

**EFFECT OF SEX PHEROMONE TRAPS AGAINST
CHICKPEA POD BORER, *HELI COVERPA ARMIGERA*
(LEPIDOPTERA: NOCTUIDAE)**

**MADHU, T. N.
PALB 2120**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU-560 065
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**MADHU, T. N.
PALB 2120**

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In partial fulfillment of the requirements

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In

AGRICULTURAL ENTOMOLOGY

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JULY, 2014

Affectionately
Dedicated to
my Beloved Parents
&
Brother

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU-560 065**

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF PHEROMONE TRAPS AGAINST CHICKPEA POD BORER, *Helicoverpa armigera* (HUBNER) (LEPIDOPTERA: NOCTUIDAE)**" submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture) in AGRICULTURAL ENTOMOLOGY** of the University of Agricultural Sciences, Bengaluru, is a record of research work done by **Mr. MADHU, T. N. ID No. PALB 2120** during the period of his study in the University under my guidance and supervision and that no part of thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
June, 2014


Dr. C. T. ASHOK KUMAR
Major Advisor

Approved by:

Chairman: _____


(C. T. ASHOK KUMAR)

Members: 1. _____


(A. K. CHAKRAVARTHY)

2. _____


(B. MALLIKARJUNA)

3. _____


(M. S. PRABHAKARA)

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Madhu, T. N.

“Effect of sex pheromone traps against chickpea pod borer *H. armigera* (Hubner) (Lepidoptera: Noctuidae).”

MADHU, T.N.

ABSTRACT

Effect of sex pheromone traps against chickpea pod borer *H. armigera* (Hubner) (Lepidoptera: Noctuidae) were undertaken at ten villages in and around Bangalore rural district during 2013-14. The four different trap densities were evaluated for optimum *H. armigera* moth catches (*i.e.*, 10, 20, 30 & 40 traps/acre). The results revealed that 20traps/acre recorded maximum moth catches (Overall mean 13.60), minimum larval count (Overall mean 0.81) and least pod damage (Overall mean 6.60%). Studies on the correlation between trap catches and pest infestation revealed that moth catches was significantly influenced by maximum temperature ($r=0.538$), minimum temperature (0.188) and evaporation (0.072). Rainfall ($r=-0.251$) and morning relative humidity ($r=-0.350$) had adverse effect on the activity of moths and on pheromone trap catches. The relationship between moth catches/week, larval count/plant/week was found to be positive at 10 and 40 traps/acre, while it was negative at 20 and 30 traps/acre. Whereas morning relative humidity, afternoon relative humidity and rainfall influence positively and maximum temperature, minimum temperature, evaporation and wind speed negatively influenced on larval count. Pod infestation was positively influenced by maximum temperature and Rainfall. Whereas minimum temperature, morning relative humidity, afternoon relative humidity and wind speed influenced negatively, peak moth catches were recorded during January 3rd week (8.52 moths/trap/week). Four insecticides were evaluated against *H. armigera* at four locations. Among them, Chlorantraniliprole 18.5SC, Indoxacarb 14.5SC and Novaluron 10EC were found to be superior in reducing the moth catches, larval count and pod infestation when executed with pheromone traps.

Department of Agricultural Entomology (C. T. ASHOK KUMAR)
College of Agriculture, G.K.V.K. Major Adviser
Bengaluru-560065

“ಕಡಲೆ ಕಾಳು ಕೊರಕದ ಹೆಲಕವರ್ಪ ಆರ್ಮಿಜರ (ಹಬ್ಬರ್) (ಲೆಪಿಡಾಪ್ಪರ : ನಾಕ್ಟುಯಿಡೆ) ಲೈಂಗಿಕ ಮೋಹಕ ಬಲೆಯ ಅಧ್ಯಯನ”

ಮಧು, ಟಿ. ಎನ್.

