BIOEFFICACY OF VARIOUS INSECTICIDES AGAINST POD BORER COMPLEX OF PIGEONPEA [*Cajanas cajan* (L.) Millsp.]

By

Mr. Warad Purushottam Janardhan
(Reg. No. 018/145)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
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MAHARASHTRA, INDIA.
2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

Place : MPKV, Rahuri

Date : / /2021

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CERTIFICATE

This is to certify that the thesis entitled, "**BIOEFFICACY OF VARIOUS INSECTICIDES AGAINST POD BORER COMPLEX OF PIGEONPEA [*Cajanas cajan* (L) Millsp.]"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** embodies the results of a piece of *bona fide* research work carried out by **Mr. WARAD PURUSHOTTAM JANARDHAN,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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Place : MPKV, Rahuri

Date : / /2021 (P. N. Rasal)

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Place : MPKV, Rahuri.

Date : / /2021 (P. J. Warad)

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LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
/	:	Per
@	:	At the rate of
+	:	Plus
<	:	Less than
>	:	Greater than
±	:	Plus or minus
a.i.	:	Active ingridient
Bt	:	*Bacilus thurengiesis*
C.D.	:	Critical difference
cm	:	Centimeter
DAS	:	Days after Spraying.
EC	:	Emulsifiable concentrate
et al.	:	*et alli* (and other)
etc.	:	Et cetera and so on
Fig.	:	Figures (s)
g	:	Gram (s)
ha	:	Hectare
ha^{-1}	:	Per hectare
*Ha*NPV	:	*Helicovepa armigera* Nuclear Polyhedrosis Virus
hrs	:	Hours
i. e.	:	id *est* (that is)
IPM	:	Integrated pest management
Kg	:	Kilogram (s)
Kg/ha	:	Kilogram per hectare
Km/hrs.	:	Kilometre per hour
lit.	:	Litre (s)
Ltd.		Limited
M	:	Metre (s)
Max.	:	Maximum
Min	:	Minimum
ml	:	Mililitre (s)
mm	:	Millimetre (s)
mm/day	:	Milimetre per day
MPKV	:	Mahatma Phule Krishi Vidyapeeth
MSP	:	Minimum support price
N.S	:	Non significant.

No.	:	Number
NSKE	:	Neem seed kernal exract
ºC	:	Degree Celsius
PGI	:	Post Graduate Institute
q/Q	:	Quintal (s)
RBD	:	Randomized block design
RH	:	Relative humidity
Rs.	:	Rupees
S.E.	:	Standard Error
SC	:	Suspension concentrate
SE	:	Suspoemulsion
SG	:	Soluble granules
SMW	:	Standard meteorological week
Sq. m.	:	Square metre
Temp.	:	Temperature
Viz.	:	Videlicet (Namely)

ABSTRACT

BIOEFFICACY OF VARIOUS INSECTICIDES AGAINST POD BORER COMPLEX OF PIGEONPEA [*Cajanas cajan* (L) Millsp.]

by

Mr. Warad Purushottam Janardhan

A candidate for the degree
of
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Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722
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Research Guide	:	**Dr. C. B. Wayal**
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Bioefficacy of various insecticides against pod borer complex of pigeonpea (*Cajanas cajan* (L) Millsp.) was studied at Department of Agricultural Entomology, Post Graduate Institute, MPKV, Rahuri during 2019-20. The field experiment consist of two objectives *viz.,* 1) To study the seasonal incidence of insect pest on pigeonpea and 2) To study the bioefficacy of various insecticides against pod borer complex of pigeonpea there are 8 treatments *viz.,* Quinalphos 25 % EC, Emamectin benzoate 5 % SG, Indoxacarb 14.5 SC, Chlorantraniliprole 18.5 % SC, Chlorpyriphos 20 % EC, Flubendamide 39.35 % SC, Lambda cyhalothrin 5 % EC and Untreated control. These treatments also replicated three times in randomized block design. The performance of each insecticide treatment was judged on the basis of larval incidence, pod damage, grain damage and grain yield. In each insecticide treatment first spray was given at 50 % flowering and subsequent sprays were given at 15 days interval.

Seven insects pest were encountered in the pigeonpea crop. Among these seven insect pests the status of four insects i.e. pod borer complex associated with flowers and pods of pigeonpea crop is most important *Helicoverpa armigera*, *Exelastis atomosa*, *Maruca vitrata* and *Melanagromyza obtusa* were noticed from the flowering to podding stage of the crop at August to October.

Gram pod borer, *Helicoverpa armigera* (Hub.) continuously attacking the pods from flowering to pod maturation stage.

It revealed that the larval population initiated during 36th SMW after that gradually increased and reached to the highest peak during 42th SMW. Larval population of *Maruca vitrata* appeared during 38th SMW and reached to the highest peak during 45th SMW. The larval population of *Exelastis atomosa* increased up to first week of December and reached to the highest during 47th SMW. Tur pod fly *Melanagromyza obtusa* (Mall) appeared on the crop quite late during the 43th SMW and its maximum population activity was 49th SMW. Population of spider appeared during 37th SMW and reached to the highest during 47th SMW. Population of *chrysoperla carnea* appeared during 41th SMW and reached to the highest during 48th SMW. The population Lady bird Beetle of appeared during 38th SMW and reached to the highest during 48th SMW.

Considering the effectiveness in reducing the larval population, the treatment with chlorantraniliprole 18.5 % SC was emerged as the most promising treatment for the management of *Helicoverpa armigera* (Hubner), *Maruca vitrata, Exelastis atomosa* (Washingham) and *Melanagromyza obtusa* (Malloch).

The next promising treatment for reducing *Helicoverpa armigera, Maruca vitrata, Exelastis atomosa* and *Melanagromyza obtusa* larval population was flubendiamide 39.35 % SC which is followed by indoxacarb 14.5 % SC.

The data representing results of pod and grain damage due to pod borers of pigeonpea revealed that the treatment with chlorantrniliprole 18.5 % SC was superior in reducing collective pod and grain damage to a lowest level of 8.82 and 19.54 per cent respectively as compared to other treatments.

The maximum grain yield was obtained from the plots treated with chlorantrniliprole 18.5 % SC (17.18 q/ha) and maximum additional return over protection cost was obtained from chlorantrniliprole 18.5 % SC treatment. Whereas, chlorantrniliprole 18.5 % SC gave highest cost benefit ratio. Flubendamide 39.35 % SC was the next best treatment, which recorded 16.19 q/ha yield of pigeonpea grain. Indoxacarb 14.5 % SC is second promising treatment in cost benefit ratio after chlorantrniliprole 18.5 % SC.

1. INTRODUCTION

Pulses constitute an integral part of Indian agriculture, because of their vital role in enriching the human diet as well as soil fertility. Being the cheapest source of protein, pulse form an inseparable part of the Indian diet. Besides their higher nutritional value, pulse crops have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation and thus play a vital role in sustainable agriculture (Asthana, 1998). Generally, pulse are grown on marginal soils both as sole and intercrop during *kharif*, *rabi* and *summer* seasons. Pulse have a capacity to tolerate drought because of their deep root system.

Pigeonpea (*Cajanus cajan*) is an important multi-use shrub legume of the tropics and subtropics. The crop originated from India and moved to Africa about 4,000 years ago. Unlike other grain legumes, pigeonpea production is concentrated in developing countries, particularly in a few South and Southeast Asia, Eastern and Southern African countries. It is the preferred pulse crop in dryland areas, where it is intercropped or grown in mixed cropping systems with cereals or other short duration annuals (Joshi *et al.,* 2001).

Pigeonpea has a wide range of products, including the dried seed, pods and immature seeds used as green vegetables, leaves and stems used for fodder and the dry stems as fuel. It also improves soil fertility through nitrogen fixation as well as from the leaf fall and recycling of the nutrients (Snapp *et al.*, 2002; Mapfumes, 1993). It is an important pulse crop that performs well in poor soils and regions where moisture availability is unreliable or inadequate (Kimani, 2001). The crop can withstand low moisture condition and performs well in areas with less than 1000 mm of annual rainfall, depending on the distribution pattern. Pigeonpea can be incorporated with crops such as maize, sorghum or groundnuts without significantly reducing the yield of the main crop.

Pigeonpea is an important pulse crop of India, meeting the protein requirement of major sections of vegetarians of the country. Among the various biotic factors affecting pigeonpea production insect pests are the major constraint with avoidable losses extending up to 80 per cent in India (Lateef and Reed, 1983).

India ranks first in area with 4.43 Million ha and production 4.25 Million Tonnes. The Area under pigeonpea crop in Maharashtra was 1.23 Million ha with annual production of 1.07 Million Tonnes. Although the area under pigeonpea is increasing but yield is not satisfactory. This is due to several limiting factors and one of them is infestation of pests (Anon., 2019).

Generally pigeonpea is grown as mixed crop or intercrop as purely rainfed or with protective irrigation during *kharif* season in India. In India, it is extensively grown in different states *viz*. Maharashtra, Utter Pradesh, Madhya Pradesh, Bihar, West Bengal, Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu,. It is also one of the most important *kharif* crop in Marathwada region of Maharashtra state.

More than 300 insect species belonging to 8 orders and 61 families have been found to infest pigeonpea starting from seedling stage and continues till harvesting and even during the storage condition (Keval *et al.*, 2010). However, about 60 per cent damage is solely caused by the pod borer complex (Wadasker *et al.*, 2013). The pod borer complex of pigeonpea includes *H. armigera, M. vitrata, Exelastis atomosa and Melanogromyza obtusa.* The pod borer complex which attack at the reproductive stage cause more yield loss as compared to the insects pests attacking at the vegetative stage.

According to Lal *et al.* (1992) pod borers caused 60 to 90 per cent loss in the grain yield under favorable conditions and damage of seed by pod fly ranged from 14.3 to 46.6 per cent. To control these pests, farmers solely rely upon insecticides as the first line of defense to get immediate action. Abuse of insecticides has aggravated the pest problem leading to resurgence, outbreak of secondary pests and development of insecticidal resistance. So that selection of ecofriendly insecticides which is safe to natural enemies and also should not leave toxic residues is essential for pest management programme.

The extent of damage leading to yield loss caused by the various insect pests clearly indicates that, the insect pests are the serious constraint in pigeonpea production despite of several other cultural constraints. In India, regular and indiscriminate use of chemical insecticides and the misuse of synthetic pesticides on the crop have led to development of insecticides resistance in target pests, pest resurgence and secondary pest out breaks, loss of bio-diversity, environmental pollution and residual toxicity and occurrence of human health hazards. However, in present day context chemical control has its own popularity over the other methods of pest control due to its immediate action and remarkable pests population control. However, recent reports have revealed that, borers had developed resistance to most of the old insecticides (Armes *et al.,* 1992). Further, insecticides applied for control of insect pests should be safe to natural enemies and also should not leave toxic residues in environment. Keeping this in view, crop protection with need based use of safer insecticides is considered as an effective and dependable component of IPM and one of the most important aspects of agro-ecosystem management with regards to the ecological and socio-economic values.

Keeping this view and considering economic importance of pigeonpea, the present investigations were undertaken with following objectives.

i. To study the seasonal incidence of insect pests on pigeonpea

ii. To study the bioefficacy of various insecticides against pod borer complex of pigeonpea

2. REVIEW OF LITERATURE

This chapter comprises of the relevant studies carried out in India and abroad by various researchers and focus has been mainly made to collect information's on population dynamics, yield losses and efficacy of different insecticides against pod borer complex in pigeonpea. The work of different research workers have been summarized under following objectives.

2.1 To Study the Seasonal Incidence of Insect Pest on Pigeonpea

Naresh and Singh (1984) observed that, the various pod boring insects like *M.obtusa*, *M. testulalis* and *H. armigera* were more associated with pigeonpea crop. *M.obtusa* and *M. testulalis* larval population was significantly influenced by average temperature and relative humidity.

Prasad and Chand (1990) reported that *Clavilgralla gibbosa, Maruca testulalis* (*M. vitrata*), *M. obtusa*, *H. armigera and E. atomosa* were the most destructive pigeonpea pod borers in India.

Hong *et al.* (1992) reported from North Vietnam that, *Melanagromyza* spp. and the pod borer *M. testulalis, H. armigera* and *Etiella zinckenella* were severe pests on pigeonpea.

Sanap *et al.* (1995) noticed the incidence of major insect pests in six pigeonpea cultivars with different maturity period at Rahuri. The most important insects attacking at the early vegetative phase were the *Cicadellids, Empoasca kerri, Megalurothrips usitatus, Bemisia tabaci* and *Cydia critica*. Serious attacks by *H. armigera*, *E. atomosa* and *M. obtusa* were recorded in the reproductive stage.

Bhagwat *et al.* (1996) reported that, among the different pests of pigeonpea like *M. testulalis*, *M. vitrata*, *H. armigera*, *Exelastis* sp., *Lampides* sp., *M. obtusa*, *Mylabris* sp. and *Sphenoptera* sp. the most damaging was *M. vitrata* in Sri lanka.

Pandey (1996) noticed that *M. obtusa* as the major insect pest of pigeonpea during a survey at seven sites in Nepal.

Benagi *et al.* (2004) noticed that, the pests population crossed the economic threshold level (ETL) during the 43rd International Standard Week (ISW) (3.7 eggs/plant), 48th ISW (1.5 larvae/plant) and 50th ISW (1.3 larvae/plant) in summer and during 47th ISW (92.08 eggs/plant), 49th ISW (1.37 larvae/plant) and 52nd ISW (1 larvae/ plant).

Subharani and Singh (2004) observed in Manipur that during the crop period thirty different insect pests were recorded on the crop in an overlapping manner right from seedling to harvesting stage of crop.

Dhaka and Pareek (2007) reported that, the population of spiders feeding on insect pests of cotton was observed throughout the growth period of the crop, being maximum in the month of July. Population of C*hrysoperla* was observed from second fortnight of June to harvesting of the crop being maximum in November. The incidence of *Coccinellids* was recorded from the middle of August to middle of September and remained till harvesting of the crop being maximum in the first fortnight of November.

Patel *et al.* (2009) noticed that, spotted pod borer (*M. vitrata* Geyer) on cowpea was initially observed during middle of March at pod setting stage and reached to its highest (1.21 larvae/plant) level during fourth week of March.

Gopali *et al.* (2010) reported that, incidence of spotted pod borer was high in early (140-150 days) and late maturing varieties (190-200 days) where, it was moderate in medium duration (170-180 days). It is noteworthy to mention that, the incidence was high in late sown condition and also in varieties having clustering type of branching habit.

Yadav and Singh (2013) reported that, incidence of spotted pod borer was noticed from 33rd standard week with a peak of 2.4 larvae per plant during 36th standard week. The correlation of spotted pod borer with weather factor exhibited significantly negative correlation with minimum relative humidity and positive significant with sunshine and evaporation.

Sujithra and Subhash (2014) observed that, pest activity commenced from 36th standard meterological week (SMW) and continued until 46th SMW. The 38th and 39th SMW were found to be more congenial for pest attack in pigeonpea. Highest larval population of *M.vitrata* was found to be 8.10 and 17.77 larvae /plant.

Mahalaxmi *et al. (*2015) reported that, the seasonal incidence of spotted pod borer differed from crop to crop and season to season. However, the peak incidence of larvae was observed at flowering and developing stage of different pulse crop.

Sathe (2016) observed that, infestation of *M. vitrata* was found maximum in 38^{th} meterological week. It shows significant negative correlation with maximum temperature and significant positive correlation with rainfall.

Anamika (2017) reported that, pest populations remain in the field up to harvesting of crop but after 50^{th} standard meterological week the population declined. There was no significant correlation observed with the weather parameter. Thus the incidence of crop damage was increased with the advancement of crop growth and actual damage occurred at flowering and fruiting period**.**

Nair *et al.* (2017) reported total 11 species of insect pests consisting pod borer complex, out of which three species *viz., M. vitrata, M. obtusa* and *Apion clavipes* found to be amost destructive key pest in Tripura.

Kaval *et al.* (2017) concluded that, *H. armigera* and *M. obtusa* were the two major insect-pests infesting long duration pigeonpea in Varanasi region of Uttar Pradesh, India. Different weather parameters determine seasonal activity and population dynamics of these insect-pests on pigeonpea. The information generated in present study gives an indication about the importance of the different weather parameters in developing weather based forecasting models for successful development and implementation of the pest management strategies against insect pests of pigeonpea for increasing production efficiency, profit, besides safety to the environment.

