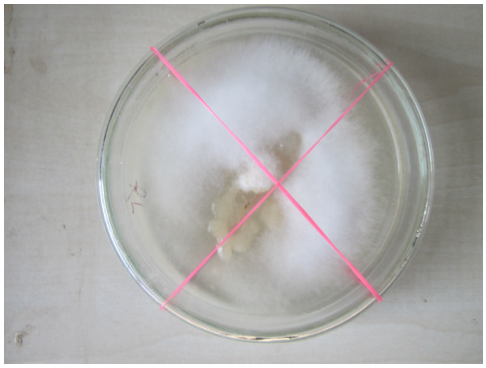


Rynaxpyr

Spinosad



Emamectin benzoate



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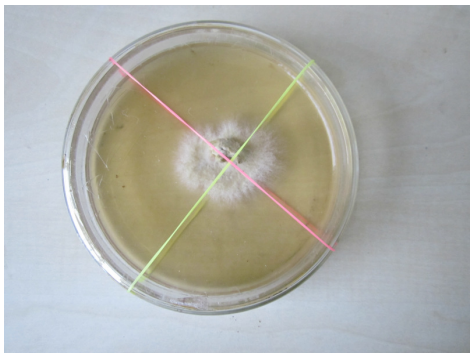

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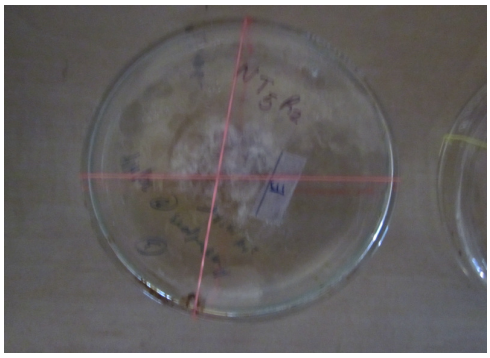
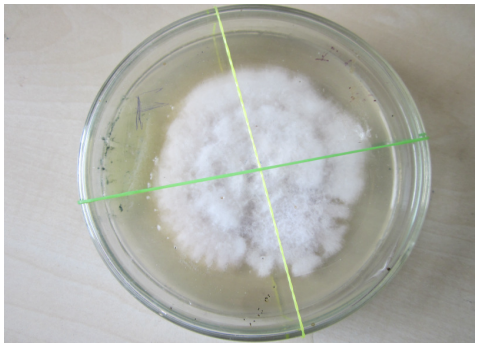
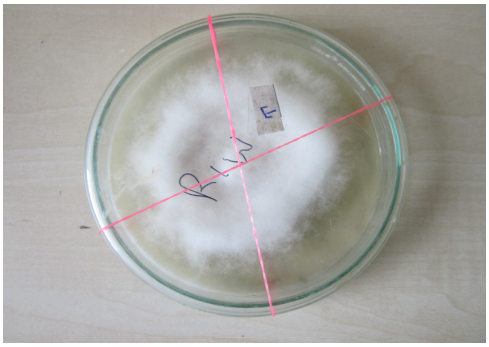


Flubendiamide

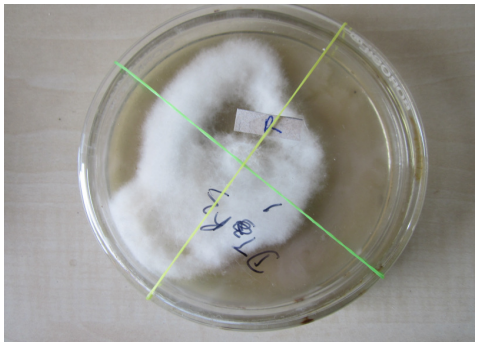
Plate 8: Mycelial growth of *B.bassiana* on different media (8 days after inoculation)