ಸಾರಾಂಶ

ಕಡಲೆ ಕಾಳು ಕೊರಕ ಹೆಲಕವರ್ಪ ಆರ್ಮಿಜರ (ಹಬ್ಬರ್) (ಲೆಪಿಡಾಪ್ಪರ : ನಾಕ್ಟುಯಿಡೆ) ಲೈಂಗಿಕ ಮೋಹಕ ಬಲೆಯ ಅಧ್ಯಯನವನ್ನು ಬೆಂಗಳೂರು ಗ್ರಾಮಾಂತರ ಜಿಲ್ಲೆಯ ಸುತ್ತಮುತ್ತಲ ಸುಮಾರು ಹತ್ತು ಗ್ರಾಮಗಳಲ್ಲಿ ೨೦೧೩-೧೪ರ ಅವಧಿಯಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಕಡಲೆಕಾಳು ಕೊರಕದ ಪತಂಗಗಳನ್ನು ಅಧಿಕವಾಗಿ ಆಕರ್ಷಿಸಲು ನಾಲ್ಕು ವಿವಿಧ ಸಾಂದ್ರತೆಯ ಮೋಹಕ ಬಲೆಗಳ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು (ಅಂದರೆ ೧೦, ೨೦, ೩೦ ಮತ್ತು ೪೦ ಬಲೆಗಳು/ಎಕರೆಗೆ). ಒಂದು ಎಕರೆಗೆ ೨೦ ಮೋಹಕ ಬಲೆಗಳ ಸಾಂದ್ರತೆಯು ಅಧಿಕ ಪತಂಗಗಳನ್ನು (ಸರಾಸರಿ ೧೩.೩೦ ಪತಂಗಗಳು/ವಾರ) ಆಕರ್ಷಿಸುವಲ್ಲಿ ಉತ್ತಮವಾಗಿದೆ. ಕಡಿಮೆ ಮರಿಹುಳು (ಸರಾಸರಿ ೦.೮೧) ಮತ್ತು ಕಡಿಮೆ ಕಾಳು ಹಾನಿ (ಶೇ. ೩.೩೦) ದಾಖಲಾಗಿದೆ. ಮೋಹಕ ಬಲೆಯ ಆಕರ್ಷಣೆ ಮತ್ತು ಪೀಡೆ ಆವರಿಸಿರುವಿಕೆಯ ಗುಣಾಂಕ ಅಧ್ಯಯನವನ್ನು ಮಾಡಲಾಯಿತು. ಪತಂಗಗಳ ಮೇಲೆ ಅಧಿಕ ಉಷ್ಣಾಂಶ (ಆರ್ = ೦.೫೩೮) ಮತ್ತು ಕಡಿಮೆ ಉಷ್ಣಾಂಶವು (ಆರ್ = ೦.೧೮೮) ಘನಾತ್ಮಕ ಪ್ರಭಾವ ಬೀರಿತಿದೆ. ಮಳೆ ಮತ್ತು ಬೆಳಗ್ಗಿನ ಆದ್ರತೆಯು ಮೋಹಕ ಬಲೆಯ ಪತಂಗಗಳ ಆಕರ್ಷಣೆಯ ಮೇಲೆ ಋಣಾತ್ಮಕ ಪ್ರಭಾವ ಹೊಂದಿದೆ. ಇದಲ್ಲದೆ ಮಳೆ, ಬೆಳಗ್ಗಿನ ಮತ್ತು ಮಧ್ಯಾಹ್ನದ ಆದ್ರತೆ ಘನಾತ್ಮಕವಾಗಿ ಮತ್ತು ಅಧಿಕ ಉಷ್ಣಾಂಶ, ಕಡಿಮೆ ಉಷ್ಣಾಂಶ, ಹಬೆಯಾಗುವಿಕೆ ಮತ್ತು ಗಾಳಿ ವೇಗವು ಋಣಾತ್ಮಕವಾಗಿ ಮರಿ ಹುಳುಗಳ ಮೇಲೆ ಅಧಿಕ ಪ್ರಭಾವ ಬೀರಿತಿದೆ. ಕಡಲೆಕಾಳು ಹಾನಿಯ ಮೇಲೆ ಅಧಿಕ ಉಷ್ಣಾಂಶ ಮತ್ತು ಮಳೆ ಘನಾತ್ಮಕವಾಗಿ ಹಾಗೂ ಕಡಿಮೆ ಉಷ್ಣಾಂಶ, ಬೆಳಗ್ಗಿನ ಆದ್ರತೆ, ಮಧ್ಯಾಹ್ನದ ಆದ್ರತೆ ಮತ್ತು ಗಾಳಿ ವೇಗವು ಋಣಾತ್ಮಕ ಪ್ರಭಾವ ಬೀರಿತಿದೆ. ಜನವರಿ ಮೂರನೇ ವಾರದಲ್ಲ (೮.೫೨ ಪತಂಗಗಳು/ಬಲೆ/ವಾರ) ಗರಿಷ್ಠ ಪತಂಗಗಳ ಆಕರ್ಷಣೆ ದಾಖಲಾಗಿದೆ. ಕಡಲೆಕಾಳು ಕೊರಕದ ವಿರುದ್ಧ ನಾಲ್ಕು ಕೀಟನಾಶಕಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ಅವುಗಳಲ್ಲಿ ಕ್ಲೋರಾಂಟ್ರಿನಿಲಪ್ರೋಲ್ ೧೮.೫ ಎಸ್.ಸಿ., ಇಂಡಾಕ್ಸಿಕಾರ್ಬ್ ೧೮.೫ ಎಸ್.ಸಿ. ಮತ್ತು ನುವಾಲೂರಾನ್ ೧೦ ಇ.ಸಿ., ಕೀಟನಾಶಕಗಳು ಜೊತೆಗೆ ಮೋಹಕ ಬಲೆಗಳನ್ನು ಕಾಳು ಕೊರಕದ ನಿರ್ವಹಣೆಗೆ ಅನುಸರಿಸಿದಾಗ ಕಡಿಮೆ ಪತಂಗಗಳ ಆಕರ್ಷಣೆ, ಕಡಿಮೆ ಮರಿ ಹುಳು ಮತ್ತು ಕಡಿಮೆ ಕಾಳುಹಾನಿ ದಾಖಲಾಗಿರುತ್ತದೆ.

ಜೂನ್ ೨೦೧೪

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ಡಾ. ಸಿ.ಟಿ. ಅಶೋಕ್ ಕುಮಾರ್

(ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರು)

Effect of Sex Pheromone Traps against Chickpea Pod Borer, *Helicoverpa armigera* (Noctuidae: Lepidoptera)

Madhu, T. N. (PALB 2120)
Department of Agricultural Entomology

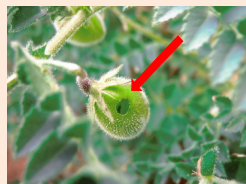


Introduction

- Chickpea (*Cicer arietinum* L.) is an important rabi season food grain legume and a rich source of protein and minerals.
- Gram pod borer, *Helicoverpa armigera* (Hubner) is a major insect pest and accounts up to 75-90% yield loss (Lal, 1996).
- Use of pheromone traps is an alternative method for insecticide in managing this pest



Larva feeding on flower



Infested pod



Pheromone trap



Moth caught in pheromone trap

Objectives

- To standardize the trap density for maximum pod borer catches
- To know the relationship between trap catches and pest infestation
- To know the influence of select insecticides on trap catches

Material and Methods

i. Trap density

10, 20, 30 and 40 traps / acre were evaluated

Observations: Moth catches / trap / week

Location: Rajanukunte, Bangalore

ii. Correlation: Moth catches and pest infestation

iii. Effect of insecticides on moth catches

Insecticides- chlorantraniliprole, indoxacarb, novaluron and quinalphos in combination with 20 traps/acre were evaluated

Observations:

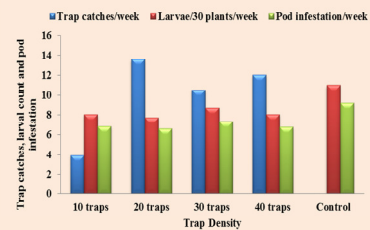
Moth catches / trap / week

Larvae / plant / week

Pod infestation (%)