Chavan *et al.* (2018) reported that, the infestation of *E. atomosa* commenced during the 43^{rd} SMW and continues till the 52^{nd} SMW. And it was evident that the pest was present on the crop during the reproductive stage and remained upto the maturity of the crop.

Bhadani and Patel (2019) reported that the larval population of *H. armigera* was recorded higher during 2^{nd} week of November. The larval population of *E. atomosa* was higher during 4^{th} week of November. In case of *L. boeticus*, the highest population was noticed during 5^{th} week of October.

Bhadani and Patel (2019a) revealed that, population of *M.obtusa* ranged from 0.0 to 3.6 maggots per pod with an average 1.20 maggots per pod. The population was first recorded (0.1 maggots/pod) during 45^{th} SMW *i.e.* 2^{nd} week of November and remained in the field up to the crop maturity. The maggot population gradually increased and showed higher infestation (> 2 maggot/pod) during December.

According to Dadas *et al*. (2019) the incidence of the gram pod borer, *H. armigera* initiated in the 40th SMW i.e. (0.20 larva/plant) and continued till 52th SMW i.e. (1.00 larvae/plant) and it was attained at peak of (4.2 larvae/plant) in the 46th SMW. The incidence of spotted pod borer, *M. vitrata* initiated in the 40th SMW i.e. (0.35 larva/plant) and continued till 48th SMW i.e. (2.80 larvae/plant) and reached its peak (3.80 larvae/plant) in the 45th SMW. The incidence of the plume moth, *E. atomosa* initiated in the 41st SMW i.e. (0.80 larva/plant) and continued till 49th SMW i.e. (0.20 larva/plant) and its peak (3.4 larvae/plant) was in the 45th SMW. As regards the tur pod fly, *M. obtusa* commenced in the 43rd SMW i.e. (0.80 maggot/10 pods) and continues till 49th SMW i.e. (3.05 maggots/10 pods) with peak population (6.20 maggots/10 pods) was observed in the 46th SMW.

2.2 To Study the Bioefficacy of Various Insecticides against Pod Borer Complex of Pigeonpea

Shrivastava (1972) reported that pigeonpea pod fly *M. obtusa* (Malloch) (Agromyzidae : Diptera) caused significant damage in pigeonpea. In general, the dipteran fly causesed on an average 34.5 per cent damage to the pods, which results in 29.8 per cent loss in grain.

Singh *et al.* (1988) tested 13 insecticides against pod borer complex of pigeonpea. Amongst them, the highest cost benefit ratio (1:15.3) was obtained in the phosalone treated plots.

Prasad *et al.* (1995) reported highest pigeonpea grain yield (63.3 %) more with compared to control. The maximum net profit obtained when the fields treated with deltamethrin, the highest return was obtained with dimethoate due to its low cost.

Ujagir and Ujagir (1999) noted that, there was a significant negative correlation between yield and mean percentage of pod borer damage when insecticides were applied except deltamethrin (0.002 %) which gave good cost benefit ratio.

Yelshetty *et al.* (1999) reported that, indoxacarb 15 SC @ 50 g a.i./ha was most effective in reducing pod damage (15.39 %) and in obtaining higher grain yield (11.68 q/ha).

Brickle *et al.* (2000) conducted comparision test with lambda cyhalothrin, spinosad, thiodicarb, pyrrole, oxadiazin and avermectin at normal growth rates on cotton bollworms *H. zea.* Result revealed that reduced rate of lambda-cyhalothrin spinosad and thiodicarb could be used for control of *H. zea* on dryland *Bt*. cotton.

Ramegowda *et al.* (2002) carried out field test during 2000 in Karnataka to evaluate nine new molecules of insecticides along with four commonly used insecticides against susceptible and resistant field population of *Spodoptera litura* (Fab). They observed that, 0.048 per cent spinasad and 0.015 per cent indoxacarb showed high mortality against resistant population (76.67 and 80.00 %, respectively).

Narkhede and Nachane (2003) tested nine newer insecticides against third instar larvae of *Earis vitella* of okra and found that 0.012 % spinosad 48 SC was superior (100 %) over 0.84 % indoxacarb (83.33 %), 0.5 % halt (72.92 %) and 0.002 % novaluron (53.33 %) for 3 days.

Kankal *et al.* (2003) investigated bioefficiency of newer insecticides against *H. armigera* in pigeonpea. They found that all doses of spinosad 45 SC and thiodicarb 14.5 SC recorded lowest larval population and per cent of green pod damage at those treatments were significantly superior over chloripyriphos 20 SC, endosulfan 35 SC and quinalphos 25 SC.

Liu *et al.* (2003) conducted study to evaluate efficacy of indoxacarb, spinosad and emamectin benzoate against *Plutella xylostella* in 1999 and 2000 at the Texas A and M Agricultural Reserch and Extension Center, Weslaco, USA and found that indoxacarb was highly toxic to *P. xylostella* and it was at par with spinosad.

Mushtaq *et al.* (2003) tested six different newer insecticides *viz.* fipronil 28 SC, chloripyriphos 36 SC, indoxacarb 15 SC, spinosad 48 SC, abamectin 18 SC and emamectin benzoate 19 SC aginst *H. armigera* for fipronil (0.48 larvae/plant). indoxacarb (1.50 larvae/plant), spinosad (1.30 larvae/plant), abamectin (0.65 larvae/plant), emamectin benzoate (2.20 larvae/plant) and chlorpyriphos (2.64 larvae/plant).

Flubendiamide 20 WDG @ 50g a.i./ha proved to be best treatment in reducing the pod borer damage (3.7 %) with highest grain yield of 13.22 q/ha at Pantnagar (Anonymous, 2004).

Bheemanna *et al.* (2005) studied bioefficacy of six newer insecticides against pest complex of cotton and their effect on yield. The results revealed that emamectin benzoate 5 SG @ 11.00 g a.i./ha appeared to be the most effective in the management of bollworms (7.88 %) with higher cotton seed yield of 15.26 q/ha and was on par with spinosad 45 SC @ 75 g a.i./ha (8.97 % and 15.12 q/ha) and indoxacarb 15 SC @ 75 g a.i./ha (9.65 and 14.44 q/ha).

Dhonde *et al.* (2005) revealed that indoxacarb 15 SC @ 75 g a.i./ha gave maximum protection exhibiting only 8.18 per cent pod damage with higher grain yield of 20.32 q/ha. They found that all the insecticidal treatments were effective in reducing pod borer damage to the extent of 8.40 to 19.85 per cent as against 28.93 per cent in untreated control.

Gupta *et al.* (2005) reported that the treatment with emamectin benzoate 5 SG @ 11.00 g a.i./ha was the most effective in reducing the bollworm incidence and also in obtaining higher yield of seed cotton *i.e.*140.3 per cent over control as compared to 127.7 per cent in abamectin, 110.3 per cent in spinosad and 55.66 per cent in indoxacarb.

Suganyakanna *et al.* (2005) conducted field trials on tomato against *H. armigera.* The results indicated that, emamectin benzoate 5 SG @ 10.00 g a.i./ha and 8.75 g a.i. were more effective as compared to profenofos 50 EC (750 g a.i./ha) and lambda cyhalothrin 5 EC (30 g a.i./ha). But it was comparable with 12.5 g a.i./ha spinosad 2.5 SC in reducing the larval population and fruit damage.

Tohnishi *et al.* (2005) reported in Japan that flubendamide was a novel class of insecticide having a unique chemical structure. The compound shows extremely strong insecticidal activity especially against lepidopterous pests including resistant strains and also used in the integrated pest management programme.

Siddegowda *et al.* (2006) evaluated efficacy of spinosad and indoxacarb against chickpea pod borer, *H. armigera* and recorded the least pod damage (6.89 %) and higher grain yield (10.30 q/ha) with spinosad 45 SC @ 22.5 g a.i./ha which was at par with indoxacarb 14.5 SC @ 21.75 g a.i./ha (7.73 % pod damage and 9.17 q/ha grain yield).

Srinivasan and Durairaj (2007) evaluated the bio-efficacy of certain newer insecticides against *H. armigera* Hubner and pod fly on pigeonpea. Results revealed that, the least *Helicoverpa* larval population of 2.0/plant was recorded in spinosad 45 SC (73 g a.i./ha) treatment followed by indoxacarb 14.8 SC (2.4/plant) as against a maximum population of 6.7/plant in untreated check. Highest grain yield was recorded in bifenthrin treated plots (925.6 kg/ha) followed by indoxacarb (864.0 kg/ha) and spinosad (841.1 kg/ha) as against the minimum yield of 432.7 kg/ha in the untreated control. A series of field experiments were conducted to study effect of newer insecticides for the management of pigeonpea pod borer complex. Mean reduction of *H. armigera* larval population at 7 and 14 days after the treatment, revealed superiority of flubendiamide 20 WDG @ 0.5 g/l, with 96.1 and 95.4 per cent over control, respectively. Flubendiamide was also efficacious against tur plume moth larvae with 83.9 and 93.3 per cent reduction over control, respectively.

Deshmukh *et al.* (2010) determined that flubendiamide 0.007 per cent in pigeonpea was found the most effective in reducing the *H. armigera* population and pod damage and showed the highest yield of 1850 Kg ha^{-1} and cost benefit ratio of 1:6.10.

Tohinshi *et al.* (2010) concluded that flubendiamide was the first example of 1, 2-benzene dicarboxamide insecticide but also the first practical synthetic insecticide with a mode of action as an activator of ryanodine receptors. It shows high selective activity against lepidopteran insect pests, which leads to excellent efficacy in the field and excellent safety against non-target organisms, including various beneficial arthropods and natural enemies.

Jagadeesh and Mallikarjun (2012) observed that the treatment of indoxacarb 0.0075 per cent caused highest mortality (89 to 96 %) of the pigeonpea pests followed by spinosad 0.009 per cent (86 to 95 % mortality) and the ready mixed insecticide profenophos + cypermethrin 0.044 per cent (85 to 94 % mortality).

Katraju *et al.* (2012) studied on efficacy of different insecticides against tomato fruit borer and noticed that all the insecticidal treatments were superior over control where, profenophos @ 1000 g a.i. ha^{-1} was most effective and significantly superior over all other treatments in reducing the fruit borer population (60.13 %) followed by bifenthrin @ 100 g a.i. ha^{-1} (59.59 %) and emamectin benzoate @ 22 g a.i. ha-1 (54.95 %) followed by spinosad @ 100 g a.i. ha^{-1} (52.99 %), profenophos @ 500 g a.i. ha^{-1} (51.09 %) and emamectin benzoate @ 11 g a.i. ha^{-1} (40.72 %) reduction of fruit borer population over control. *Bacillus thuringiensis* @ 25 g a.i. ha^{-1} was least effective with population reduction of 20.86 per cent.

Patel and Patel (2013) concluded that chlorantraniliprole @ 30 g a.i./ha was the most effective insecticide against pod borer complex and recorded highest grain yield of pigeonpea, while profenophos @ 250 g a.i./ha, chlorantraniliprole + lambda cyhalothrin @ 37.5 g a.i./ha, chlorantraniliprole + lambda cyhalothrin @ 30 g a.i./ha and indoxacarb @ 75 g a.i./ha were less effective and rank second in controlling the pod borer complex and yield.

Priyadarshini *et al.* (2013) opined that flubendiamide 480 SC @ 60 g/ha was the most effective compound with a maximum reduction in pod borers population with pod damage, grain damage and weight loss of 5.3, 3.3 and 2.9 per cent, respectively followed by lambda-cyhalothrin 5 EC at 25 g /ha (8.0, 3.4 and 2.9 %) and beta-cyfluthrin 25 SC at 18.8 g/ha (10.3, 6.4 and 5.6 %), respectively.

Wadaskar *et al.* (2013) reported that flubendiamide effectively restricted the lepidopteran pod borer damage (4.4 %), pod damage by pod fly (7.8 %) and grain damage by pod fly (6.0 %) to minimal, whereas, untreated control plot had 15.9 %, 4.2 % and 11.0 % respectively. Treatment with flubendiamide also recorded highest yield of 13.3 q/ha as against 8.8 q/ha. in untreated control. Other effective treatments were indoxacarb 14.5 SC @ 0.55 ml/L. emamectin benzoate 5 SG @ 0.3 g/L. and spinosad 45 SC @ 0.3 ml/L.

Sreekanth *et al.* (2014) reported that the number of *Helicoverpa l*arvae 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 per cent larval reduction over control, respectively. Pod damage due to pod borer, *H. armigera* 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, as against maximum pod damage of 10.22 % in untreated control. Highest grain yield was recorded in chlorantraniliprole treated plots (686.1 kg/ha) followed by flubendiamide (595.8 kg/ha) and spinosad (589.0 kg/ha) as against the minimum yield of 301.6 kg/ha in untreated check.

Bandi and Naik (2014) evaluated different insecticides against major pod borers (gram pod borer, plume moth and pod fly) in pigeonpea. The results revealed that, the treatment sequence comprising of nimbecidine 0.03 EC (3 ml/L.), *Ha*NPV (250 LE/ha) and flubendiamide 480 SC (0.1 ml/L.) was found promising against gram pod borer by recording least pod damage (21.33 and 19.52 %) and grain yield (888 kg/ha) during both the years of study. Similarly the pod damage by plume moth and pod fly was lowest in the sequence, nimbecidine 0.03 EC (3 ml/L) *Beauveria bassiana* (2 x 10^8 spores/g) (2 g/L.) flubendiamide 480 SC (0.1 ml/L.) with a record of 7.51 to 9.59 % and 6.67 to 6.78, respectively.

Chandra and Singh (2014) revealed the superiorty of spinosad 45 SC @ 73 g a.i./ha with no pod damage by the gram pod borer as well as plume moth *i.e.* (0.00 %). Flubendiamide 20 WG was considered as second effective insecticide against both the insects in reducing the pod damage upto (0.60 %) and (0.30 %) followed by rynaxypyr 20 SC and emmamectin benzoate 5 % SG. In case of grain yield, spinosad treated plots recorded maximum grain yield of (2732 kg/ha) followed by flubendiamide (2323.89 kg/ha) and rynaxypyr with 2501.33 kg/ha.

Ghosal *et al.* (2014) concluded that Novaluron + Indoxacarb @ 825 and 875 ml ha^{-1} were excellently effective against *H. armigera* of pigeonpea and were safe to three important predators recorded in pigeonpea field.

Khorasiya *et al.* (2014) recorded highest grain yield in chlorantraniliprole treated plots (686.1 kg ha^{-1}) with 127.5 percent increase over control, followed by flubendiamide (595.8 kg ha^{-1}) and spinosad (589.0 kg ha^{-1}) with 97.6 and 95.3 per cent increase over control respectively as against the minimum yield of 301.6 kg ha^{-1} in the untreated check. Similar studies indicated that Indoxacarb 0.0075 % recorded significantly highest grain yield (1486 kg ha^{-1}) in comparison to control (778 kg ha^{-1}).

Sreekanth *et al.* (2014) reported that, maximum yield of 743.1 kg/ha was obtained in plots treated with chlorantraniliprole, followed by flubendiamide (630.5 kg ha^{-1}) and spinosad (622.0 kg ha^{-1}) as against the lowest yield of 324.1 kg ha^{-1} in untreated check during 2010. The cost effectiveness of chlorantraniliprole and flubendiamide was also high and very favorable with incremental cost-benefit ratios of 1: 4.64 and 1: 4.50, respectively followed by indoxacarb (1:3.67), emamectin benzoate (1: 3.13) and spinosad (1: 2.97).

Manisha *et al.* (2014) concluded that, based on percentage infestation of *H. armigera* on pigeonpea all insecticidal treatments were significant and superior over untreated control.

Yogeeswarudu and Krishna (2014) conducted field trials for evaluating effect of different insecticides *viz.,* indoxacarb 14.5 SC @ 0.5 ml/L., profenofos 50 EC @ 2.0 ml/L., imidacloprid 17.8 SL @ 1 m/L., novaluron 10 EC @ 1.5 ml/L., fipronil 5 SC @ 2.0 ml/L. and lambda cyhalothrin 5 EC @ 1 ml/L. against *Helicoverpa armigera* larvae. The results revealed that, at first spray, indoxacarb 14.5 SC @ 0.5 ml/L. was found to be best among all the treatments with the minimum larval population of 1.53, 0.46, 0.73 larvae/five plants being 89.45, 97.01, 95.83 per cent reduction over control at 3 DAS, 5 DAS and 7 DAS respectively. The minimum larval population at second spray of 0.00, 0.26 and 0.00 larvae/five plants by giving 100, 98.74 & 100 percent reduction over control at 3 DAS, 5 DAS and 7 DAS, respectively.