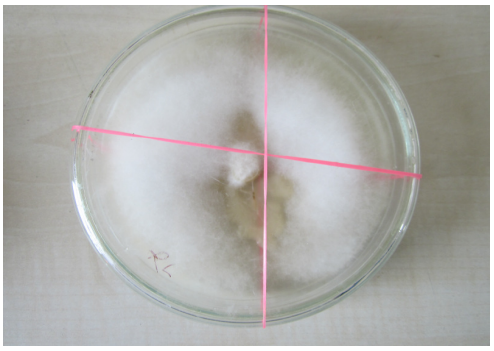
Rynaxpyr



Spinosad



Emamectin benzoate



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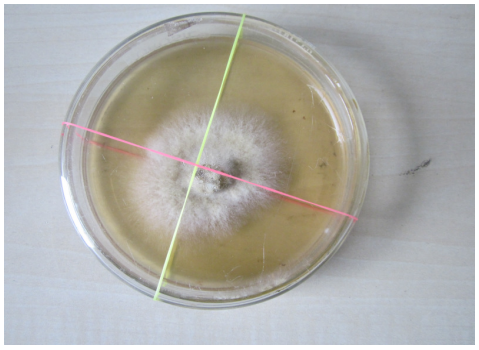

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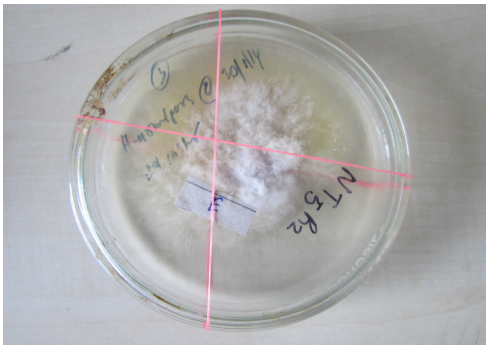


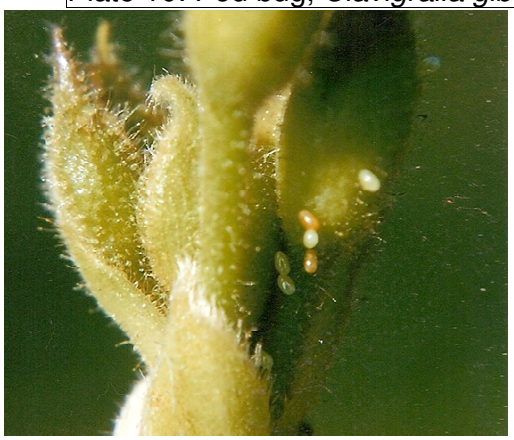
Flubendiamide

Plate 9: Mycelial growth of *B. bassiana* on different media (10 days after inoculation)

Eggs mass

Newly hatched nymphs

Plate 10: Pod bug, *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae)



Eggs

Larvae

Plate 11:Gram pod borer, *Helicoverpa armigera* Hub. (Lepidoptera: Noctuidae)

Plate 12: Green stink bug, *Nezara viridula* Linn (Hemiptera: Pentatomidae)

Maggot feeding on developing grain

Pupae

Plate 13: Pod fly, *Melanagromyza obtusa* Malloch (Diptera: Agromyzidae)

Larvae

Pupae

Plate 14: Red gram plume moth, *Exelastis atmosa* Walsingham (Lepidoptera: Pterophoridae)

Exelastis atomosa

Melanagromyza obtusa

Clavigralla gibbosa

Helicoverpa armigera

Plate 15: Damaging symptoms by pod infesting insect pests on pigeonpea grains

ABSTRACT

Title of the thesis	:	"**Studies on mass production of *Beauveria bassiana*, its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex**"
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Name and address of Major advisor	:	Dr. A.K. Saxena, Associate professor Department of Entomology, JNKVV, Jabalpur (M.P.)
Degree to be awarded	:	Master of Science in Agriculture
Year of award of degree	:	2015
Major subject	:	Entomology
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Signature of Advisor	Signature of Head of Department	Signature of Student
(Dr. A.K. Saxena)	**(Dr. A. K. Bhoumick)**	**(Narendra Tank)**

ABSTRACT

Present research work on “Studies on mass production of *Beauveria bassiana* (Bals.) Vuill., its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex” was carried out in the experimental field of Department of Entomology, Live Stock Farm, Adhartal, JNKVV, Jabalpur (M.P.) during *kharif* 2014-15. The experiments were conducted with the following objectives:

1. To study the influence of temperature and nutrient on mass production of *Beauveria bassiana* on local substrates.
2. To study the bioefficacy and compatibility of *B.bassiana* with new generation insecticides against pigeonpea pod borer complex.
3. To study the population dynamics of pigeonpea pod infesting insect pest complex.