Results

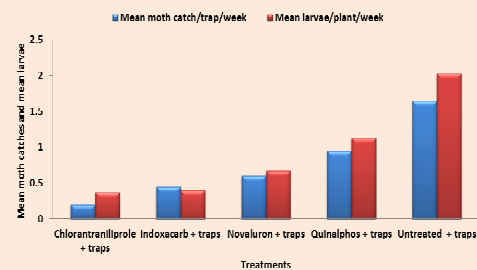
i. To standardize the trap density for maximum pod borer catches



ii. To know the relationship between trap catches and pest infestation

20 traps / acre recorded the maximum moth catches (13.60 moths/week), least larval count (0.81 larvae/plant/week) and pod infestation (6.60%)

iii. To know the influence of select insecticides on trap catches



Discussion

- 20 traps/acre recorded maximum moth catches, hence the least pod infestation and also the relationship between moth catches and pest infestation was significantly negative whereas Gomphero (2009) standardized 10 traps/acre as optimum for managing *Helicoverpa armigera* in chickpea ecosystem.
- Chlorantraniliprole treatment in trap installed plots recorded least larval population, hence the least moth catches.

Summary

- 20 traps/acre is the optimum trap density for effective management of the gram pod borer.
- Traps in combination with insecticides is better in managing this pest than the traps alone.

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Advisory committee:

Chairman: Dr. C. T. Ashok Kumar

Members.: Dr. A. K Chakravarthy

Dr. M. S. Prabhakar

Mr. G. B. Mallikarjun

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I. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important grain legume in Asia, and being a rich source of protein and cheap source of minerals. Chickpea can help to remove malnutrition. Inadequate intake of pulses could lead to serious consequences on human health. Chickpea is of relatively minor importance on the world market but it is extremely important for local trade in numerous tropical and subtropical regions. It is grown and consumed in large quantities from South East Asia to India and in the Middle East and Mediterranean countries. It ranks second in area and third in production among the pulses worldwide.

Pulses, generally known as food legumes (Fabaceae) are an important group among staple crops, next only to cereals. They form a major and the cheapest source of dietary proteins especially for vegetarians which form a major part of our Indian population. Chickpea is a rabi season food legume grown over 11.97 million hectares, producing 10.89 million tonnes with an average productivity of 764 kg per hectare in the world. It represents 17 per cent of world pulses area and 17.68 per cent of world's pulse production. In India and Karnataka it is grown in 8.32 million hectares and 0.96 million hectares with production of 7.58 million tonnes and 0.68 million tonnes respectively (Anon., 2012). Estimated productivity during 2011-12 was 841 kg/ha.

The high nutritional value makes chickpea an important food particularly in famine prone areas of the world. The leaves are eaten as vegetable, drinks are prepared from the plant exudates, the green seeds are consumed raw, roasted or boiled and the dry seeds can be used to prepare amazing array of different dishes. No crop other than chickpea is covered on all its surfaces with acid exudates and as a consequence has few insect problems. Chickpea is also credited with the ability of atmospheric nitrogen fixation through symbiotic process and it has been estimated that chickpea has the capacity to fix 140 kg N ha⁻¹ in a growing season (Rupela and Saxena, 1987). The fixed N not only can meet the requirements of the legume for maximum grain formation, but can also be available for use by subsequent crops, after mineralization of chickpea crop residues.

Chickpea has relatively few insect pests but gram pod borer, *Helicoverpa armigera* (Hubner) is the major pest (Naresh and Malik 1986, Lal 1996). The pod borers inflicted heavy crop losses from seedling to maturity. But the losses reached peak when the pods appeared (Mehta and Singh 1983, Deka *et al.* 1989). Lal (1996) reported that the seed yield losses due to *H. armigera* were 75-90% and in some places the losses were up to 100%. The yield loss in chickpea due to the pod borer was 10 to 60 per cent in normal weather conditions, while it was 50 to 100 per cent in favourable weather conditions. These losses can be reduced by the application of insecticides (Sinha *et al.*, 1983, Singh *et al.*, 1987, Rakesh *et al.*, 1996.) In addition to chickpea the borer attacks pigeonpea, sunflower, cotton, safflower, chilli, sorghum, groundnut, tomato and other crops. It is a devastating pest of pulses and oilseeds. The infestation starts on chickpea usually a fortnight after germination and becomes serious just after the initiation of flower bud coupled with cloudy and humid weather.

The eggs are laid on tender leaves / flowers / pods and upon hatching, the young caterpillar skeletonises the leaves, while grown up caterpillar bores into the

Pods and feeds on the seeds (Plate 1, 2 & 3). Insecticides are generally used in pod borer control due to their effectiveness and easy availability. Recently, *H. armigera* is reported to have developed resistance to many commonly used insecticides (Lande 1992). Phokela *et al.* (1990) observed a tendency of increased resistance to cypermethrin in the population of *H. armigera*. Moderate to high levels of resistance to cypermethrin and moderate resistance to endosulfan were recorded in field populations of *H. armigera* (Ahmad *et al.*, 1995).

In many cases, the insecticides did not provide satisfactory control of the target pest. Such phenomenon is apprehended to the development of insecticide resistance in the insect which leads to their misuse and threatening environmental safety. Therefore, there is a need to look for better and environmentally safer methods of control. In order to reduce the pesticide load in the environment and cost of production and to be abreast with sustainability, certain behavioral chemicals could be harnessed. Such an endeavour is the use of sex pheromones. This dynamic and paradigm shift in management strategies satisfies all the bio-safety concerns as well will play a pivotal role in combating insect pests of high-value. (Mazumder and Khalequzzaman, 2010).

Pheromone traps offer one of the best sampling tools for flying adult insects. The use of sex pheromones for monitoring insect pests is of recent origin. It has been reported to be very useful for determining seasonal activity of pests species by several workers (Tamhankar *et al.*, 1989; Singh and Sachan, 1991; Patil *et al.*, 1992). The knowledge on the influence of abiotic factors like temperature and humidity on population build-up of *H. armigera* would facilitate forecasting of pest attack. The investigations were therefore undertaken on the incidence of the pest and to find out the impact of environmental factors on the incidence of this pest on chickpea.