Kumbhar and Syed (2017) concluded that approaches of chemical management of *H. armigera* were found effective. The chemical insecticide radiant 100 ml/acre, belt 50 ml/acre and steward 90 ml/acre were found most effective in controlling *H. armigera* larval population to reduce the pod infestation and also produce the maximum grain yield.

Dinesh *et al.* (2017) concluded that flubendamide 480 SC @ 200 ml/ha was most effective which cause highest mean per cent reduction in population of gram pod borer larvae on chick pea. It was followed by the treatment indoxacaeb 14.5 SC @ 500 ml.

Patange and Chiranjeevi (2017) concluded that, the treatment application of rynaxypyr 18.5 SP @ 30 g a.i./ha was found effective for suppression of pod borers population and extenuate yield. The cost benefit ratio was highest from profenofos + DDVP @ 2 ml + 0.5 ml/lit and rynaxypyr 18.5 SP @ 30 g a.i./ha resulted in superior at par yield due to their systemic action against pigeonpea pod borers.

Meena *et al.* (2018) studied the overall efficacy of insecticides at different time intervals evaluated against *H. armigera* in respect to population reduction and pod damage over control revealed that, indoxacarb (1.0 ml/lit.) was found most effective followed by NSE (5.0 ml/lit.) and azadirachtin (5.0 ml/lit.).

Dagne *et al.* (2018) noticed that, diazenon and lamda cyhalothrin 5 % EC were the most effective insecticide to give high mortality to pod borer on chick pea under field condition.

Rani *et al.* (2018) reported that, among all the insecticides, larval population of *H. armigera* infesting redgram was proven to be significantly lower in plots treated with chlorantraniliprole 20 SC (0.62 larvae/plant) and flubendamide 20 WG (1.04 larvae/plant) exhibiting 76.36 and 69.09 per cent reduction over control respectively. Similar trends was also observed with respect to per cent reduction of pod damage over control, where chlorantraniliprole 20 SC and flubendamide 20 WG exhibited 63.65 and 59.57 per cent control, respectively. Yield increase over control was recorded to be higher in plots treated with chlorantraniliprole 20 SC (60.78 %) and flubendamide 20 WG (54.93 %). The other treatments in order of yield efficacy were indoxacarb 14.5 SC (46.73 %) > emamectin benzoate 5 SG (43.68 %) > thiodicarb 75 % WP (42.45 %) > novaluron 10 EC (27.37 %).

Sonune and Bhamare (2018) reported that ,maximum reduction in pod and grain damage due to *E. atomosa* was registered in the plots treated with emamectin benzoate 0.0022 per cent to the tune of 2.33 and 1.67 per cent, respectively followed by chlorantraniliprole 0.0055 per cent (3.00 and 2.33 %) and flubendiamide 0.0070 per cent (3.67 and 3.00 %). Highest reduction in pod and grain damage due to *M. obtusa* was exhibited in the plots treated with emamectin benzoate 0.0022 per cent to the extent of 9.00 and 6.33 per cent, respectively followed by chlorantraniliprole 0.0055 per cent (9.67 and 7.00 %) and spinosad 0.0070 per cent (10.33 and 7.67 %).

Dadas *et al.* (2019a) revealed that all the insecticide treatments were significantly effective to minimize the pod borers population and found at par with each other. However, clorantriniprole 18.5 % SC was found to be most promising treatment to minimize the larval population of gram pod borer, *H. armigera* (Hubner), spotted pod borer, *M. vitrata* (Geyer), plume moth, *E. atomosa* (Walshingham) and pod fly, *M. obtusa* (Malloch) to the extent of mean larvae/maggot populations of 0.47, 0.48, 0.37 and 0.47 larva/plant followed by flubendiamide 39.37 % SC (0.56, 0.0.62, 0.47 and

0.57 larva/plant) and indoxacarb 14.5 % SC (0.66, 0.86, 0.57 and 0.69 larva/plant) after first and second spray. Chlorantraniliprole 18.5 % SC was found most effective in reducing the per cent pod damage *i.e*. 5.59 per cent by the pod bores of pigeonpea after second spraying and it was statistically at par with flubendiamide 39.37 % SC (5.00 %).

3. MATERIAL AND METHODS

During the course of the present investigation an experiment was laid down to study the seasonal incidence of insect pests on pigeonpea and efficacy of some newer insecticides against pigeonpea pod borers *viz.* gram pod borer; *Helicoverpa armigera* (Hub), plume moth; *Exelastis atomasa* (Washi) and pod fly; *Melanagromyza obtusa* (Malloch). A field experiment was planned with an object to find out the effective and economical insecticidal treatment for management of the pests. The particulars of material and methods employed in the conduct of experiment were presented in this chapter.

3.1 Geographical Location

The present experiment was conducted at AICRP on pigeonpea, Pulses Improvement Peoject, Mahatma Phule Krishi Vidyapeeth, Rahuri. Geographically, Central Campus of Mahatma Phule Krishi Vidyapeeth is situated between 19º47 and 19º57 North latitude and between 74º32 and 74º19 East longitude. The altitude varies from 495 to 569 meter above the mean sea level.

3.2 Climate

Climatically, this area fall in semi-arid tropic with annual rainfall varying from 307-619 mm. The average rainfall being 520 mm distributed over 25 to 45 rainy days in different months nearly 80 per cent of total rainfall is received from South West monsoon from June to September. The annual average maximum temperature of 38°C varied from 33°C to 43°C and minimum temperature of 17.2°C in range of 13°C to 17°C and average minimum and maximum humidity ranged from 35 to 59 per cent, respectively.

3.3 Land Preparation

The experimental field was first opened with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally levelled with the help of rotavator.

3.4 Material

3.4.1 Seed

The seed of pigeonpea variety 'ICPL-87' was made available from Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist-Ahmednagar (MS).

3.4.2 Seed Treatment

Seeds of pigeonpea were treated with *Trichoderma* @ 5 g/kg of seed + carbendazim @ 2 g/kg of seed + rhizobium culture @ 5 g/kg of seed + phosphate solubilizing bacteria @ 5 g/kg of seed to protect the seed from different rot and wilt diseases and to enhance the nutrients uptake by the pigeonpea crop. The seeds of other intercrops were treated with *Trichoderma* @ 5 g/kg of seed to protect the seed from different rot and wilt diseases.

3.4.3 Fertilizer Application

Standard doses of fertilizers comprising N, P and K @ 25 kg, 50 kg and 25 kg per hectare in the form of urea, single super phosphate and muriate of potash were applied, respectively as basal dose at the time of sowing.

3.4.4 Intercultural Operations

To avoid moisture stress and ensuring good germination, post-sowing irrigation was applied. Intercultural operations like thinning and weeding were done as and when necessary for proper growth and development of the crop.

3.4.5 Insecticides

All the chemical insecticides were made available through by Department of Agricultural Entomology, MPKV, Rahuri, Dist-Ahmednagar. The details of insecticides given in Table 3.3

3.4.6 Equipments

Battery operated spray pump also known as electric sprayer, manufactured by ASPEE American spring and pressing company, Malad, Mumbai was used for the application of insecticides.

3.5 Method for Field Experiment

3.5.1 Experimental Details

A field experiment was conducted during *Kharif* of 2019 at Pulses Improvement Project, MPKV, Rahuri. Eight treatments with three replications were imposed in Randomized Block Design (RBD). Uniform plant population was maintained and the crop was raised by following all the recommended package of practices except plant protection measures against pod borers (Plate 3.1).

3.5.2 Insecticide Treatments

The spraying was done by battery operated knapsack sprayer using the spray fluid at the rate of 500 L/ha, for each spray. The details of insecticide treatments given in Table 3.3. Each insecticide treatment consisted of three sprays. The first spray was given at 50 % flowering and subsequent sprays were given at 15 days interval. In all, three sprays of insecticides were applied.

3.5.3 Method of Recording Observation

3.5.3.1 Seasonal incidence

Weekly observations on seasonal incidence of pigeonpea pests were recorded from germination to till maturity in each meteorological week.

i. **Pod borer :** Number of pod borer larvae (*Helicoverpa armigera* Hubner) were recorded from ten randomly selected tagged plants.

ii. **Spotted pod borer :** Number of spotted pod borer larvae (*Maruca vitrata* Geyer) were recorded from ten randomly tagged plants.

iii. **Pod fly :** Number of damaged pods by pod fly maggot (*Melanagromyza obtusa*) was recorded from ten randomly selected and tagged plants.

iv. **Tur plume moth :** Number of tur plume moth larvae (*Exelastis atomosa*) were recorded from ten selected tagged plants.

v. **Natural enemies :** Natural enemies were recorded from ten randomly selected tagged plants.

Table 3.1 Details of the experiment

Design	:	Randomized Block Design
Replications	:	Three
Treatments	:	Eight
Variety	:	ICPL-87
Plot size	:	4.50 x 3.60 m^2
Spacing	:	90 x 60 cm
Fertilizer dose:	:	25 : 50 : 25, NPK kg / ha.
Method of sowing	:	Dibbling
Seed rate	:	12 kg /ha.
Date of sowing	:	23 July 2019.
Date of spraying First spray Second spray Third spray	: : :	10 /10/2019 25/10/ 2019 09/11/ 2019
Date of harvesting	:	8/12/2019

Table 3.2. Treatment details

Sr. No	Treatment	Formulation	Dose g/ml/lit.
1	Quinalphos	25 EC	2.00 ml
2	Emamectin benzoate	5 SG	0.40 gm
3	Indoxacarb	14.5 SC	0.70 ml
4	Chlorantraniliprole	18.5 SC	0.30 ml
5	Chlorpyriphos	20 EC	2.00 ml
6	Flubendiamide	39.35 SC	0.25 ml
7	Lambda cyhalothrin	5 EC	1.00 ml
8	Untreated Control	---	---

Table 3.3 Details of insecticides evaluated against pod borers of pigeonpea

Sr. No.	Common Name	Trade Name	Chemical Name	Source
1	Quinalphos 25 EC	Gold lux	O,O-Diethyl O-2-quinoxalinyl phosphorothiote	401- B , Usha Kiran Building, Azadpur Complex New delhi-110033.
2	Emamectin benzoate 5 SG	Proclaim	4”-Deoxy-4-epi-methylamino-avermectin B1;Epi-methylamino-4-deoxy-avermectin; MK 243;EMA;GWN 1972.	Sygenta India Limited,Near Sadanand Hotel Pune 411045.
3	Indoxacarb 14.5 SC	Karate	(S) –Methyl 7 chloro-2-{[(methoxycarbonyl)[4-(trifluromethoxy)phenyl]amino] Carbonyl}-2H,3H,4a,5H-o[1,2-e][1,3,4]oxadiazone-4a-carboxylate.	Sygenta India Limited, Near Sadanand Hotel Pune 411045.
4	Chlorantraniliprole 18.5 SC	Coragen	5-Bromo-N-(4-Chloro-2 Methyl-6-(Methylcarbonyl)Phenyl-2-3Chloropyridin2-yl) Pyrazol-3-Carboxamide.	FMC corporation India Pvt.Ltd.,Bandra Kurla Complex,Mumbai 400098.
5	Chlorpyriphos 20 EC	Lethal	O,O-Diethyl O-3,5,6–trichloropyridin-2yl phosphorothioate.	Insecticide India Limited, Kurla Road, Mittal Industrial Estate, Mumbi 400059.
6	Flubendiamide 39.35 SC	Fame	27245165-73-indoN_{2}-(2-methyl-1methyl sulfonyl) (propan-2-yl)-N1-(2-methyl-4-(perfluoropropan-2-yl) phenyl) pthalamideUNII-GEV84ZI4K6.	Byer (India) Ltd. Hiranandani Estste Thane west,Mumbai 400076.
7	Lambda cyhalothrin 5 EC	Prahar	(R)–α –Cyno -3-phenoxybenzyl(1s)-Cis-3-[(Z)-2-Chloro-3,3,3-triflyropropenyl]-2,2dimethylcyclopropanecarboxyl Late and (s)-a-cyno-3-phenoxybenzyl(1R)-cis-3-[(Z)-2-chloro-3,3,3-trifluropropynyl]2,2dimethylcycloproprne carboxylate.	Rain Bio Tech,SIDC Road,Near Maheshwari Agro,Gujrat,360024.

3.5.3.2 Observations of bioefficacy

3.5.3.2.1 Before harvest

The efficacy of insecticides was evaluated by selecting five plants randomly from each treated plot for recording observations on number of pod borer larvae before each application and at 3, 7 and 14 days after the application of insecticide treatment. Following marks of identification of larvae of the pod borers as suggested by Reddy and Joshi (1991) were utilized for differentiation.

i. Gram pod borer, *Helicoverpa armigera* Hub.

The larvae were greenish or brownish yellow or pink with dark broken gray lines on the lateral sides of the body. Full grown larvae were measured 35 to 40 mm in length (Plate 4.2).

ii. Spotted pod borer, *Maruca vitrata* Geyer

The larvae are whitish to pale green in colour with dark black spot on the dorsal surface of the body (Plate 4.3).

iii. Plume moth, *Exelastis atomosa* washi

The larvae were greenish brown in colour with short hairs and spines on the body. Full grown larvae were about 12 mm in length (Plate 4.4).

iv. Pod fly, *Melanagromyza obtusa* Malloch

Maggots were whitish with dark brown mouth parts. Anterior side of maggots was slender and pointed. The maggot was smooth and apodus. Fifty pods were collected randomly from last but second row of both sides of each plot at the time of taking the observations of pod fly maggot (Plate 4.5).

3.5.3.2.2 Post harvest observation

3.5.3.2.2.1 Pod borer infestation

Five plants selected earlier randomly from each plot were observed for pod damage at the time of harvesting. Number of damaged pods and healthy pods were counted. The pods were critically examined for the damage as suggested by Bindra and Jokhmola (1967) for recording the damage caused by specific borer.

i. Gram pod borer. *H. armigera* Hub.

The pod shells with relatively large holes indicate the boring by larvae of gram pod borer, *H. armigera.* Such pods were also found devoid of excreta. Numbers of pods with these symptoms were counted to assess the damage by gram pod borer (Plate 4.2).

ii. Plume moth *E. atomosa* Washi.

The pod showing holes opposite to seed and without grains and partially eaten grains with blackish excreta were accounted for the plume moth damage (Plate 4.4).

iii. Pod fly *M.obtusa* Malloch

The pods damaged by pod fly were brownish in color with externally visible pin holes from which adults emerged. Mines were prepared below the testa by the maggots and an along notch was found eaten into the grain due to initial feeding by maggots internally as a miner and later becomes an external feeder of the grain (Plate 4.5).

Also, the pods were opened and examined for grain damage. From that per cent pod damage and grain damage were calculated by following using formula.

$$\text{Per cent pod damage} = \frac{\text{Infected pods}}{\text{Total number of pods}} \times 100$$

$$\text{Per cent grain damage} = \frac{\text{Number of damaged grain}}{\text{Total number of grains}} \times 100$$

3.5.3.2.2.2 Grain yield

The yield of pigeonpea grains obtained from the total plants from each of the net plot was recorded separately. The yield per plot was converted into the yield per hectare.

Yield was calculated under different treatments as per formula.

$$\text{Yield (q/ha)} = \text{Factor} \times \text{grain yield (kg)/plot}$$

$$\text{Factor} = \frac{10000}{\text{Net plot size}}$$

3.5.3.2.2.3 Incremental cost benefit ratio

The incremental cost benefit ratio of each insecticide was calculated by using prevailing market price of inputs, produce and the labour charges.

3.5.3.2.2.4 Statistical analysis

Statistical analysis of the data on per cent pod damage obtained from field experiment was done. The data on per cent damaged pods and grains were transformed into arc sin values to reduce the variation in different treatments and then subjected to statistical anlysis. The significance of treatments was assessed by determining critical difference (C.D.) at 5 % level of significance. The larval numbers were transformed into $\sqrt{n + 0.5}$ for further statistical analysis.

4. RESULTS AND DISCUSSION

Observations recorded on various aspects are briefly illustrated in the present chapter. The data are presented in appropriate tables and some of them are illustrated graphically. The results and discussion are presented objective wise as follows.

4.1 Seasonal Incidence of Insect Pests on Pigeonpea

The data on seasonal incidence of pod borer complex on pigeonpea is presented in Table 4.1.