Broken wheat grains were found to be the best substrate for mass production of *B. bassiana* as it produced maximum spore production in minimum time followed by broken rice, but in case of viability of spore broken rice grains was recorded maximum viable spores, highest biomass production was recorded on broken wheat grains media and highest dry matter production was recorded on water soaked rice and substrate with nutrient for mass production of *B. bassiana* as it produced maximum spore, viable spore, biomass and dry matter production and best temperature was found at 30^0C.

All the chemical insecticides and biopesticides proved their superiority over control in reducing the pod and grain damage and increasing the grain yield.

On the basis of the effectiveness of different treatments against pod borer complex on grain damage and grain yield revealed that among chemicals rynaxypyr 20%SC and in case of pod fly triazophos 40%EC is effective treatments.

Insecticide *B.b* + emamectin benzoate maximum cost benefit ratio (1:9.60).

Invitro studies in compatibility of *B. bassiana* with chemicals show that rynaxypyr 20%SC was most compatible with least growth inhibition percentage.

The first group insects to appear on the crop were pod bug, gram pod borer, pod fly, green stink bug and red gram plume moth respectively. These appeared when the crop age was reproductive stage and remained available upto the maturity of the crop. These pests were the major key pests which caused colossal yield losses.

Green stink bug :

Green stink bug was first observed in the 40th SW. Minimum temperature, evening relative humidity, morning and evening vapour pressure exhibited negative effect on green stink bug (nymph + adult) population.

Pod bug :

Pod bug (nymph + adult) was first observed in the 40th SW. Maximum and minimum temperature and morning and evening vapour pressure showed negative effect on nymph and adult population.

Gram pod borer :

Gram pod borer larva was first observed in the 45th SW. Maximum temperature showed positive and morning relative humidity showed negative effect on pod borer larvae population

Tur plume moth ;

Plume moth larva and pupa was first observed in the 45th SW. All the abiotic factors (included in the study) did not exhibit any impact on plume moth larval population.

Pod fly :

Pod fly population was first observed in the 45th SW. All the abiotic factors (included in the study) did not exhibit any significant influence on pod fly maggot population.

CURRICULUM VITAE

The author of this thesis, Mr. Narendra Tank S/o Shri. Gulab Chandra Ji Tank and Smt. Shanti Bai Tank .V .S was born on 12 Sep. 1989 at, Runija, Distt. Ujjain (M.P.).

After graduation, for furthr study, he got admission in M.Sc. (Ag.) for specialization in Entomology at the college of Agriculture, JNKVV, Jabalpur (M.P) where successfully completed all the course requirement for master's degree with OGP 7.6 out of 10 point scale in the year 2015.

For the partial fulfillment of the master's degree "Studies on mass production of Beauveria bassiana, its efficacy and compatibility with some new generation insecticides against pigeonpea pod borer complex" under Jabalpur condition, which was successfully conducted by him and being submitted in the form of this thesis.

He took admission for B.Sc. (Ag.) in the College of Agriculture, JNKVV (Jabalpur) in the year 2009. He has successfully completed his graduation with 7.1 OGPA in the year 2013.

He passed his High School (10^{th}) with (58.00%) in the year 2006 from Runija higher secondary school, Runija, Distt. Ujjain (M.P.) and Higher Secondary School (12^{th}) with distinction (80.88%) in the year 2008 from Sun Shine higher secondary school, Khandwa Naka, Indore (M.P.)