To manage this pest farmers apply insecticides instead of using non chemical tool such as pheromone traps. In view of the above condition present investigation has been made to study the “Effect of sex pheromone traps against chickpea pod borer *H. armigera* (Hubner) (Lepidoptera: Noctuidae).” Attempts will be made to carry out investigation on the field studies on chickpea pod borer by sex pheromone trap with the following objectives.

1. To standardize the trap density per acre for maximum pod borer catches
2. To know the correlation between trap catches and pest infestation
3. To know the influence of select insecticides on trap catches



Plate 1. Egg of *H. armigera* on chickpea tender leaves



Plate 2. *H. armigera* larva feeding flower



Plate 3. Pod infestation by *H. armigera* larva

II. REVIEW OF LITERATURE

The published literature on chickpea crop on aspects like, trap density for maximum moth catches, correlation between moth catches and pest infestation, influence of selected insecticides on the efficiency of pheromone trap catches are reviewed in this chapter.

2.1. Role of Pheromones in Pest Management

Srivastava *et al.* (1991) studied the network of pheromone traps for *H. armigera* and reported that the traps baited with a mixture of (Z)-11-hexadecenal and (Z)-9-hexadecenal in a ratio of 97:3, showed the maximum catches in the first fortnight of April.

Pheromones of insects have multiple roles to play in the management of insects (Pawar and Singh, 1993). They can be deployed directly for management of insect pests or may be used as a tool for survey and surveillance (Jayaraj *et al.*, 1995; Hall, 1995; Howse, 1998; Kehat *et al.*, 1982) to guide the pest management decisions.

2.1.1. Monitoring pest populations

Monitoring pest population with pheromones has long been recognized as one of the major benefits of sex pheromone research. Pheromone baited traps can be effectively used in estimating the population of a pest, so that chemicals can be applied at the most appropriate time for controlling pests (Minks and De Jung, 1975; Vakenti and Kadsen, 1976; Toscano *et al.*, 1974).

Monitoring of chickpea pod-borer, *H. armigera* and its activities throughout the year was studied by installing pheromone traps from January 2004 to December 2006. Pod-borer moth catching in pheromone traps was started between 3rd week of January to 2nd week of February depending on the climatic conditions of the year. Catching of moths was increased gradually and reached peak in April then gradually decreased and diminished to zero in the last week of July and ultimately remained zero up to December (Hossain, 2008).

2.1.2. Mass trapping

Pheromones can be utilized in mass trapping to control insects. In mass trapping programme, trap design, trap location and efficiency of formulation are the three most important considerations (Veeresh and Lingappa, 1986).

2.1.3. Altered sex ratio

Pheromones can be utilized in altering sex ratio. In disruption programmes, difficulties in formulation of pheromones and application of formulated pheromones have to be overcome. The possible mode of action of disruptant will also be possible in relation to the application of disruptant formulations (Veeresh and Lingappa, 1986). Successes and failures using pheromones to disrupt chemical communication have been reviewed by Veeresh and Lingappa (1986).

2.1.4. Direct suppression

Direct suppression is also possible in pests like *Leucinodes orbonalis* Guenee in brinjal and *Spodoptera litura* (Fabricius) in potato fields, where one can reduce the pest population to an extent of 75 to 80 per cent without using synthetic insecticides (Tamaki *et al.*, 1973).

2.2. To standardize the trap density per acre for maximum pod borer catches.

Koshihara *et al.* (1978) reported that field attractiveness of *P. xylostella* (L.) was more when sticky traps baited with pheromone. On the other hand Balasubramanian *et al.* (1979) monitored the activity of *P. gossypiella* with sex pheromones baited in water traps placed @ 8 traps per acre in cotton field.

Thwaite and Madsen (1983), studied the influence of trap height on *Cydia pomonella* (Linn.) moth catches revealed that traps at a density of one per ha was adequate to estimate *C. pomonella* (Linn.) populations.

Kafka and Kreig (1987) while working with codling moth, *C. pomonella* (Linn.) using pheromone codlemone, placed the traps at 5, 50, 500 and 1000 cm apart in apple orchard; so that the attractiveness of codlemone was strongly reduced by the other two components when placed at distance less than 50 cm. Lopez and Witz (1988) suggested that traps baited with sex pheromone should be placed 75 cm apart in maize field to capture the population of *Helicoverpa zea* and *H. virescens* (F.).

Flint *et al.* (1989) in Australia found that pheromone trap efficiency was low and varied with moth population density as male moths attempted to drive one another away in high-density populations.

Srivastava *et al.* (1992) in India studied over a decade using pheromone and light traps. It was anticipated that such data together with egg and larval population densities would enable a model to be developed that could be used to estimate crop damage in relatively small areas.

Giampiero (1993) compared the trap densities for male moth capture rate. The first trial compared densities of 2, 10, and 20 traps per hectare, and the second trial compared 10, 20, and 40 traps per hectare. Doubling the number of traps in the test plots resulted in a 50 per cent increase in capture rate in the first trial and 10-20 per cent increase in the second. Emelyanov and Bulyginskaya (1998) reported that 15 to 30 traps per ha of an orchard provide a high rate of male capture and their disorientation in female search.

Jenn-Sheng (2000) conducted an experiment to evaluate the integrated effect of sex pheromone and insecticide in the control of sweet potato weevil. Results indicated that the use of pheromone-baited traps placed at 4 traps/0.1 ha reduced damage to tubers caused by Sweet potato weevil by 57-65 per cent.

The delta and wing traps baited with synthetic female sex pheromone of *L. orbonalis* were found to catch and retain ten times more moths than either *Spodoptera* or uni-trap designs. Locally-produced water and funnel traps were as effective as delta

traps, although “windows” cut in the side panels of delta traps significantly increased trap catch from 0.4 to 2.3 moths per trap per night; further suggested to place the traps at a density of 100 per ha. (Cork *et al.*, 2003).