4.1.1 Gram Pod Borer, *H. armigera*

From the results presented in (Fig. 4.1) it was noticed that, incidence of gram pod borer, *H. armigera* on pigeonpea was observed from flowering to continued till pod filling pod maturation stage. From the data it was revealed that larval population initiated (0.40 larvae/plant) during 36th SMW *i.e.* first week of September gradually increased and reached to its peak (2.50 larvae/plant) peak during 42th SMW *i.e.* 3rd week of October.

Dadas *et al.* (2019) reported that the seasonal incidence of *H. armigera* on pigeonpea was noticed from flowering stage continued upto harvest of the crop.

Bhadani and Patel (2019) observed that, larval population of *H. armigera* was noticed higher during 2nd week of November and the maximum larval population of *H. armigera* at 16th and 18th week after sowing. The results of the present finding are in accordance with the earlier workers.

4.1.2 Spotted pod borer, *M. vitrata*

Among the pod borer complex insect pests, *M. vitrata* remained active only during flowering and podding stage of pigeonpea crop. The larval population of *M. Vitrata* appeared first (0.40 larvae/plant) during 38th SMW *i.e.* third week of Septeber. Population gradually increased up to first week of December (1.40 larvae/plant) and reached to its maximum (2.50 larvae/plant) during 45 th SMW *i.e.* first week of November (Fig. 4.2).

Mahalaxmi *et al.* (2015) reported that, the seasonal incidence of spotted pod borer differed from crop to crop and season to season. However the peak incidence of *M. vitrata* larvae was observed at 45th SMW and flowering and developing stage of different pulse crops. The results of present finding are in conformity with Sujithra and

Subhash (2014) who reported that the legume pod borer *M. testulalis* was observed only for about fortnight in the month of November.

4.1.3 Tur Plume Moth, *E. atomosa*

The larval population of *E. atomosa* appeared (0.20 larvae/plant) during 39th SMW *i.e.*fourth week of September. Population increased gradually up to first week of December (2.20 larvae/plant) and reached to the highest peak (2.60 larvae/plant) during 47th SMW *i.e.* third week of November (Fig.4.3).

These results are agreement with Chavan *et al.* (2018) who reported that the infestation of *E. atomosa* commenced during the 43rd SMW and continues till the 52nd SMW. This was evident that the pest present on the crop during the reproductive stage and remained upto the maturity of the crop.

Bhadani and Patel (2019) reported that, the larval population of *E. atomosa* was highest during 4th week of November and appearance of plume moth, *E. atomosa* from flowering stage and remained active till pod maturity of the crop.

Table 4.1. Seasonal incidence of pod borer complex on pigeonpea crop

Std. Met. Week	*H. armigera* larvae/ plant	*M. vitrata* larvae /plant	*E. atomosa* larvae/ Plant	*M.obtusa* maggots / 10 green pods	Temperature (^{0}C)		Relative Humidity (%)		Wind Velocity Km/hr.	Rain (mm)
					Max	Min	Morn.	Even.		
30	0.00	0.00	0.00	0.00	30.5	23.6	78	68	4.1	18.4
31	0.00	0.00	0.00	0.00	27.0	22.8	88	77	4.8	47.8
32	0.00	0.00	0.00	0.00	28.0	23.3	80	68	8.2	3.6
33.	0.00	0.00	0.00	0.00	31.0	22.5	75	59	6.9	1.4
34.	0.00	0.00	0.00	0.00	32.5	21.3	72	47	4.1	00
35.	0.00	0.00	0.00	0.00	32.0	23.0	75	56	4.1	87.2
36.	0.40	0.00	0.00	0.00	30.0	23.3	77	71	3.6	3.0
37.	0.80	0.00	0.00	0.00	28.8	22.5	78	68	4.6	21.6
38.	1.10	0.40	0.00	0.00	29.8	21.7	83	71	1.6	84.2
39.	1.60	0.80	0.20	0.00	30.2	21.9	83	69	0.8	36.6
40.	2.00	1.40	0.60	0.00	31.1	21.1	80	59	1.1	7.8
41.	2.30	1.60	0.80	0.00	31.7	21.1	77	50	0.7	2.8
42.	2.50	2.20	1.10	0.00	28.2	18.6	81	68	1.4	52.4
43.	1.60	1.30	1.30	0.20	25.7	20.8	87	79	1.3	141.8
44.	2.10	2.00	1.80	0.50	30.4	21.0	84	58	1.1	4.0
45.	1.80	2.50	2.10	0.80	31.1	18.4	76	46	0.6	23.4
46.	1.40	2.00	2.40	1.10	29.7	16.7	73	48	0.8	---
47.	1.20	1.40	2.60	1.60	30.0	15.2	74	45	0.3	---
48.	1.00	0.80	2.20	2.10	30.5	15.9	74	44	0.2	---
49.	0.70	0.40	1.50	2.40	28.8	16.4	71	47	0.3	---
50.	0.30	0.00	1.20	2.20	29.6	16.3	74	42	0.3	---

4.1.4 Pod Fly, *M. obtusa*

Tur pod fly, *M. obtusa* (Mall) appeared (0.20 maggots/plant) on the crop quite late *i.e.* during the 43th SMW *i.e.* third week of October. The eggs laid inside the pods during last week of October, after hatching maggots fed on seeds inside the pods. It remained active till second week of December and its maximum population (2.40 maggots/plant) recording during (49th SMW) *i.e.* first week of December (Fig. 4.4).

Dadas *et al.* (2019) observed that the appearance of pod fly *M.obtusa* started from pod filling remained upto pod maturation.

Results of present finding are in accordance with Bhadani and Patel (2019a) who noticed first apperence of the pest during 43rd SMW i.e. 5th week of October and pest reached to peak during first week of December (48th SMW).

4.1.5 Spider; *Distina albida*

Natural enemies of pigeonpea pests, spider (*Distina albida*) were appeared (0.30 adults/plant) during 37th SMW *i.e.* 2nd week of September. Population of spiders were gradually increased and it reached to the highest peak (1.40 adults/plant) during 47th SMW *i.e.* Second week of November (Table 4.2 and Fig. 4.5).

The results of present findings were more or less similar with the findings of Dhaka and Pareek (2007). Who noticed first incidence of spider in last fortnight of June and obtain its peak population during August. The results of present studies were in accordance with that of Sharma *et al.* (2004) who reported more population of spider in August to September.

4.1.6 Green Lace Wing; *Chrysoperla carn*ea

Natural enemies of pigeonpea pests, *C. carnea* appeared (0.20 adults /plant) during 41th SMW *i.e.* Second week of October. Population of *C. carnea* were gradually increased and it reached to its highest peak (0.70 adults/plant), during 48th SMW *i.e.* Last week of November (Table 4.2 and Fig. 4.6).

The present investigation corroborates with Sharma *et al.* (2004) who noticed *C. carnea* adults were more during Septeber to November. Dhaka and Pareek (2007*)* find out that *C. carnea* was observed from second fortnight of June to harvesting of the crop being maximum in November.

4.1.7 Lady bird beetle ; *Coccinella septempunctata*

The population of lady bird beetle appeared (0.20 adults/plant) during 38[th] SMW *i.e.*third week of Septeber. Population of lady bird beetle gradually increased and it reached to its highest peak (1.10 adults/plant) during 48 [th] SMW *i.e.* Last week of November (Table 4.2 and Fig.4.7).

Table 4.2 Seasonal incidence of natural enemies on pigeonpea crop

Std. Met. Week	Spider/ plant	Chrysoperla (adults/plant)	L.B.B/ plant	Temperature (^{0}C)		Relative Humidity (%)		Wind Velocity (Km/hr.)	Rain (mm)
				Max	Min	Morn.	Even.		
30	0.00	0.00	0.00	30.5	23.6	78	68	4.1	18.4
31	0.00	0.00	0.00	27.0	22.8	88	77	4.8	47.8
32	0.00	0.00	0.00	28.0	23.3	80	68	8.2	3.6
33.	0.00	0.00	0.00	31.0	22.5	75	59	6.9	1.4
34.	0.00	0.00	0.00	32.5	21.3	72	47	4.1	00
35.	0.00	0.00	0.00	32.0	23.0	75	56	4.1	87.2
36.	0.00	0.00	0.00	30.0	23.3	77	71	3.6	3.0
37.	0.30	0.00	0.00	28.8	22.5	78	68	4.6	21.6
38.	0.40	0.00	0.20	29.8	21.7	83	71	1.6	84.2
39.	0.70	0.00	0.40	30.2	21.9	83	69	0.8	36.6
40.	0.80	0.00	0.50	31.1	21.1	80	59	1.1	7.8
41.	1.10	0.20	0.70	31.7	21.1	77	50	0.7	2.8
42.	1.20	0.40	0.40	28.2	18.6	81	68	1.4	52.4
43.	0.80	0.30	0.30	25.7	20.8	87	79	1.3	141.8
44.	1.00	0.20	0.50	30.4	21.0	84	58	1.1	4.0
45.	1.10	0.40	0.70	31.1	18.4	76	46	0.6	23.4
46.	1.30	0.40	0.60	29.7	16.7	73	48	0.8	---
47.	1.40	0.60	0.90	30.0	15.2	74	45	0.3	---
48.	0.80	0.70	1.10	30.5	15.9	74	44	0.2	---
49.	0.50	0.30	0.80	28.8	16.4	71	47	0.3	---
50.	0.30	0.20	0.40	29.6	16.3	74	42	0.3	---

*L.B.B.- Lady bird beetle.

Dhaka and Pareek (2007*)* observed that the population of *coccinellids* increased gradually and reached to its maximum in first fortnight of November. The present results partially corroborates with those of Kapadia and Puri (1989) and Sharma *et al.* (2004) who reported that the predators of cotton pests were more active during September-October.

Dadas *et al.* (2019) reported that the two natural enemies *i.e.* lady bird beetle was recorded on pigeonpea during the course of investigation. The occurrence of the lady bird beetle commenced in the 41st SMW *i.e.* 0.10 adult/plant and continues till 51st SMW *i.e.* 0.20 adult/plant with the population attained its peak (0.60 adult/plant) in the 46th SMW.

4.2 Bioefficacy of various Insecticides against Pod Borer Complex of Pigeonpea

4.2.1 Bioefficacy against *Helicoverpa armigera*

4.2.1.1 After first spray

The effect of various treatments under investigation on the survival larvae of *H. armigera* is illustrated in Table 4.3 and Fig. 4.8.

The average number of *H.armigera* larvae per plant prior to insecticidal treatments ranged from 1.87 to 2.67 larvae/plant and differences among the treatments were non-significant.

The data recorded 3 days after spraying revealed that, all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.53 to 0.93 in the various insecticidal treatments as against 2.13 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was found to be most effective treatment and recorded 0.53 larvae per plant and was significantly superior over rest of the treatments. It was followed by the treatment with flubendiamide 39.35 % SC (0.63 larvae/plant) and indoxacarb 14.5 % SC (0.67 larvae/plant) which were at par with each other. The next best treatment were emamectin benzoate 5 % SG (0.73 larvae/plant) and lambda cyhalothrin 5 % EC (0.80 larvae/plant).

The observations of *H. armigera* larvae/plant recorded 7 days after spraying showed that the average number of larvae ranged from 0.33 to 0.80 larvae/plant in the insecticidal treatments as against 2.27 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5 % SC (0.33 larvae/ plant) was found significantly superior over all the treatment in reducing the *H.armigera* larval population expect the treatment with flubendiamide 39.35 % SC (0.53 larvae/plant) which were at par with each other. In order of efficacy the next best treatment were T_3, T_4, T_7, with 0.60, 0.63 and 0.67 larvae/plant, respectively.

At 14 days after first spraying *H. armigera* recorded larval population varied from 0.47 to 1.07 larvae/plant in the insecticidal treatments as against 2.53 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.47 larvae/ plant and was at par with flubendiamide 39.35 % SC with 0.60 larve/plant. The next promising treatments were by indoxacarb 14.5 % SC (0.73 larvae/plant) followed by T_2 (0.80 larvae/plant), T_7 and T_5 which were also at par with each other.

4.2.1.2 After Second spray

The effect of various insecticidal treatments on the survival of *H. armigera* after second spray was presented in Table 4.3 and graphically illustrated in Fig. 4.9.

From the results it was revealed that, 3 days after spray all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* ranged from 0.33 to 0.87 larvae/plant in the insecticidal treatments as against 2.67 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.33 larvae per plant and was significantly superior over rest of the treatments except the treatment flubendiamide 39.35 % SC (0.53 larvae/plant) which were at par with each other. The next promising treatments indoxacarb 14.5 % SC (0.60 larvae/plant) followed by the treatment with emamectin benzoate 5 % SG (0.67 larvae/plant) and T_7 (0.73 larvae/plant) which were at par with each other.

At 7 days after spray showed that the average number of *H. armigrea* larval population ranged from 0.27 to 0.67 larva/plant in different insecticidal treatments as against 2.87 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.27 larvae/ plant. In the order of effectiveness the next best treatment were flubendiamide 39.35 % SC (0.40 larvae/plant), indoxacarb 14.5 % SC (0.47 larvae/plant) and emamectin benzoate 5 % SG (0.53 larvae/ plant).

The observations on *H. armigera* larval population at 14 days after spray showed that the average number of larval population ranged from 0.40 to 0.87 larvae/plant in various insecticidal treatments as against 3.07 larvae/plant in untreated control.

From the result it was revealed that the treatment with chlorantraniliprole 18.5 % SC was found to be significantly superior over all the treatment with least *H. armigera larval* population of 0.40 larvae/plant. It was followed by the treatment with flubendiamide 39.35 % SC with 0.58 larvae/plant and were at par with each other. The next best treatment were indoxacarb 14.5 % SC (0.60 larvae/plant), emamectin benzoate 5% SG (0.63 larvae/plant) and chlorpyriphos 20 % SC (0.80 larvae/plant). Untreated control recorded maximum *H. armigera* larval population (3.07 larvae/plant).

4.2.1.3 After third spray

The effect of various treatments under investigation on survival larval population of *H. armigera* is illustrated in Table 4.3 and Fig. 4.10.

The data recorded 3 days after spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.20 to 0.67 larvae/plant in the insecticidal treatments as against 3.13 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.20 larvae/plant which was significantly superior over rest of the treatments expect the treatment with flubendiamide 39.35 % SC (0.47 larvae/plant) which were at par with each other. The next effective treatments were indoxacarb 14.5 % SC (0.53 larvae/plant), emamectin benzoate 5 % SG (0.58 larvae/plant), lambda cyhalothrin 5 % EC (0.60 larvae/plant), chlorpyriphos 20 % EC (0.63 larvae/plant) and quinolphos 25 % EC (0.67 larvae/plant) which were on par with each other.

Table 4.3 Bioefficacy of various insecticides against *Helicoverpa armigera* on pigeonpea

Tr. No.	Treatments	Dose ml or gm/Lit	Number of *H. armigera* larvae/plant									
			Precount	After 1st Spray			After 2nd Spray			After 3rd Spray		
				3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
T_1	Quinalphos 25 EC	2.00 ml	2.40 (1.70)	0.93 (1.20)	0.80 (1.14)	1.07 (1.25)	0.87 (1.17)	0.67 (1.08)	0.87 (1.17)	0.67 (1.08)	0.63 (1.06)	0.80 (1.14)
T_2	Emamectin benzoate 5 SG	0.40 gm	2.20 (1.64)	0.73 (1.11)	0.63 (1.06)	0.80 (1.14)	0.67 (1.08)	0.53 (1.06)	0.63 (1.06)	0.58 (1.04)	0.47 (0.98)	0.63 (1.06)
T_3	Indoxacarb 14.5 SC	0.70 ml	1.87 (1.54)	0.67 (1.08)	0.60 (1.05)	0.73 (1.11)	0.60 (1.05)	0.47 (0.98)	0.60 (1.05)	0.53 (1.01)	0.47 (0.98)	0.58 (1.04)
T_4	Chlorantraniliprole 18.5 SC	0.30 ml	2.13 (1.62)	0.53 (1.01)	0.33 (0.91)	0.47 (0.98)	0.33 (0.91)	0.27 (0.88)	0.40 (0.95)	0.20 (0.83)	0.13 (0.79)	0.33 (0.91)
T_5	Chlorpyriphos 20 SC	2.00 ml	2.67 (1.78)	0.87 (1.17)	0.73 (1.29)	0.93 (1.20)	0.80 (1.14)	0.63 (1.06)	0.80 (1.14)	0.63 (1.06)	0.60 (1.05)	0.73 (1.11)
T_6	Flubendiamide 39.35 SC	0.25 ml	2.20 (1.64)	0.63 (1.06)	0.53 (1.01)	0.67 (1.08)	0.53 (1.01)	0.40 (0.95)	0.58 (1.04)	0.47 (0.98)	0.40 (0.95)	0.53 (1.01)
T_7	Lambda cyhalothrin 5 EC	1.00 ml	2.33 (1.68)	0.80 (1.14)	0.67 (1.08)	0.87 (1.17)	0.73 (1.11)	0.58 (1.04)	0.67 (1.08)	0.60 (1.05)	0.53 (1.01)	0.67 (1.08)
T_8	Untreated control	-	1.87 (1.54)	2.13 (1.62)	2.27 (1.66)	2.53 (1.74)	2.67 (1.78)	2.87 (1.84)	3.07 (1.89)	3.13 (1.28)	3.27 (1.94)	3.33 (1.95)
	S E ±		0.08	0.05	0.06	0.06	0.06	0.05	0.04	0.07	0.07	0.06
	C D at 5 %		N.S.	0.15	0.18	0.18	0.19	0.17	0.12	0.21	0.23	0.18
	C V %		12.26	12.17	13.11	12.66	13.43	12.54	12.07	13.78	13.26	12.87

Figures in parentheses are √x+0.5 transformed value.