Jhala *et al.* (2005) estimated the action threshold to be 5 moths/trap/night employing 5 to 10 traps/ha in cotton but found that this threshold did not hold true under all circumstances.

On farm, large-scale mass trapping trials demonstrated that 20 traps/ha were sufficient to reduce male yellow stem borer populations significantly. The trials provided good evidence that mass trapping could significantly reduce the level of mating, with consequent reductions in larval progeny (Cork *et al.*, 2005).

At trap densities of 3 to 6 per 100m², there was no significant difference in catch but the maximum number of moths caught per unit area was the same for densities between 4 and 6 traps per 100m² which caught significantly fewer male moths. Thus, it was established that 4 traps per 100m² at crop height would catch an optimal number of male moths of *L. orbonalis* in brinjal crop (Cork *et al.*, 2005).

The pheromone trap catches of *H. armigera* were negligible from 45th to 50th week and again from 1st to 10th standard week of March 2005, 2006 and 2007, trap catches were nil, though the larval population was noticed during pre-winter months. From the 11th standard week, moth catches/trap started increasing and it reached to peak in 15th–16th standard week of April (6.57, 11.88 and 6.64 moths/trap during rabi 2004-05, 2005-06 and 2006-07, respectively). It further decreased till 19th–20th standard week of May when the crop was harvested (Reena *et al.*, 2009).

Setting of only pheromone trap @ 75 numbers per hectare gave quite substantial protection from *L. orbonalis* in shoot damage (58.35%), fruit damage (33.73%) and yield (28.67%) in brinjal crop (Chatterjee, 2009).

The study evaluated densities of 10, 20, and 40 traps per ha, baited with 0.2 mg of PTM sexual pheromone, and water-detergent for captures. Results indicated that larger numbers of male PTM were captured per trap with densities of 20 and 40 traps per hectare, resulting in a significant reduction of tuber damage in these treatments compared with the control which used conventional chemical insecticide sprays. 20 traps per ha appear to be the most effective and convenient trap density to use in a potato tuber moth integrated management program (Larraín *et al.*, 2009).

Sarwar *et al.* (2009) reported as a part of integrated pest management, installing pheromone traps @ 10/ha can monitor pest build up to take decision on timely control measures.

Singh *et al.* (2009) studied the effectiveness of integrated pest management (IPM) modules against gram pod borer *H. armigera* on chickpea. Among the various modules evaluated, M₅ (sole chickpea, pheromone traps at 20/ha, bird perches at 20/ha, endosulfan 35 EC at 0.07% a.i. and chlorpyrifos at 0.05% a.i.), followed by M₂ (sole chickpea, pheromone traps at 20/ha, bird perches at 20/ha, methomyl 40 SP at 1.0 kg/ha and 2 sprays of HaNPV at 400 LE/ha) were effective in managing the population of *H. armigera*.

Sharma *et al.* (2011) suggested 5 traps/ha was found to be effective for monitoring the chickpea pod borer.

2.3. Correlation between trap catches and pest infestation

Dent (1985) studied population studies of *H. armigera* through pheromone trap catches and larval counts (1981-1984) for three consecutive chickpea seasons; accordingly, the peak catch occurred during 19-25 Nov in 1981 with a peak catch of 859 moths, 17-23 Dec in 1982 with a peak catch of 1178 moths and 3-9 Dec in 1983 with catch of 137 moths; further reported that the trend in the size of the peak trap catch corresponded to the trend in total mean larval number but the time of peak catch did not seem to have any relation to the size of the peak catch.

Allen *et al.* (1986) observed that mean trap catch of *Choristoneura fumiferana* was significantly correlated with densities of 2nd larval stage ($R^2 = 0.52$).

Upadhyay *et al.* (1989) reported positive correlation of weather parameters and infestation of *H. armigera* on ground nut with maximum temperature ($r=0.63$), minimum temperature ($r=0.67$) and relative humidity($r=0.59$).

Palaniswamy *et al.* (1990) reported that there was no correlation between egg mass densities and pheromone trap catch of European corn borer, *Ostrinia nubilalis*.

Srivastava *et al.* (1991) monitored *H. armigera* by pheromone trap in chickpea and reported significant positive correlation between egg and larval count $r=0.89$ and $r=0.94$ for the year 1986 and 1987 respectively.

Anwar *et al.* (1992) reported that pheromone trap catches of *H. armigera* on chickpea crop showed rapid increase from February to march with rise in temperature.

Srivastava *et al.* (1992) studied light and pheromone trap networks to monitor and compare moth catches of *H. armigera* in both types of traps at many locations across India. The results revealed, at north locations the correlation between light and pheromone trap catches were higher as compared to southern locations.

Thorpe *et al.* (1993) reported a similar observation stating a significant relationship between trap catch and egg mass density of gypsy moth, *Lymantra dispar* and observed significant slopes with R^2 -values of 0.60 and 0.65 for the low and high lure traps, respectively

Chaudhry *et al.* (1995) studied the response of males of *H. armigera* to sex pheromone sources on chickpeas at Rawalpindi, Pakistan, during 1986, 1987, 1989, 1990 and 1991; populations of this insect were abundant from mid-March to the 1st week of May. Sex pheromone traps were useful indicator for timing insecticide application and monitoring the population on chickpea. The total number of males caught in sex pheromone traps during 1986, 1987, 1989, 1990 and 1991 were 2040, 169, 596, 619 and 482 respectively. Correlation of weekly catch data with weather parameters showed that 6.0-78.0% of change in populations was due to the combined effect of abiotic factors.

Evenden *et al.* (1995) also observed that male moth catches of *Lambdina fiscellaria* (Lepidoptera: Geometridae) were significantly correlated with larval and pupal counts within the same generation.

Srivastava *et al.* (1995) reported pheromone trap catches of *H. armigera* moths were invariably followed by the peaks in egg and larval counts (early instars) in chickpea. The correlation between pheromone trap catches of week_{n-1} and egg counts for week_{n=0} were positive, $r = +0.35$ in 1986 and positive and significant $r = +0.69$ in 1987. The correlations between egg counts of week_{n-1} and larval counts for week_{n=0} were also significant and positive, $r = +0.89$ and $+0.94$ for the years 1986 and 1987, respectively.

Izquierdo (1996) observed positive correlation between egg densities and trap catches of *H. armigera* on tomato and carnation crops.

Parajulee *et al.* (2004) studied monitoring activities of male adult moths of bollworm, *Helicoverpa zea* and tobacco budworm, *Heliothis virescens*, between 1982 and 1995 by using sex pheromone traps in the Texas High Plains. The 14-yr average (\pm SE) bollworm moth abundance (moths per trap per week) at Lubbock was significantly higher (226.5 ± 10.4) compared with that at Halfway (153.7 ± 8.1). Correlation analyses showed a significant positive relationship between moth abundance and average weekly temperatures, whereas a significant negative relationship was observed between moth abundance and average weekly wind velocity for both species.

Ahmed and Khalique (2012) conducted studies on natural infestation of the cotton bollworm, *H. armigera*. The linear regressions between the number of adults by trap catch and 1st instar larvae were significant at $p < 0.05$ and $p < 0.001$ with significant positive correlation ($r = 0.59$, $r = 0.57$, $r = 0.80$, $r = 0.71$ and $r = 0.92$ in year 1, 2, 3, 4 and 5, respectively) and regression trends between eggs and 1st instar were significant at $p < 0.05$, $p < 0.001$, $p < 0.001$ and $p < 0.001$ with $r = 0.43$, $r = 0.74$, $r = 0.69$, and $r = 0.89$ in year 2, 3, 4 and 5, respectively.

Sharma *et al.* (2012) Monitored *H. armigera* male moths through pheromone traps was carried out in chickpea crop during 2011-12. Maximum number of male moths trapped were 105.66/trap/week, while maximum number of larvae were 30.0/10 plants recorded during 12th standard week (19 March -25 March), and revealed that adult male moth catches in pheromone traps positively correlated ($r=0.77$ and $r=0.63$) with maximum and minimum temperatures, while it was negatively correlated ($r= -0.79$) with relative humidity.

Sonkar *et al.* (2012) studied the correlation between pheromone trap catch and larval population of *H. armigera* and influence of weather parameters on moth. Data indicated that the *H.armigera* moth was first trapped in 2nd fortnight of December with an average of 2.55 moths /trap and showed two peaks *i.e.*, 1st fortnight of January and 2nd fortnight of March, respectively. The correlation between moth population and next fortnight larval population of *H.armigera* and mean relative humidity was found to be positively significant while correlation with maximum temperature, minimum temperature, and sun shine hours was found negative but non-significant.

2.4. Influence of selected insecticides on pheromone trap catches of *H. armigera*

Kakar *et al.* (1980) studied the effect of foliar sprays on tomato fruit borer with monocrotophos (0.06%), quinolphos (0.05%), methyl parathion (0.05%), carboryl (0.05%), endosulfan (0.05%), phasalone (0.05%), leptophos (0.05%), fenitrothion (0.05%) and malathion (0.05%), reported 30-80 percent increase in yield. Combined spray of the insecticide with dithane M-45 gave further significant increase in yield.

Deware and Dhanokar (1981) conducted an experiment with monocrotophos, endosulfan, dimethoate, quinalphos, fenitrothion, phosalone and formothion, where in all the treatments have shown significant reduction in the pod damage. The pod damage varied from 4.39 per cent in dimethoate (0.03%) to 4.1 per cent in monocrotophos (0.04%).

Santharam *et al.* (1981) reported that endosulfan (0.07%), monocrotophos (0.04%) and endosulfan (4%) dust recorded maximum mortality (100 per cent) of *H. armigera* larva in red gram.

Chabra *et al.* (1984) reported quinalphos (0.05%), carboryl (0.05%), monocrotophos (0.04%) and endosulfan (0.07%) were promising insecticides in controlling the pod borer complex of pigeonpea.

Hargreaves and Cooper (1984) conducted seven trials with 11 insecticides as spray against the eggs of *H. armigera* on tomato. Methomyl had a ovicidal action at all the concentrations tested (0.0125 – 0.05%), while fenvelerate and sulprofos had medium ovicidal action only at their highest concentrations (0.005 and 0.072% respectively), whereas deltamethrin, endosulfan, methamidophos, monocrotophos, quinalphos, permethrin and prothiofos showed only low ovicidal activity and other two insecticides showed no ovicidal activity.

Nine insecticides were screened for their toxicity to eggs of *H. armigera* under laboratory conditions (Vekaria and Vyas, 1985). None of the insecticides resulted in cent per cent mortality of the eggs. The insecticides in the order of ovicidal toxicity were cypermethrin 0.04 per cent (96.2%), fenvelerate 0.01 per cent (94.6%), permethrin 0.0125 per cent (89.9%), quinalphos 0.05 per cent (88.4%), monocrotophos 0.04 per cent (72.3%), phenthoate 0.05 per cent (55.6%), endosulfan 0.07 per cent (56.8%), phosalone 0.07 per cent (21.0%) and chlorpyriphos 0.04 per cent (19.6%).

Bhalian and Kotadi (1986) found deltamethrin (0.002cypermethrin (0.01%) and endosulfan (0.07%) were found to be effective in controlling the pod borer in redgram and all the pyrerhroids were found to be superior to endosulfan except fenvelerate.

Rabindra and Jayraj (1986) observed increased mortality of second instar larvae of *H. armigera* with the use of 0.1 per cent boric acid and 1 per cent magnesium sulphate with NPV on chickpea. Further, application of NPV @ 250 LE plus boric acid 125g per ha has significantly reduced the larval population over the application of NPV alone.

The fumigation effect of chlorpyrifos, methyl parathion, monocrotophos, methomyl, amitraz, chlordimeform and fenvelerate was studied on the eggs of *H. virescens*. It revealed chlordimeform and methyl parathion caused 30 per cent egg mortality as compared to 20 per cent mortality for other insecticides (Horowitz and Toscano, 1988).