The data recorded at 7 days after spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.13 to 0.63 larvae/plant in the insecticidal treatments as against 3.27 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.13 larvae/plant which was followed by the treatment with flubendiamide 39.35 % SC (0.40 larvae/plant) and were at par with each other. The next promising treatments were indoxacarb 14.5 % SC (0.47 larvae/plant), emamectin benzoate 5 % SG (0.47 larvae/plant), lambda cyhalothrin 5 % EC (0.53 larvae/plant) and chlorpyriphos 20 % SC (0.60 larvae/plant). Untreated control recorded maximum of 3.27 larvae/plant.

From the data it was noticed that at 14 DAS all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.33 to 0.80 in the insecticidal treatments as against 3.33 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment with 0.33 larvae per plant and was significantly superior over rest of the treatments except the treatment flubendiamide 39.35 % SC (0.53 larvae/plant) and were at par with each other. The next best treatments in effectiveness were indoxacarb 14.5 % SC (0.58 larvae/plant), emamectin benzoate 5 % SG (0.63 larvae/plant) and lambda cyhalothrin 5 % EC (0.67 larvae/plant) and were at par with each other.

4.2.2 Bioefficacy against *Maruca vitrata*

4.2.2.1 After first spray

Data prataining to bioeficacy of various insecticides against *M. vitrata* on pigeonpea is presented in Table 4.4 and Fig. 4.11. The average number of *M. vitrata* larvae/plant prior to insecticidal treatments were ranged from 2.53 to 3.13 larvae/plant and non significant differences amongst the treatments were noticed.

The data recorded at 3 days after spraying revealed that, all the insecticidal treatments were significantly superior over untreated control. The average number of *M. vitrata* larvae/plant ranged from 0.58 to 1.20 in the insecticidal treatments as against 2.67 in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.58 larvae per plant and was significantly superior over rest of the treatments. The second best treatment was flubendiamide 39.35 % SC (0.73 larvae/plant) which were at par with each other. The next promising treatment were quinolphos 25 % EC (0.87 larvae/plant), emamectin benzoate 5 % SG (1.07 larvae/plant) and indoxacarb 14.5 % SE (0.93 larvae/plant).

The observations on larval population of *M. vitrata* recorded at 7 days after spray showed that the average number of larvae ranged from 0.40 to 1.07 larvae/plant in the insecticidal treatments as against 2.73 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was found to be most effective treatment with least no. of *M. vitrata* larvae (0.40 larvae/plant) followed by the treatment with flubendamide 39.35 % SC (0.58 larvae/plant) which were at par with each other . In order of effectiveness the next best treatment were T_1, T_3 and T_2 with 0.73, 0.80 and 0.87 larvae/plant respectively.

Data on *M. vitrata* larval population at 14 DAS showed significant differences amongst the various treatment under study and the average number of larvae ranged from 0.60 to 1.13 larvae plant as against 2.80 larvae/plant in an untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments with 0.60 larvae/plant and was at par with flubendamide 39.35 % SC, quinalphos 25 % EC and indoxacarb 14.5 % SC with 0.60, 0.80 and 0.87 larvae/plant respectively. In the order of effectiveness the next best treatment were T_2 (0.93 larvae/plant), T_7 (1.07 larvae/plant) and T_5 (1.13 larvae/ plant).

4.2.2.2 After second spray

The effect of various treatments on survival larval population of *M. vitrata* is given in Table Table 4.4 and graphically depicted in Fig. 4.12.

The data recorded 3 days after spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. vitrata* larvae/plant ranged from 0.47 to 0.93 in the insecticidal treatments as against 2.87 larvae/plant in untreated control.

The treatment with chlorantraniliprol 18.5 % SC was found to be most effective treatment and suppressing larval population of 0.47 larvae /plant which was followed by the treatment with flubendamide 39.35 % SC (0.58 larvae/plant), quinalphos 25 % EC (0.63 larvae/plant) and indoxacarb 14.5 % SC (0.67 larvae/plant) which were at par with each other. The next promising treatment were T_2 followed by T_7 and T_5 with 0.73, 0.87 and 0.93 larvae/plant, respectively.

At the 7 days after spray, the average survived larval population of *M. vitrata* ranged from 0.33 to 0.80 larvae/plant in the insecticidal treatments as against 2.93 larvae/plant in untreated control.

From the results it was revealed that, chlorantraniliprole 18.5 % SC was found significantly superior over all the treatments which recorded 0.33 larvae/plant and followed by the treatment flubendamide 39.35 % SC (0.47 larvae/plant) which were at par with each other. Next best treatment were quinolphos 25 % EC (0.58 larvae/plant), indoxacarb 14.5 % SC (0.60 larvae/plant) and emamectin benzoate 5 % SG (0.63 larvae/plant) and were at par with each other.

Larval population of *M. vitrata* at 14 days after sprays varied from 0.40 to 1.07 larvae/plant in the insecticidal treatments as against 3.13 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was proved to be the promising treatment in lowering the *M. vitrata* larval population which recorded 0.40 larvae/ plant. It was followed by flubendamide 39.35 % SC (0.53 larvae/plant) and were at par with each other. Next promising treatment were quinolphos 25 % EC and indoxacarb 14.5 % SC with 0.60 and 0.80 larvae/plant.

4.2.2.3 After third spray

The effect of various treatments against larval population of *M. vitrata* is illustrated in Table 4.4 Fig. 4.13.

From the data on larval population of *M. vitrata* at 3 DAS revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. vitrata* larvae/plant ranged from 0.27 to 0.80 in the insecticidal treatments as against 3.21 in untreated control.

Table 4.4 Bioefficacy of various insecticides against *Maruca vitrata* on pigeonpea

Tr. No.	Treatments	Dose ml or gm/Lit	Number of *Maruca vitrata* larvae/plant									
			Precount	After 1st Spray			After 2nd Spray			After 3rd Spray		
				3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
T_1	Quinalphos 25 EC	2.00 ml	2.80 (1.82)	0.87 (1.14)	0.73 (1.11)	0.80 (1.14)	0.63 (1.06)	0.58 (1.04)	0.60 (1.05)	0.47 (0.98)	0.33 (0.91)	0.53 (1.01)
T_2	Emamectin benzoate 5 SG	0.40 gm	2.67 (1.78)	1.07 (1.25)	0.87 (1.14)	0.93 (1.20)	0.73 (1.11)	0.63 (1.06)	0.87 (1.17)	0.58 (1.04)	0.47 (0.98)	0.63 (1.06)
T_3	Indoxacarb 14.5 SC	0.70 ml	2.87 (1.84)	0.93 (1.20)	0.80 (1.14)	0.87 (1.14)	0.67 (1.08)	0.60 (1.05)	0.80 (1.14)	0.53 (1.01)	0.40 (0.95)	0.58 (1.04)
T_4	Chlorantraniliprole 18.5 SC	0.30 ml	3.00 (1.87)	0.58 (1.04)	0.40 (0.95)	0.60 (1.05)	0.47 (0.98)	0.33 (0.91)	0.40 (0.95)	0.27 (0.88)	0.20 (0.83)	0.33 (0.91)
T_5	Chlorpyriphos 20 SC	2.00 ml	2.53 (1.74)	1.20 (1.30)	1.07 (1.25)	1.13 (1.28)	0.93 (1.20)	0.80 (1.14)	1.07 (1.25)	0.80 (1.14)	0.63 (1.06)	0.87 (1.14)
T_6	Flubendiamide 39.35 SC	0.25 ml	3.13 (1.91)	0.73 (1.01)	0.58 (1.04)	0.63 (1.06)	0.58 (1.04)	0.47 (0.98)	0.53 (1.01)	0.40 (0.95)	0.27 (0.88)	0.47 (0.98)
T_7	Lambda cyhalothrin 5 EC	1.00 ml	2.73 (1.79)	1.13 (1.28)	0.93 (1.20)	1.07 (1.25)	0.87 (1.14)	0.73 (1.11)	0.93 (1.28)	0.67 (1.08)	0.53 (1.01)	0.80 (1.08)
T_8	Untreated control	----	2.63 (1.77)	2.67 (1.78)	2.73 (1.80)	2.80 (1.82)	2.87 (1.84)	2.93 (1.85)	3.13 (2.28)	3.21 (1.93)	3.33 (1.95)	3.53 (1.99)
	S E ±		0.09	0.06	0.07	0.06	0.06	0.05	0.05	0.06	0.05	0.05
	C D at 5 %		N.S.	0.19	0.22	0.18	0.15	0.19	0.16	0.18	0.15	0.16
	C V %		13.17	12.54	12.18	11.76	10.82	12.13	11.56	11.92	12.03	12.14

Figures in parentheses are $\sqrt{x+0.5}$ transformed value

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.27 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.40 larvae/plant) which were at par with each other. The next promising treatment was quinolphos 25 % EC (0.47 larvae/plant), indoxacarb 14.5 % SC (0.53 larvae/plant) and emamectin benzoate 5 % SG (0.58 larvae/plant) which were at par with each other.

At 7 days after third spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. vitrata* larvae/plant ranged from 0.20 to 0.63 in the insecticidal treatments as against 3.33 in untreated control. Among the all treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.20 larvae /plant except the treatment with flubendamide 39.35 % SC (0.27 larvae/plant) which were at par with each other. In order of efficacy the next best treatment were quinolphos 25 % EC (0.33 larvae/plant) which is at par with indoxacarb 14.5 % SC (0.40 larvae/plant).

The data recorded 14 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. vitrata* larvae/plant ranged from 0.33 to 0.87 in the insecticidal treatments as against 3.53 in untreated control. The treatment with chlorantraniliprol 18.5 % SC was most effective treatment and recorded 0.33 larvae per plant except the treatment with T6 (0.47 larvae/plant) which is followed by quinolphos 25 % EC and indoxacarb 14.5 % SC at par with each other with 0.53 and 0.58 larvae/plant.

4.2.3 Bioefficacy against *Exelastis atomosa*

The incidence of tur plume moth was observed 10th day after first spray.

4.2.3.1 After second spray

The effect of various treatments under investigation on the survival larvae of *E. atomosa* is illustrated in Table 4.5 Fig. 4.14. The average number of *E.atomosa* larvae per plant prior to insecticidal treatments ranged from 2.40 to 2.93 larvae/plant and differences among the treatments were non-significant.

The observations of *E. atomosa* recorded 3 days after spraying showed that the average number of larvae ranged from 0.53 to 0.93 larvae/plant in the insecticidal treatments as against 2.58 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.53 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.60 larvae/plant) The next best treatment were indoxacarb 14.5 % SC and emamectin benzoate 5 % SG which were at par with each other with 0.67 and 0.73 larvae/plant.

The observations of *E. atomosa* recorded at 7 days after spraying showed that the average number of larvae ranged from 0.40 to 0.87 larvae/plant in the insecticidal treatments as against 2.63 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.40 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.47 larvae/plant). Next best treatmentwere indoxacarb 14.5 % SC (0.53 larvae/plant) and emamectin benzoate 5 % SG (0.67 larvae/plant) at par with each other.

The data recorded 14 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average numberof *E. atomosa* larvae/plant ranged from 0.58 to 1.07 larvae/plant in the insecticidal treatments as against 2.67 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.58 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.63 larvae/plant) followed by indoxacarb 14.5 % SC (0.73 larvae/plant).

4.2.3.2 After third spray

The effect of various treatments under investigation on the survival larvae of *E.atomosa* is illustrated in Table 4.5 Fig. 4.15.

The data recorded 3 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *E.atomosa* larvae/plant ranged from 0.20 to 0.63 larvae/plant in the insecticidal treatments as against 3.07 larvae/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.20 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.27 larvae/plant). The next best treatment were indoxacarb 14.5 % SC and emamectin benzoate 5 % SG which were at par with each other with 0.40 and 0.47 larvae/plant.

Table 4.5 Bioefficacy of various insecticides against *Exelastis atomosa* on pigeonpea

Tr. No.	Treatments	Dose ml or gm/Lit	Number of *Exelastis atomosa* larvae/plant						
			Precount	After 2nd Spray			After 3rd Spray		
				3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
T_1	Quinalphos 25 EC	2.00 ml	2.63 (1.77)	0.80 (1.14)	0.73 (1.11)	0.87 (1.17)	0.53 (1.01)	0.47 (0.98)	0.60 (1.05)
T_2	Emamectin benzoate 5 SG	0.40 gm	2.40 (1.70)	0.73 (1.11)	0.67 (1.08)	0.80 (1.14)	0.47 (0.98)	0.40 (0.95)	0.58 (1.04)
T_3	Indoxacarb 14.5 SC	0.70 ml	2.80 (1.52)	0.67 (1.08)	0.53 (1.01)	0.73 (1.11)	0.40 (0.95)	0.33 (0.91)	0.53 (1.01)
T_4	Chlorantraniliprole 18.5 SC	0.30 ml	2.67 (1.78)	0.53 (1.01)	0.40 (0.95)	0.58 (1.04)	0.20 (0.83)	0.13 (0.79)	0.27 (0.88)
T_5	Chlorpyriphos 20 SC	2.00 ml	2.93 (1.85)	0.87 (1.17)	0.80 (1.14)	0.93 (1.20)	0.60 (1.05)	0.53 (1.01)	0.67 (1.08)
T_6	Flubendiamide 39.35 SC	0.25 ml	2.73 (1.80)	0.60 (1.05)	0.47 (0.98)	0.63 (1.06)	0.27 (0.88)	0.20 (0.83)	0.40 (0.95)
T_7	Lambda cyhalothrin 5 EC	1.00 ml	2.53 (1.74)	0.93 (1.20)	0.87 (1.17)	1.07 (1.25)	0.63 (1.06)	0.58 (1.04)	0.73 (1.11)
T_8	Untreated control	-	2.47 (1.72)	2.58 (1.75)	2.63 (1.77)	2.67 (1.78)	3.07 (1.89)	3.13 (1.91)	3.27 (1.94)
	S E ±	-	0.08	0.05	0.06	0.05	0.05	0.06	0.05
	C D at 5 %	-	N.S.	0.15	0.18	0.15	0.16	0.18	0.16
	C V %	-	13.64	12.76	12.05	11.91	12.04	13.05	12.54

Figures in parentheses are $\sqrt{x+0.5}$ transformed value

The observations of *E. atomosa* recorded at 7 days after spraying showed that the average number of larvae ranged from 0.13 to 0.58 larvae/plant in the insecticidal treatments as against 3.13 larvae/plant in untreated control.

The treatment with chlorantraniliprol 18.5 % SC was significantly superior over all the treatments which recorded 0.13 larvae/plant except the treatment with flubendiamide 39.35 % SC (0.20 larvae/plant) which is followed by indoxacarb 14.5 % SC, emamectin benzoate 5 % SG which were at par with each other with 0.33 and 0.40 larvae/plant.

The data recorded 14 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *E. atomosa* larvae/plant ranged from 0.27 to 0.73 larvae/plant in the insecticidal treatments as against 3.27 larvae/plant in untreated control.

The treatment with chlorantraniliprol 18.5 % SC was most effective treatment and recorded 0.27 larvae per plant except the treatment with Flubendiamide 39.35 % SC (0.40 larvae/plant).

The next effective treatment were indoxacarb 14.5 % SC, emamectin benzoate 5 % SG, quinolphos 25 % EC (0.60 larvae/plant) at par with each other with 0.53, 0.58 and 0.60 larvae/plant, respectively.

4.2.4 Bioefficacy against *Melanagromyza obtusa*

The incidence of tur pod was observed 12th day after first spray.