Synthetic pyrethroids have been reported to be most effective against *H. armigera* on various crops; because of low mammalian toxicity; these chemicals have also been tested on vegetable crops and proved very effective against their pests (Sinha, 1988).

Ovicidal toxicity of insecticides against the eggs of *H. armigera* was studied by Balikai *et al.* (1989). Accordingly, monocrotophos 0.05% plus amitraz 0.03% was the most toxic insecticide alone and in combination applied to eggs (73-74%), followed by monocrotophos 0.1% (74.73%) and amitraz 0.08% (69.31%).

Patel and Patel (1989) studied the toxicity of synthetic pyrethroids, aorganophosphates and cyclodiene insecticides against the eggs of *H. armigera*. Fenvelerate (0.02%) and quinalphos (0.05%) caused cent per cent mortality of eggs and the least mortality of eggs was observed in the eggs treated with endosulfan 0.07 per cent (45.02%).

Ahmed *et al.* (1990) tested eight insecticides against eggs of *H. armigera* at both recommended and half the recommended concentrations. The egg mortality corresponding to the recommended and half the recommended concentrations were highest in methomyl, followed by fenvelerate, triazophos, monocrotophos, quinalphos and the least in acephate. Dubey *et al.* (1991) under laboratory conditions observed methyl parathion 0.04 per cent and quinalphos 0.03 per cent recorded significantly higher mortality of 94.0 and 93.12 per cent respectively compared to other treatments.

Methamidophos (0.07%) and fenvelerate (0.01%) were tested for the control of *H. armigera* on pigeonpea in Maharashtra. Among the insecticides, fenvelerate (0.01%) was found to be the most effective in reducing the larval population (Patel and Patel, 1990).

Rao *et al.* (1990) evaluated nineteen insecticides with respect to reduction in grain damage and all the chemicals were found to be superior to control. Lowest grain damage was recorded in fenvelerate at 0.4 per cent dust (12.87%) followed by cypermethrin at 0.01 per cent (13.15%), fenvelerate at 0.01 per cent (13.46%) and formothion at 0.05 per cent (13.79%). The maximum grain damage was observed in the treatment acephate @0.05 per cent (20.03%) as against control(25.36%).

Critchley *et al.* (1991) reported that there were no significant differences in the mean boll infestations in the pheromone + pesticide and only pesticide treatment regimes against pink bollworm in cotton.

Chamberlain *et al.* (1993) reported that there was no infestation of flower by larvae of *P. gossypiella* in the pheromone + insecticide plot and low infestations in both the insecticides and untreated plots and also reported that boll infestation by *P.*

gossypiella, *E. vittella*, *E. insulana* and *H. armigera* were all lower in the pheromone + insecticide plot than in either the insecticide only or untreated plots.

Efficacy of foliar spray of fenthion, phosalone, quinolphos, chlorpyrifos each at 0.05 per cent and endosulfan (0.07%), malathion (0.075%), cypermethrin, fenvelerate each at 0.006 per cent and deltamethrin 0.002% were evaluated against *H. armigera* on tomato in reducing the borer damage. Synthetic pyrethroids proved effective, besides, endosulfan among chlorinated hydrocarbons and fenthion among organophosphates also gave better results (Sharma *et al.*, 1993).

Mathur *et al.* (1994) evaluated nine insecticides for the control of fruit borer, *H. armigera* infesting tomato, of which Methomyl @ 0.50 kg a.i/ha, monocrotophos @ 0.75 kg a.i/ha., carboryl @ 2 kg a.i/ha., Fenitrothian @ 1 kg a.i/ha, closely followed by malathion @ 1 kg a.i/ha controlled the pest effectively.

Flufenoxuron at 75 and 100 g a.i/ha an insect growth regulator was found more effective in managing *H. armigera* compared to teflubenzuron, diflubenzuron, Monocrotophos and dichlorovas (Raja Sekhar *et al.*, 1995).

The ovicidal action of two insecticides against *H. armigera* revealed that both methomyl 40SP and profenofos 50EC were effective ovicides. Methomyl at 0.03 to 0.06 per cent concentration recorded 74.97 to 80.96 per cent egg mortality, while profenofos at 0.2 to 0.5 per cent recorded 81.61 to 98.50 per cent mortality (Sharma *et al.*, 1996).

The various concentrations of two insecticides *viz.*, profenofos 50EC and methomyl 12.5SL were evaluated for their ovicidal activity against *H. armigera*. The study revealed that the older eggs of 48 to 72 h age were most sensitive compared to early age eggs. The mortality of eggs aged 0 to 22 h, 24 to 48 h and 48 to 72 h was 95, 70 and 100 per cent respectively (Pachori and Sharma, 1996).

Thirteen insecticides were tested against pigeonpea pod borers. Amongst, monocrotophos (0.04%) and cypermethrin (0.006%) treated plots gave significantly better results than other chemicals; cypermethrin and permethrin proved better than other chemicals for controlling lepidopteran borers; deltamethrin, cypermethrin and permethrin plots gave significantly higher yield (Singh *et al.*, 1988).

Bheemanna and Patil (1999) reported that indoxacarb at 75 g a.i/ha recorded lower bollworm incidence, maximum number of good opening bolls and minimum number of bad opening bolls per plant and higher seed cotton yield.

Suhas Yelshetty *et al.* (1999) reported that indoxacarb at 75 g a.i/ha was effective in suppressing the pod borer, *H. armigera* and resulting in higher yield compared to other treatments.

Among the various dosage of indoxacarb evaluated against American bollworm in cotton, the higher dosage (80 g a.i/ha) gave better control and resulted in higher seed cotton yield than chlorpyrifos (Dhawan and Simwat, 2000).

Dhandale *et al.* (2000) studied the efficacy of spinosad against cotton bollworms compared to synthetic pyrethroids. The treatments spinosad at 50 and 75 g a.i/ha was equally effective as that of synthetic pyrethroids.