4.2.4.1 After second spray

The effect of various treatments under investigation on the survival maggots of *M. obtusa* is illustrated in Table 4.6 and Fig. 4.16.

The average number of *M. obtusa* maggots prior to insecticidal treatments ranged from 2.20 to 3.13 maggots/10 pods and differences among the treatments were non-significant.

The data recorded at 3 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. obtusa* mggots/10 pods ranged from 0.40 to 0.87 mggots/10 pods in the insecticidal treatments as against 2.33 mggots/10 pods in untreated control.

Table 4.6 Bioefficacy of various insecticides against *Melanagromyza obtusa* on pigeonpea

Tr. No.	Treatments	Dose ml or gm/Lit	Number of *Melanagromyza obtusa* maggots/10 pods						
			Precount	After 2nd Spray			After 3rd Spray		
				3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
T_1	Quinalphos 25 EC	2.00 ml	2.67 (1.78)	0.67 (1.08)	0.63 (1.06)	0.80 (1.14)	0.53 (1.01)	0.47 (0.98)	0.60 (1.05)
T_2	Emamectin benzoate 5 SG	0.40 gm	3.07 (1.89)	0.80 (1.14)	0.73 (1.11)	0.93 (1.20)	0.60 (1.05)	0.58 (1.04)	0.63 (1.06)
T_3	Indoxacarb 14.5 SC	0.70 ml	3.13 (1.96)	0.63 (1.06)	0.60 (1.05)	0.67 (1.08)	0.47 (0.98)	0.40 (0.95)	0.53 (1.01)
T_4	Chlorantraniliprole 18.5 SC	0.30 ml	2.63 (1.77)	0.40 (0.95)	0.33 (0.91)	0.47 (0.98)	0.20 (0.83)	0.13 (0.79)	0.27 (0.88)
T_5	Chlorpyriphos 20 SC	2.00 ml	2.93 (1.85)	0.87 (1.17)	0.80 (1.14)	1.07 (1.25)	0.63 (1.06)	0.60 (1.05)	0.67 (1.07)
T_6	Flubendiamide 39.35 SC	0.25 ml	2.87 (1.84)	0.58 (1.04)	0.53 (1.01)	0.60 (1.05)	0.40 (0.95)	0.33 (0.91)	0.47 (0.98)
T_7	Lambda cyhalothrin 5 EC	1.00 ml	2.93 (1.85)	0.73 (1.11)	0.67 (1.08)	0.87 (1.17)	0.58 (1.04)	0.53 (0.01)	0.67 (1.08)
T_8	Untreated control	-	2.20 (1.64)	2.33 (1.68)	2.47 (1.72)	2.63 (1.77)	3.27 (1.94)	3.33 (1.96)	3.47 (1.99)
	S E ±	-	0.07	0.05	0.06	0.07	0.06	0.08	0.06
	C D at 5 %	-	N.S.	0.15	0.18	0.21	0.18	0.24	0.17
	C V %	-	13.28	12.14	11.86	13.07	13.07	13.24	11.76

Figures in parentheses are $\sqrt{x+0.5}$ transformed value

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.40 maggots/10 pods and was significantly superior over rest of the treatment except the treatment with flubendiamide 39.35 % SC (0.58 maggots/10 pods) which is followed by indoxacarb 14.5 % SC, quinalphos 25 % EC and and lambda cyhalothrin 5 % EC at par with each other with 0.63, 0.67 and 0.73 maggots/10 pods.

The observations of *M. obtusa* recorded 7 days after spraying showed that the average number of maggots ranged from 0.33 to 0.80 maggots/10 pods in the insecticidal treatments as against 2.47 maggots/plant in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all the treatments which recorded 0.33 maggots/10 pods except the treatment flubendiamide 39.35 % SC (0.53 maggots/10 pods). Next best treatment were indoxacarb 14.5 % SC, quinolphos 25 % EC and lambda cyhalothrin 5% EC which is at par with each other with 0.60, 0.63 and 0.67 maggots/10 pods.

The observations of *M. obtusa* recorded at 14 days after spraying showed that the average number of maggots ranged from 0.47 to 1.07 maggots/10 pods in the insecticidal treatments as against 2.63 maggots/10 pods in untreated control.

The treatment with chlorantraniliprol 18.5 % SC was significantly superior over all the treatments which recorded 0.47 maggots/10 pods except the flubendiamide 39.35 % SC (0.60 maggots/10 pods). Next best treatment were indoxacarb 14.5 % SC, quinolphos 25 % EC and lambda cyhalothrin 5 % EC at par with each other with 0.67, 0.80 and 0.87 maggots/10 pods.

4.2.4.2 After third spray

The effect of various treatments under investigation on the survival maggots of *M.obtusa* is illustrated in Table 4.6 and Fig. 4.17.

The data recorded 3 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M.obtusa* maggots/10 pods ranged from 0.20 to 0.63 maggots/10 pods in the insecticidal treatments as against 3.27 maggots/10 pods in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.20 maggots/10 except the treatment with flubendiamide 39.35 % SC (0.40 mggots /10 pods) which is followed by indoxacarb 14.5 % SC, quinolphos 25

% EC and lambda cyhalothrin 5 % EC at par with each other with 0.47, 0.53 and 0.58 maggots/10 pods.

The observations of *M. obtusa* recorded 7 days after spraying showed that the average number of maggots ranged from 0.13 to 0.60 maggots/10 pods in the insecticidal treatments as against 3.33 maggots/10 pods in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was significantly superior over all treatments which recorded 0.13 maggots/10 pods except the treatment with flubendiamide 39.35 % SC (0.33 mggots/10 pods) followed by indoxacarb 14.5 % SC, quinolphos 25 % EC and lambda cyhalothrin 5 % EC which were at par with each other with 0.40, 0.47 and 0.53 maggots/10 pods.

The data recorded 14 days after spraying revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *M. obtusa* maggots/10 pods ranged from 0.27 to 0.67 maggots/10 pods in the insecticidal treatments as against 3.47 maggots/10 pods in untreated control.

The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and recorded 0.27 maggots per plant and was significantly superior over rest of the treatments. In order of effectiveness the next promising treatment were flubendiamide 39.35 % SC (0.47 mggots/10 pods) which is followed by indoxacarb 14.5 % SC, quinolphos 25 % EC and emamectin benzoate 5 % SG at par with each other with 0.53, 0.60 and 0.63 maggots/10 pods.

4.2.5 Bioefficacy of the various Insecticide Treatments against per cent pod bamage due to pod borer complex

4.2.5.1 Pod damage inflicted by *Helicoverpa armigera*

The data on effect of insecticide treatments on pigeonpea due to *H. armigera* based on observations of pods after final harvest are presented in Table. 4.7 and Fig. 4.18.

The data indicated that, all the treatments with insecticide were significantly superior over the untreated control. Maximum pod damage of 22.64 per cent due to *H. armigera* plot was recorded in untreated control plot whereas, per cent pod damage in various insecticide treated plot varied from 3.64 to 9.21 per cent.

Amongst the treatments, chlorantraniliprole 18.5 % SC recorded least pod damage of 3.64 per cent and remain superior over all the treatments. The next promising treatments were flubendiamide 39.35 % SC (4.82 %) followed by indoxacarb 14.5 % SC (6.12 %) and emamectin benzoate 5 % SG (6.64 %) which were at par with each other.

4.2.5.2 Pod damage inflicted by *Exelastis atomosa*

The data on pod damage caused due to tur plume moth, *E. atomosa.* Table 4.7 and Fig. 4.18 revealed that, the damage was to the extent of 8.57 % per cent in untreated control plot.

Table 4.7 Bioefficacy of various insecticides against per cent pod damage due to pod borer complex

Tr. No.	Treatment	Dose ml or gm/Lit	Per cent pod damage due to			Total pod damage %
			H.armigera	***E.atomosa***	***M.obtusa***	
T_1	Quinalphos 25 EC	2.00 ml	9.21 (17.64)	4.76 (12.52)	5.63 (13.63)	19.60 (26.26)
T_2	Emamectin benzoate 5 SG	0.40 gm	6.64 (14.87)	3.98 (11.43)	4.72 (12.45)	15.34 (23.04)
T_3	Indoxacarb 14.5 SC	0.70 ml	6.12 (14.26)	3.67 (10.98)	4.38 (12.02)	14.17 (22.10)
T_4	Chlorantraniliprole 18.5 SC	0.30 ml	3.64 (10.94)	2.13 (8.31)	3.05 (9.92)	8.82 (17.23)
T_5	Chlorpyriphos 20 SC	2.00 ml	8.17 (16.56)	4.53 (12.22)	5.21 (13.09)	17.91 (24.97)
T_6	Flubendiamide 39.35 SC	0.25 ml	4.82 (12.59)	2.97 (9.84)	3.74 (11.05)	11.53 (19.83)
T_7	Lambda cyhalothrin 5 EC	1.00 ml	7.80 (1.16)	4.12 (11.64)	4.92 (12.27)	16.84 (24.21)
T_8	Untreated control	----	22.64 (28.40)	8.57 (16.98)	9.38 (17.81)	40.59 (39.51)
	S E ±	-	0.75	0.89	0.92	---
	C D at 5 %	-	2.28	2.71	2.78	---
	C V %	-	11.67	13.20	12.78	---

Figures in parentheses are $\sqrt{x+0.5}$ transformed value

All the evaluated insecticides were highly effective in reducing the pod damage and varied from 2.13 to 4.76 per cent.

The treatment with chlorantraniliprole 18.5 % SC recorded least pod damage of 2.13 % and remain superior over all the treatments. The next promising treatments were flubendiamide 39.35 % SC (2.97 %), indoxacarb 14.5 % SC (3.67 %), emamectin benzoate 5 % (3.98 %), lambda cyhalothrin 5 % EC (4.12 %), chlorpyriphos 20 % EC (4.53%) and quinolphos 25 % EC (4.76 %) which were at par with each other.

4.2.5.3 Pod damage inflicted by *Melanagromyza obtusa*

Infestation of pods due to pod fly, *M.obtusa* was presented in (Table 4.7 and Fig. 4.18) revealed that the damage in the untreated plot was to the extent of 9.38 per cent.

All the insecticidal treatments recorded significantly lower pod damage which was in the range of 3.05 to 5.63 per cent.

Treatment with chlorantraniliprol 18.5 % SC recorded minimum pod damage of 3.05 per cent and remain superior over all the treatments. The next promising treatments were flubendiamide 39.35% SC, indoxacarb 14.5% SC, emamectin benzoate 5 %, lambda cyhalothrin 5 % EC, chlorpyriphos 20 % EC and quinolphos 25 % EC, which were at par with each other with 3.74, 4.38, 4.72, 4.92, 5.21 and 5.63 per cent pod damage, respectively.

4.2.5.4 Collective pod damage due to pod borers

The data on collective pod damage due to all pod borers presented in Table 4.7. Infestation of pods in untreated plot was to the extent of 40.59 %. All the insecticidal treatments recorded significantly lower pod damage as against untreated control.

From the data, it was revealed that, the treatment with chlorantraniliprole 18.5 % SC recorded least pod damage of 8.82 per cent and remained superior over all the treatments. The next promising treatments were flubendiamide 39.35 % SC (11.53 %) followed by indoxacarb 14.5 % SC (14.17 %) emamectin benzoate 5 % SG (15.34 %) lambda cyhalothrin 5 % EC (16.84 %), chlorpyriphos 20 % EC (17.91%) and quinolphos 25% EC (19.60 %).

4.2.6 Efficacy of the Treatments in Reducing Grain Damage

4.2.6.1 Grain damage influenced by *Helicoverpa armigera*

The data on grain damage caused by pigeonpea pod borer complex is presented in Table 4.8 and graphically depicted in Fig. 4.19. It indicated that the damage due to the *H. armigera* was 24.64 per cent in untreated plot as against 6.37 to 14.49 per cent in treated plots.

All the insecticidal treatments were significantly superior over untreated control in reducing the per cent the grain damage. The treatment with chlorantraniliprol 18.5 % SC recorded lowest grain damage of 6.37 % followed by flubendiamide 39.35 % SC (8.02 %), indoxacarb 14.5 % SC (8.94 %), emamectin benzoate 5 % SG (9.24 %), lambda cyhalothrin 5 % EC (10.87 %) chlorpyriphos 20 % EC (12.21 %), quinolphos 25 % EC (14.49 %).

4.2.6.2 Grain damage influenced by *Exelastis atomosa*

The data on grain damage presented in Table 4.8 and fig. 4.19 indicated that the damage due to plume moth was 16.13 per cent in untreated plot against 5.34 to 11.02 per cent in treated plots.

All the insecticidal treatments were significantly superior over untreated control in minimizing the grain damage.

Among the all treatments with chlorantraniliprole 18.5 % SC recorded lowest grain damage of 5.34 % followed by flubendiamide 39.35 % SC (6.45 %), indoxacarb 14.5 % SC (7.70 %) and emamectin benzoate 5 % SG (7.93 %) which were at par with each other.

4.2.6.3 Grain damage influenced by *Melanagromyza obtusa*

The data on grain damage caused due to pod fly, *M.obtusa* (Table 4.8 and Fig. 4.19) revealed that the damage was 20.22 per cent in untreated plot while the range of damge was 7.83 to 12.29 per cent grain damage in insecticide treated plots.

All the insecticidal treatments were significantly superior over untreated control minimizing the grain damage.

Among the treatments chlorantraniliprole 18.5 % SC recorded lowest grain damage of 7.83 per cent followed by flubendiamide 39.35 % SC (9.98 %) and indoxacarb 14.5 % SC (10.07) which were at par with each other.

4.2.7 Effect of different treatments on grain yield of pigeonpea.

Data pertaining to effect of different treatments on grain yield of pigeonpea is presented in Table 4.9 and Fig. 4.20. From the data it was noticed that all the insecticide treatments were found significantly superior over untreated control.

Table 4.8 Bioefficacy of various insecticides against per cent grain damage due to pod borer complex

Tr. No.	Treatment	Dose ml or gm/Lit	Per cent grain damage due to			Total grain damage %
			H.armigera	*E.atomosa*	*M.obtusa*	
T_1	Quinalphos 25 EC	2.0 ml	14.49 (22.36)	11.02 (19.36)	12.29 (20.51)	37.50 (37.76)
T_2	Emamectin benzoate 5 SG	0.4 gm	9.24 (17.69)	7.93 (16.32)	10.46 (18.85)	27.63 (31.70)
T_3	Indoxacarb 14.5 SC	0.7 ml	8.94 (17.36)	7.70 (16.06)	10.07 (18.48)	26.71 (31.11)
T_4	Chlorantraniliprole 18.5 SC	0.3 ml	6.37 (14.57)	5.34 (13.29)	7.83 (16.20)	19.54 (26.22)
T_5	Chlorpyriphos 20 SC	2.8 ml	12.21 (20.43)	10.22 (18.62)	11.37 (19.69)	33.80 (35.54)
T_6	Flubendiamide 39.35 SC	0.25 ml	8.02 (16.40)	6.45 (14.65)	9.98 (18.40)	24.45 (29.62)
T_7	Lambda cyhalothrin 5 EC	1.0 ml	10.87 (19.22)	8.71 (17.14)	11.28 (19.60)	30.86 (33.73)
T_8	Untreated control	---	24.64 (29.75)	16.13 (23.31)	20.22 (26.69)	62.99 (52.53)
	S E ±	-	0.98	0.84	0.86	---
	C D at 5 %	-	2.95	2.54	2.60	---
	C V %	-	13.18	14.21	12.82	---

Figures in parentheses are $\sqrt{x+0.5}$ transformed value

Maximum pigeonpea grain yield of 17.18 q/ha was harvested from the treatment with chlorantraniliprole 18.5 % SC and it was significantly superior over rest of the treatment. Next promising treatment were T_6, T_3 and T_2 with 16.19, 15.55 and 14.92 q/ha grain yield respectively. It was followed by the treatment with lambda cyhalothrin 5 % EC (14.57 q/ha), chlorpyriphos 20 % EC (14.07 q/ha) , quinolphos 25 % EC (13.45q/ha).Untreated plot registered lowest yield (9.63 q/ha) of pigeonpea.

On the basis of influence of treatment on yield chlorantraniliprol 18.5 % SC is best treatment which is followed by flubendiamide 39.35 % SC. During the present investigation chlorantraniliprole 18.5 % SC were found most effective with significantly high reduction of pod and grain damage collectively due to *H. armigera, E. atomosa* and *M. obtuse.* The present findings in respect of chlorantraniliprole 18.5 % SC are in agreement with those of Dadas *et al.* (2019a). The performance of spinosad has been well documented by earlier workers like Rani *et al.* (2018) and Patel and Patel (2013). Similarly, Sreekanth *et al.* (2013) obtained effective control of pod borers through application of chlorantraniliprole 18.5 per cent in pigeonpea. The findings of these workers are confirmative with present findings.

The next treatment in order of efficacy against collective pod and grain damage flubendiamide 39.35 % SC. This result is in conformity with the findings of Priyadarshini *et al*. (2013) and Wadaskar *et al.* (2013) proved to be the best treatment in reducing the pod damage. Similarly, Deshmukh *et al.* (2010) determined that flubendiamide 0.007 per cent in pigeonpea was found the most effective in reducing the *H. armigera* population and pod damage and showed that the highest yield of 1850 kg ha^{-1} and cost benefit ratio of 1:6.10. Similar with Tohinshi *et al.* (2010).

Table 4.9. Effect of insecticidal treatment on grain yield of pigeonpea

Tr. No.	Treatment	Dose ml or gm/Lit	Yield (kg /plot)	Yield (q/ha)
T_1	Quinalphos 25 EC	2.0 ml	2.18	13.45
T_2	Emamectin benzoate 5 SG	0.4 gm	2.42	14.92
T_3	Indoxacarb 14.5 SC	0.7 ml	2.52	15.55
T_4	Chlorantraniliprole 18.5 SC	0.3 ml	2.78	17.18
T_5	Chlorpyriphos 20 SC	2.8 ml	2.28	14.07
T_6	Flubendiamide 39.35 SC	0.25 ml	2.62	16.19
T_7	Lambda cyhalothrin 5 EC	1.0 ml	2.36	14.57
T_8	Untreated control	---	1.56	9.63
	S E ±	-	-	0.76
	C D at 5 %	-	-	2.28
	C V %	-	-	14.27

Plot size : 4.5 x 3.6 m^2 Hector factor : 617.28

The next best treatment in order of effectiveness was Indoxacarb 14.5 % SE. These results corroborate the findings of Meena *et al.(*2018) which is similar with

Patange and Chiranjeevi (2013) and Dinesh *et al.* (2017), who reported that indoxacarb 14.5 % SC provided good control against pod borer complex of pigeonpea.

The next primising treatment was emamectin benzoate 5 % SG effective in reducing larval population and pod and grain damage. These results corroborate the findings of Chandra and Singh (2014) and Sonune and Bhamare (2018).

According Dadas *et al.* (2019a), application of chlorantraniliprole 18.5% SC at the stage of 50% flowering and podding stage of 15 days interval resulted in higher yield of pigeonpea (8.79 q/ha). Similarly, Sreekanth *et al.* (2014) also observed effective control of pod borer with hgiest yield of 886.1 kg/ha when chlorantraniliprole 18.5 SC was applied thrice, commensing from 50 % flowering stage. Also, higher yield of pigeonpea by using chlorantraniliprole 18.5 % SC (686.1 kg/ha) was reported by Khorasiya *et al.* (2004).

4.2.8.1 Incremental cost benefit ratio (ICBR)

The cost benefit ratio in different insecticidal treatments is calculated and presented in Table 4.10. Maximum net monetary return of Rs. 72156/ha was obtained from chlorantraniliprole 18.5 % SC treatment followed by flubendiamide 39.35 % SC with Rs. 67998/ha which was followed by indoxacarb 14.5 % SC with net monetary return of Rs. 65310/ha. The least monetary return was obtained from quinalphos 20 % EC. The highest cost benefit ratio was obtained in chlorantraniliprole 18.5 % SC was 1:5.3 and was followed by indoxacarb 14.5 % SC with 1:5.1. emamectin benzoate 5 % SG and flubendiamide 39.35 % SC are at par with each other with 1:4.5 least cost benefit ratio of 1:3.6 with quinolphos 25 % EC.

The present findings corroborates with Dadas *et. al. (*2019a). These results corroborate the findings Sreekanth *et al.* (2014) showed that the cost effectiveness of chlorantraniliprole and flubendiamide was also high and very favorable with incremental cost-benefit ratios of 1: 4.64 and 1: 4.50, respectively followed by indoxacarb (1: 3.67), emamectin benzoate (1:3.13) and spinosad (1:2.97).

Table 4.10 Incrimental cost benefit ratio of insecticides

Sr. No.	Treatment	Dose ml or g/lit	Yield (q/ha)	Increase in yield over control	Monitory value of produce (Rs)	Value of additional yield(Rs)	Plant protection cost(Rs)	Net profit over control (Rs)	I.C.B.R.
T_1	Quinalphos 25 EC	2.0 ml	13.45	3.82	56490	16044	3475	12569	1:3.6
T_2	Emamectin benzoate 5 SG	0.4 gm	14.92	5.29	62664	22218	4075	18143	1:4.5
T_3	Indoxacarb 14.5 SC	0.7 ml	15.55	5.92	65310	24864	4150	21389	1:5.1
T_4	Chlorantraniliprole 18.5 SC	0.3 ml	17.18	7.55	72156	31710	4975	26735	1:5.3
T_5	Chlorpyriphos 20 SC	2.8 ml	14.07	4.44	59094	18648	4165	14483	1:3.4
T_6	Flubendiamide 39.35 SC	0.25ml	16.19	6.56	67998	27552	4940	22612	1:4.5
T_7	Lambda cyhalothrin 5 EC	1.0 ml	14.57	4.94	61194	20748	3775	16973	1:4.4
T_8	Untreated control	---	9.63	-	40446	-	-	-	-

<u>Note :</u>

1. Spray pump rental value : Rs.200 /day /Sprayer
2. Labour charges : Rs. 250 / Labour
3. Labour required : 2 / Spraying
4. i. Quinalphos 25 EC : Rs.335 / 1L
   ii. Emamectin benzoate 5 SG : Rs.525 / 250g
   iii. Indoxacarb 14.5 % SC : Rs.550 / 350ml
   iv. Chlorantraniliprol 18.5 SC : Rs. 825 / 150ml
   v. Chlorpyriphos 20 EC : Rs.555 / 1.5L
   v. Flubendiamide 39.35 SC : Rs.980 /125ml
   vii. Lambda cyhalothrin 5 EC : Rs.425 / 500ml
5. pigeonpea grain cost : Rs.4200 / q

5. SUMMARY AND CONCLUSION

Investigations on seasonal incidence of insect pests and bioefficacy of various insecticides against pod borers *viz.,* Gram pod borer, *Helicoverpa armigera* (Hubner), Spotted pod borer, *Maruca vitrata*, plume moth, *Exelastis atomosa* (Washingham) and pod fly, *Melanagromyza obtuse* (Malloch) of pigeonpea. The field experiment was conducted during *'Kharif* season of 2019 at Pulses Improvement project, MPKV, Rahuri. Recordings of these studies are summarized in this chapter.

5.1 Summary

Weekly observations on seasonal incidence of pigeonpea pests were recorded from germination to till maturity in each meteorological week. During the field trial, three sprays were conducted on pigeonpea. The first spray was given at 50 % flowering and subsequent sprays were given at 15 days interval. The larval population of *H. armigera* and *E. atomosa* were recorded on randomly selected five plants in each treatment plot and number of maggots of pod fly were counted by splitting ten pods which were collected randomly from last but second row of both sides of the plot. For calculation of per cent pod damage at the time of harvesting, five plants were randomly selected earlier from each pod were observed for pod damage. Number of damaged pods and total pods were counted.

5.1.1 Seasonal incidence of insect pests on pigeonpea

The seasonal incidence of insect pests of pigeonpea were studied from seedling to harvesting stage of the crop. Seven insect pests were encountered in the pigeonpea crop. Among these seven insect pests, the status of four insects *i.e*. pod borer complex associated with flowers and pods of pigeonpea crop is most important *H. armigera*, *E. atomosa*, *M.vitrata* and *M. obtusa* were noticed from the flowering to podding stage of the crop from Auguest to October. These insect pest were found ultimately reduced to yield of pigeonpea crop. Natural enemies *i.e*. Spider, chrysoperla and lady bird beetle also noticed on pigeonpea.

5.1.2 Effect on larval population

Gram pod borer, *Helicoverpa armigera* (Hubner)

The average number of *H. armigera* larvae per plant prior to insecticidal treatments ranged from 1.87 to 2.67 larvae/plant and differences among the treatments were non-significant. All the insecticidal treatments were significantly superior over untreated control. The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and was significantly superior over rest of the treatments. It was followed by flubendiamide 39.35 % SC which is at par with indoxacarb 14.5 % SC . The next best treatment was emamectin benzoate 5 % SG and lambda cyhalothrin 5 % EC at par with each other.

Spotted pod borer, *Maruca vitrata*

The average number of *M. vitrata* larvae per plant prior to insecticidal treatments ranged from 2.53 to 3.13 larvae/plant and differences among the treatments were non-significant. The treatment with chlorantraniliprole 18.5 % SC was most effective treatmen and it was significantly superior over rest of the treatments. The second best treatment was flubendiamide 39.35 % SC which was followed by quinolphos 25 % EC and indoxacarb 14.5 % SC.

Tur plume moth, *Exelastis atomosa*

The average number of *E.atomosa* larvae per plant prior to insecticidal treatments ranged from 2.40 to 2.93 larvae/plant and differences among the treatments were non-significant. The treatment with chlorantraniliprol 18.5 % SC was most effective treatment and it was significantly superior over rest of the treatments. It was followed by flubendiamide 39.35 % SC which was at par with indoxacarb 14.5 % SC. The next promising treatment was emamectin benzoate 5 % SG and quinolphos 25 % EC and at par with each other.

Pod fly, *Melanogromyza obtusa*

The average number of *M.obtusa* maggots per 10 pods prior to insecticidal treatments ranged from 2.20 to 3.13 maggots/plant and differences among the treatments were non-significant. The treatment with chlorantraniliprole 18.5 % SC was most effective treatment and it was significantly superior over rest of the treatments. In the order of effectiveness the next best treatment was flubendiamide 39.35 % SC which is followed by indoxacarb 14.5 % SC, quinolphos 25 % EC and lambda cyhalothrin 5 % EC at par with each other.

5.1.3 Pod damage

Results indicated that the chlorantraniliprole 18.5 % SC recorded the lowest pod damage (3.64 %) and proved to be promising against *H. armigera.* It was however, at par with flubendiamide 39.35 % SC (4.82 %).

Chlorantraniliprol 18.5 % SC proved to be significantly superior to rest of the treatments by recording the lowest pod damage 2.13 % due to *E. atomosa.* It was followed by flubendiamide 39.35 % SC (4.82 %) and indoxacarb 14.5 % SC (6.12 %).

As regards *M. obtusa,* chlorantraniliprole 18.5 % SC established its superiority over all other treatments by recording lowest pod damage (3.05 %). Next in the order of effectiveness were flubendiamide 39.35 % SC recording 3.74 % of pod damage.

The data on collective pod damage due to different pod borers revealed that chlorantraniliprole 18.5 % SC was the most effective treatment by recording lowest pod damage of 8.82 per cent. Next in the order of effectiveness were flubendiamide39.35 % SC (11.53 %) followed by indoxacarb 14.5 % SC (14.17%) emamectian benzoate 5 % SG (15.34 %), lambda cyhalothrin 5 % EC (16.84 %), chlorpyrifos 20 % EC (17.91 %) and quinolphos 25 % EC (19.60 %).

5.1.4 Grain damage

Result indicated that chlorantraniliprole 18.5 % SC recorded lowest grain damage (6.37 %) and proved to be promising against *H. armigera.* It was followed by flubendiamide 39.35 % SC (8.02 %).

The data on grain damage due to *E. atomosa* indicate that chlorantraniliprol 18.5 % SC proved to be significantly superior to rest of the treatment by recording the lowest (5.34 %) grain damage. It was followed by flubendiamide 39.35 % SC (6.45 %) and indoxacarb 14.5 % SC (7.70 %).

Chlorantraniliprole 18.5 % SC recorded lowest grain damage (of 7.83 %) and proved to be promising against *M. obtusa.* It was followed by flubendiamide 39.35 % SC recording 9.98 % grain damage.

The data on collective grain damage due to different pod borers revealed that chlorantraniliprole 18.5 % SC was the most effective treatment by recording lowest grain damage of 19.54 per cent. Next in the order of effectiveness were flubendiamide 39.35 % SC (24.45 %) followed by indoxacarb 14.5 % SC (26.71 %).

5.1.5 Grain yield

In the present investigation, effective control of pod borers has influenced the yield of pigeonpea to the extent of 3.82 to 7.75 q /ha increases over untreated plots. Highest yield (17.18 q/ha) was registered in the plots treated chlorantraniliprole 18.5 % SC, flubendiamide 39.35 % SC) was the next best by recording 16.19 q/ha of pigeonpea.

5.1.6 Incremental cost benefit ratio

From the analysis of cost effectiveness of insecticides, highest ICBR was reaped from the chlorantraniliprole 18.5 % SC (1:5.3) followed by indoxacarb 14.5 % SE (1:5.1).

5.2 Conclusions

From the results obtained in the present investigation the following conclusions have been drawn.

5.2.1 Seasonal incidence of insect pest on pigeonpea

Insects' biodiversity in a particular agro ecosystem depend on available food and climatic conditions of the region. Pod borer complex and natural enemies were encountered in the pigeonpea crop in this agro climatic zone. Among these insect pests, four insect *viz.* Gram pod borer, *H. armigera*, Spotted pod borer, *M. vitrata*, Plume moth, *E. atomosa*, pod fly, *M. obtusa* were found to be major significance and was mainly associated with flowers and pods of pigeonpea. Natural enemies *viz*., spider, chrysoperla and lady bird beetle were also observed on pigeonpea crop.

5.2.2 Bioefficacy of various insecticides against pod borer complex of pigeonpea

The treatment with chlorantraniliprole 18.5 % SC and flubendiamide 39.35 % SC were found to be most effective treatments against pod borer complex of pigeonpea and give best control coupled with maximum yield.

The next best treatment were indoxacarb 14.5 % SE and emamectin benzoate 5 % SG.

6. LITERATURE CITED

Anamika, K. 2017. Seasonal incidence on population dynamics of pigeonpea pod bug clavegralla gibbosa (Spinola). *J. Entomol. Res.* 41(I) 4 : 409-412.

Anonymous, 2004. Annual Report 2003-04. All India Coordinated Reserch Project on Pigeonpea, Indian Institute of Pulses Research, Kanpur, 199-143.

Anonymous, 2019. Directorate of Economics and Statistics DAC and FW.

Armes, N. J., Jadhav, D. R., Bond, G. S. and King, A. B. S. 1992. Insecticide resistance of *H. armigera* (Hub) in South India. *Pesticide Science*. 34 : 355-364.

Asthana, A. N. 1998. Pulse crops research in India, *Indian J. of Agric.Sci*. 68 (8) : 448-452.

Bandi, S. and Naik, L. K. 2014. Management of Pod Borers in Pigeonpea through Biorational Approaches*, Trends in Biosciences. 7* (5) : 3.

Benagi, V. I., Kumar, N. M. S.,Teggelli, R. G. and Kalavati, K. 2004. Seasonal incidence of *Helicoverpa armigera* Hubner and validation of integrated pest management in pigeonpea ecosystem. *Karnataka J. Agric. Sci.* 17 (3) : 494-497.

Bhadani, D. J. and Patel, J. J., 2019. Seasonal Incidence of Lepidopteran Pod Borers Infesting Pigeonpea, *Int. J. Pure App. Biosci.* 7 (2) **:** 119-126.

Bhadani, D. J. and Patel, J. J., 2019a. Seasonal Incidence of Pod Fly, *M. obtusa* Infesting Pigeonpea, *Int. J. Pure App. Biosci.* 7 (2) : 44-50.

Bhagwat, V. R., Chandrasena, G. D. S. N., Iqbal, Y. B., Hettiarchchi, K., Sexena, K. B. and Shanower, T. G. 1996. A survey of pigeonpea pests in Sri Lanka. *International Chickpea and* Pigeonpea *Newsletter.* 3 : 93-95.

Bheemanna, M. and Patil, B. Y. 2005. Bioeficacy of indoxacarb (Avaunt) 15 % SC against cotton insect. Pests in irrigated conditions. *Pestology*. 23 (10).

Bindra, D. S. and Jokhmola, S. S. 1967. Incidence and losses caused by some pod infecting insects. *Melanagromyza obtusa* (Mall.), *Exelastis atomosa* (Wism), *Clavigrelia gibbosa* (Spin) and *Bruchus* sp. In different varieties of pigeonpea in Madhya Pradesh. *Indian J. Agric. Sci.* 387(3) : 117-186.

Brickle, D. S., Tunipseed, S. G. and Sullivan, M. J. 2000. Comparision of different chemistries and rates against bollworm in *Bt*. and coventional cotton . In Proc. Beltwide Cott. Conf. Nat. Cott. Coun, Memphis, USA. 2 : 971-975.

Chandra, N. and Singh, D.C. 2014. Evaluation of newer insecticides against pod borer complex in pigeonpea. *Progressive Agriculture*, *14* (1) : 200-202. 73-376.

*C*havan, A. P., Chavan, K. A., Latake, S. B., Kute, N. S., Mhase, L. B., Rangari, P. S. 2018. Incidence and damage severity of pod borers complex in pigeonpea. *Int. J. Agric. Sci.* 10 (18) : 7141-7144.

Dadas, S. M., Gosalwad, S. S. and Patil, S. K. 2019. Seasonal abundance of pod borers on pigeonpea and their natural enemies in relation with weather parameters, *J. Entomol. Zoo. Stud.* 7 (5) : 702-705.

Dadas, S. M., Gosalwad, S. S. and Patil, S. K. 2019a. Efficacy of different newer insecticides against pigeonpea pod borers. *J. Entomol. Zoo. Stud.* 7 (5) : 784-791.

Dagne, K., Ermias, T. and Amare, B. 2018. Farm Demonstration and Evaluation of Synthetic Insecticides for the Control of Pod Borer *(Helicoverpa armigara* Hubner) on Chickpea in Bale Zone. *Am. J. Plant Bio.* 3 (3) : 29-32.

Deshmukh, S. G., Sureja, B. V., Jethva, D. M and Chatar, V. P. 2010. Field efficacy of different insecticides against *Helicoverpa armigera* (Hubner) infesting chickpea. *Legume Research.* 33 (4) : 269-273.

Dhaka, S. R. and Pareek*,* B. L. 2007. Seasonal incidence of natural enemies of key insect pests of cotton and their relationship with weather parameters. *J. Plant Prot. Res.,* 47(4) : 32-35..

Dhonde, S. V., Bhamare, V. K., Sarode, S. V., Khan, M. I. and Deshmukh, A.. 2005. Efficacy of newer insecticides along with biorationals against *Helicoverpa armigera* (Hubner) in chickpea. *PKV Res. J.* 29(1) : 48-50.

Dinesh, K. R., Singh, B., Kavita, K. R. and Chaudhary, R. S. 2017. Relative efficacy of newer insecticides and biopesticides against *H. armigera* (Hub) in chickpea. *J. Entomol. Zoo. Stud.* 5(3) : 455-462.

Ghosal, A., Dolai, A. K. and Chatarjee, M. L. 2014. Bioefficacy of new ready mixed insecticide (navaluron 5.25 % + indoxacarb 4.5 % SC) against pigeonpea pod borer *(Helicoverpa armigera* Hubner). *Agriculture Research Communication Centre.* 39(1) : 135-139.

Gopali, J. B.,Tegelli, D. M., Mannur, A. and Yelshetty, S. 2010. Studies on web forming lepidpoteran *maruca vitrata* (Geyar) emerging and desrucrive pest in pigeonpea Karnataka. *J. Agric.sci.* 23 (1) : 35-38.

Gupta, G. P., Raghuraman, M., Ajanta Birah and Brijesh Singh. 2005. Field efficacy of newer insecticide against bollworm in cotton. *Indian J. Entomol.,* 67(1) : 16-20.

Hong, N. X., Nam, N. H., Yen, T. N. and Yuong, L.K. 1992. First survey of pigeonpea insect pests in Vietnam. *International* Pigeonpea *Newsletter,* 15 : 30-31.

Jagadeesh, C. S. and Mallikarjun, B. 2012. Evaluation of different insecticides and bio-pesticides for control of pigeonpea pod borer (*Helicoverpa armigera* Hubner). *Int. J. Plant. Prot.* 2 : 272-274.

Joshi, P. K., Parthasarathy, Rao P., Gowda, C. L .L., Jones, R. B., Silim, S. N., Saxena, K. B. and Kumar, J. 2001. The world chickpea and pigeonpea economies : facts, trends, and outlook. Patancheru 502 324, Andhra Pradesh, India : International Crops Research Institute for the Semi-Arid Tropics.

Kankal, S. M., Kausale, P. P. and Sarkate, M. B. 2003. Bioefficacy of newer insecticide against gram pod borer *(H.armigera*) in pigeonpea. State leval saminar on pest management for sustsinable agriculture MAU, Parbahni. Feb. 6-7, 2003. pp.156-158.

Kapadia, M. N. and Puri, S. N. 1989. Seasonal incidence of natural enemies of *Bemisia tabaci* (Gennadius) on cotton. *Indian J. Ecol*. 16 (2) : 164-168.

Katraju, R. K., Rao, S., Cherukuri, Vemuri, S. B. and Reddy, N. 2012. Bio-efficacy of insecticides against fruit borer (*Helicoverpa armigera*) in tomato *(Lycopersicon esculentum). Int. J. Appl. Biol. and Pharma.* 5 (1) : 239-241.

Kaval, R., Chakravarti, S. and Ganguly, S. 2017. Sesonal incidence of major insect pest on early maturing pigeonpea *Cajanas cajan* (L) Millsp. in relation to abiotic factor of Varanasi region of indo gangatic plains. *Advances in Research.* 17(5) : 1-13.

Kevel, R., Kerketta, D., Nath, P. and Singh, P. S. 2010. Population fluctuation of pod fly of some variety of pigeonpea. *J. Food Legume*, 23 (2) : 164-165.

Kimani, P. M. 2001. Pigeonpea Breeding : Objectives, Experiences and Strategies for Eastern Africa, in S. N. Silim, G. Mergeai, and P. M, Kimani (eds) 2001. Status 30 and potential of pigeonpea in Eastern and Southern Africa : proceedings of a regional workshop, 12-15 Sep 2000, Nairobi, Kenya. B-5030 Gembloux, Belgium : Gembloux Agricultural University and Patancheru 502 324, Andhra Pradesh, India : International Crops Research Institute for the Semi-Arid Tropics. 232 pp. ISBN 92-9066-432-0. Order code CPE 130.

Kumbhar, V. R. and Syed Shahzad Ali. 2017. Effect of Novel Insecticides against *Helicoverpa armigera* (HBN.) on chickpea crop under field conditions. *Int. J. Sci. Res. Pub.* 7 (2) : 387-393.

Khorasiya, S. G., Vyas, H. J., Jetha, D. M. and Joshi, P. H. 2014. Field efficacy of *Helicoverpa armigera* (Hubner) hardwick on pigeonpea. *Int. J. Plant Prot.* 7 (2) : 325-329.

Lal, C., Sharma, S. K. and Chahota, R. K. 1992. Oviposition response of pod fly (*Melanagromyza obtusa*)on resistant pigeonpea (*Cajanus cajan*) selections, *Indian J. Agric. Sci.* 64 : 658-660.

Lateef, S. S. and Reed, W. 1983. Review of crop losses caused by insect pests in pigeonpea internationally and in India, All India Seminar on Crop Losses due to Insect Pests, 7-9 January, APAU, Hyderabad.

Liu, T. X., Sparks, J. R. and Chen, W. 2003. Toxicity, persistence and efficacy of indoxacarb and two other insecticides on *Plutella xylostella* (Lepidoptera : Plutellidae) immature on cabbage. *Int. J. Pest Manag.* 49 (3) : 235-241.

Mahalaxmi, M. S., Sreekanth, M., Adinarayan, M., pushpa, R. R. and Narayana, Y. K. 2015 incidence of bionomics and management of spotted borer (*Maruca vitrata* Geyar) in major pulse crop in India. Regional Agricultural

Research Station, Lam, Guntoor- 522 034, AP, India. *Agricultural Review*, 37 (1) : 19-26.

Manisha, J., Urkude, R. and Deshmukh, L. 2014. Evaluation of effect of different pesticide on pigeonpea using ststistical tools in field experiment. IOSR *J. Environ. Sci*. 8 (8) : 24-27.

Meena, R. K., Naqui, A. R., Meena, D. S and Shivbhagvan. 2018. Evaluation of biopesticides and indoxacarb against gram pod borer of chickpea. *J. Entoml. Zoo. Stud.* 6(2) : 2208-2212.

Mapfumes, P. 1993. Pigeonpea in Zimbabwe : A new crop with potential in soil fertility research for maize based farming systems in Malawi and Zimbabwe.

Mushtaq, A., Iqbal, A.M. and Zahoor A. 2003. Susceptibility of *Helicoverpa armigera* (Lepidoptera : Noctuidae) to new chemistries in Pakistan, *Crop Protection*, 22 : 539-544.

Nair, N., Shah, S. K., Thangjam, B., Debnatn, M. R., Das, D. B., Dey, D. and Aswati, S. H. 2017. Insect pest complex of pigeonpea (*Cajanas cajan*) in agro ecosystem of Tripura, *N. E. India.* Vol. 5 (4) : 765-771.

Narkhade, A.L. and Nachane, M.N. 2003. Toxicity of new molecules of insecticides against *Earias vitella* (Fabricius). *PKV Res. J.* 27 (1) : 16-18.

Naresh, J. S. and Singh, J. 1984. Population dynamics and damage of insect pest in flowering pigeonpea (*Cajanus cajan* (L.) Millsp). *Indian J. Entomol.* 46 (4) : 412-420.

Pandey, R. P. 1996. Survey of pigeonpea insect pest in Nepal. *International Chickpea and* Pigeonpea *Newsletter,* 3 : 90-91.

Patange, N. R., and Chiranjeevii, B. 2017. Bioefficacy of newer insecticides against pigeonpea (*Cajanas cajan* L. Millsp.) pod borer. *J. Entomol. Zoo.* 5(3) : 28-31.

Patel, S. A. and Patel, R. K. 2013. Bio-efficacy of newer insecticides against pod borer complex of pigeonpea (*Cajanus cajan), AGRES - An int. e-J.* 2 (3) : 398-404.

Patel, S. K., Patel, B. H. and Korat, D. M. 2009. Studies on seasonal incidence of major insect pest of cowpea, *Vigna unguiculata* (Linn.) Walpers in relation to weather parameters. *Karnataka J. Agric. Sci.* 23 (3) : 497-499.

Prasad, D. and Chand, P. 1990. Pests of red gram and their management. *Recent Researches in Ecology, Environment and Pollution,* 5 : 247-260.

Prasad, Y.G., Singh, Y. and Singh, Y. 1995. Increase in grain yield in pigeonpea due to chemical control of insect pest. *Bulletin of Entomology,* New Delhi. 36 (1-2) : 57-59.

Priyadarshini, G., Reddy, C. N. and Reddy, D. J. 2013. Bioefficacy of selective insecticides against lepidopteran pod borers in pigeonpea. *Indian J. Plant* P*rot.* 41(1) : 6-10.

Ramegowda, G. K., Basavanagoud, K., Patil, R. K. and Kulkarni, K. A. 2002. Evaluation of new molecules of insecticides on susceptible and resistant population of *Spondaptera litura* (Fabricius). *Pesticides Information.* 28 (3) : 17-18.

Rani, D. S., Kumar, S. P., Venkatesh, M. N., Sri, C. H .N. S. and Kumar, K .A. 2018. Bio efficacy of insecticides against gram pod borer, *Helicoverpa armigera* in Redgram. *J. Entomol. Zoo. Stud.* 6 (2) : 3173-3176.

Reddy, C. D. and Joshi, N. C. 1991. Study of pests of pulses. *Plant Protection in India, Second edition,* 1992 : 165-167.

Sanap, M. M., Aher, R. P. and Deshmukh, R. B. 1995. Incidence of major insect pests associated with pigeonpea at Rahuri. *Indian J. Pul. Res.* 8(2) : 192-194.

Sathe, S. S. 2016. Seasonal incidence of insect pest on pigeonpea *Cajanas cajan.* M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.

Sharma, P. D., Jat, K. L. and Takar, B. L. 2004. Population dynamics of insect pests of American cotton (*Gossypium hirsutum* L.) in Haryana. *J. Cotton Res. Dev.* 18 (1) : 104-106.

Shrivastava, P. 1972. Eastimation of loss in T-21 variety of arhar (*Cajanus cajan* Linn.) due to tur pod fly (*Melanagromyza obtusa* Malloch). *Indian J. Entomol.* 34(1) : 82-83.

Siddegowda, D. K., Yelshetty, S. and Patil, B.V. 2006. Field evaluation of newer insecticides against gram pod borer (*H. armigera* Hub) on chickpea. *Pestology.* 30 (4) : 27-29.

Singh, H. M., Singh, R. and Rizvi, S.M.A. 1988. Insecticidal evaluation against pigeonpea pod borers. *Indian J. Plant Prot.* 16(2) : 217-220.

Snapp, S. S., Rohrbach, D.D., Simtowe, F. and Freeman, H.A. 2002. Sustainable soil management options for Malawi : can small holder farmers grow more legumes ? *Agriculture, Ecosystems and Environment.* 91 : 159–174.

Sonune, K. R. and Bhamare, V. K. 2018. Bio-efficacy of different insecticides against pod fly, *M.obtusa* (Malloch) and plume moth, *E. atomosa* (Walsingham) infesting pigeonpea. *Int. J. Curr. Microbiol. App. Sci*. 2018 ; 6 : 2027-2035.

Sreekanth, M., Lakshmi, M. S. and Rao,Y. K. 2014. Bio-efficacy and economics of certain new insecticides against gram pod borer, *Helicoverpa armigera* (Hubner) infesting pigeonpea (*Cajanus cajan* L.), *Int. J. Plant Animal env. Sci.* 4 (1) : 11-15.

Srinivasan, T. and Durairaj, C. 2007. Newer insecticides against pod borer complex of pigeonpea with special reference to *Helicoverpa armigera* and *Melanagromyza obtuse, Indian J. Plant Prot.* 35(1) : 47-49.

Subharani, S. and Singh, T. K. 2004. Insect pest complex of pigeonpea (*Cajanus cajan*) in Agro-ecosystem of Manipur. *Indian J. Entomol.* 66 (3) : 222-224.

Suganyakanna, S., Chandrashekharan, S., Regupathy, A. and Sataniy, J. 2005. Filed efficacy of emamectin benzoate 5 SG against tomato fruit borer *Helicoverpa armigera* (Hubner). *Pestology*, 29 (4) : 35-38.

Sujithra, T. and Subhash C. 2014. Seasonal incidence and damage of major insect pest of pigeonpea, *cajamus cajan* (L.). *Indian J. Entomol.* 76(3) : 202-206.

Tohnishi, M., Nakako, H., Faruya, T., Seo, A. Kodama, H., Tasubata, K. Fujioki, S., Kodama, H.T. and Nishimastu, T. 2005. Flubendamide is novel insecticide is highly active against lepidoptran pest. *J. Pesticide Sci.* 30 (4) : 354-360.

Tohnishi, M., Nishimatsu, T., Motoba, K., Hirooka, T and Seo, A. 2010. Development of a novel insecticide, flubendiamide. *J. Pesticide Sci.* 35 (4) : 490-491.

Ujagir, R. and Ujagir, R.1999. Field efficacy of insecticides against pod borer complex in early pigeonpea (*Cajanus cajan* (L) Millsp) at Pantnagar. *Northern Indian Ann. Plant Prot.Sci.* 7 (1) : 19-25.

Wadaskar, R. M., Bhalkare, S. K. and Patil, A. N. 2013. Field efficacy of newer insecticides against pod borer complex of pigeonpea, *J. Food Legumes.* 26 (1 & 2) : 62-66.

Yadav, N.K. and Singh, P.S. 2013. Seasonal abundance of insect pests on mung bean and its correlation with aboitic factors. *Banaras Hindu University J. Entomol.Res.*3 7 (4) : 297-299.

Yelshetty, S., Siddegowda, D. K. and Patil, B. V. 1999. Efficacy of indoxacarb (Avaunt 15 % SC) against pod borer, *H armigera* (Hub) in chickpea. *Pestology,* 30 (4) : 18-20.

Yogeeswarudu, R. and Krishna, V. 2014. Field studies on efficacy of novel insecticides against *Helicoverpa armigera* (Hubner) infesting on chickpea. *J. Entomol. Zoo. Stud.* 2 (4) : 286-289.

7. VITAE

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IN
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2021

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