Chakraborti and Chatterjee (2000) studied the bio-efficacy of four benzophenyl ureas, *viz.*, triflumuron, diflubenzuron, teflubenzuron and flufenoxuron against chickpea pod borer, *H. armigera*. All the chitin synthesis inhibitors were effective at 50, 75 and 100 g ai/ha, but diflubenzuron was comparatively more effective.

Trap catches of pink bollworm increased after the applications of the two organophosphate insecticides and decreased after the applications of the permethrin in the cotton field (Bariola, 2001). Ashok *et al.* (2001) studied the effect of some novel insecticides against *Plutella xylostella*; results showed that novaluron 0.00075 per cent was the most effective followed by abamectin 0.00045 per cent and diafenthiuron 0.12 per cent.

The pod damage was low in spiceturin (13.12%), followed by chlorpyrifos 0.25 kg a.i/ha and maximum yield was obtained in chlorpyrifos (2120 kg/ha), followed by spiceturin (2050 kg/ha) in chickpea (Balasubramanian *et al.*, 2001).

Quinalphos 25 EC (0.05%) when sprayed at 15-day intervals commencing at 50 per cent flowering found significantly superior over the untreated control with pod damage and yield of 19.6 per cent and 7.4 q/ha against the chickpea pod borer, *H. armigera* in chickpea (Balikai *et al.*, 2001).

Narendra Reddy *et al.* (2001) reported that 2 to 3 times spraying of fenvalerate @ 0.02 per cent was most effective against pod borer complex in pigeonpea.

Binay Kumar and Devendra Prasad (2002) evaluated the efficacy of neem based insecticides and biopesticides against *H. armigera* in chickpea. The highest larval reduction of *H. armigera*, ranging from 75.25 to 100 per cent was recorded in the application of lufenuron + profenphos and HaNPV and was found to be effective biopesticide; it recorded lowest pod damage and highest grain yield of chickpea.

Giraddi *et al.* (2002) revealed that indoxacarb 14.5SC and thiodicarb 75 WP were highly efficient in reducing *H. armigera* population in pigeonpea, recording a seed yield of 1.40 t/ha and 1.36 t/ha in indoxacarb 14.5SC and thiodicarb 75 WP treated plots respectively.

Bharpoda *et al.* (2003) reported that indoxacarb 14.5SC at 75 g a.i/ha was significantly superior in controlling cotton boll worm and increasing the seed yield of cotton (2055 kg/ha).

Chaudhari *et al.* (2003) reported that novaluron 0.010 per cent recorded the lowest number of surviving *H. armigera* larvae/plant on chickpea and also highest yield of 16.73 q/ha.

Novaluron (1ml/lit) was evaluated against American bollworm in cotton; it revealed lower larval population and higher yield (Murthy and Maruthi Ram, 2003).

Aslam *et al.* (2004) evaluated ten insecticides under field conditions against *Earias insulana*, *E. vitella* and *H. armigera* at recommended doses. For American bollworm, Patriot 360SC (Chlorfenapyr) followed by Taophos 25EC (Quinalphos) were most effective up to 3 DAT, while Larvin 80DF (Thiodicarb), Tracer 240SC (Spinosad) and Lorsban 40EC (Chlorpyrifos) were also effective even after 3DAT.

Udikeri *et al.* (2004) reported that emamectin benzoate 5 SG at 11 g a.i/ha resulted significantly lowest larval population (0.10/plant) of cotton bollworm and was found at par with spinosad 48 SC @ 50 g a.i/ha (0.14/plant) and indoxacarb 15 SC @ 75 g a.i/ha (0.16/plant).

Ladaji (2004) reported that the new molecule, spinosad 48 SC (@ 0.2 ml/l) proved significantly superior over rest of the molecules by reducing the pod borer incidence in chickpea to the extent of 84.43 and 82.04 per cent after first and second spray and the treatment recorded highest pod yield of 14.53 q/ha; other better treatments to follow are spinosad (@0.1 ml/l), indoxacarb (0.5 ml/l) and emamectin benzoate (0.4 g/l). However, the highest BC ratio (1:1.26) was obtained with lambda cyhalothrin.

Sawant *et al.* (2004) reported that novaluron (0.01%) was found significantly effective over untreated control in reducing the Brinjal shoot and fruit infestation and recorded higher yield.

Siddegowda *et al.* (2004) tested the bio efficacy of novaluron (Rimon 10 EC), an insect growth regulator on pigeonpea pod borer, *H. armigera*. Lower per cent pod damage (18.03 and 11.72) and higher grain yield (585 and 515 q/ha) was recorded in case of plots treated with novaluron 10 EC at 75 and 100 g a.i. per ha, respectively compared to endosulfan 35 EC (700 g a.i. /ha) and monocrotophos 36 SL (360 g a.i. /ha).

Srinivasan *et al.* (2004) reported that indoxacarb (50 g a.i/ha) was the most effective treatment in controlling cotton bollworm. Indoxacarb recorded a maximum seed cotton yield of 22.6 q/ha, followed by spinosad 21.7q/ha.

Emamectin benzoate (11g a.i/ha), a new insecticide was evaluated against cotton bollworm complex, which recorded lower fruiting bodies damage and higher seed cotton yield. It was found to be highly promising and was on par with other new molecules like spinosad and indoxacarb at 75 g a.i/ha (Bheemanna *et al.*, 2005)

Suganya kanna *et al.* (2005) reported that emamectin benzoate (10g and 8.75g a.i/ha) and spinoad (12.5g a.i/ha) record lower larval population and higher yield against tomato fruit borer, *H.armigera*.

Murugaraj *et al.* (2006) evaluated emamectin benzoate (11g a.i/ha) against tomato fruit borer, *H.armigera*; accordingly, emamectin benzoate was highly effective in reducing the larval population of pest compared to other insecticides.

Field evaluation of novaluron (50, 75 and 100 g a.i/ha), emamectin benzoate (8 and 11 g a.i/ha), spinosad (60 g a.i/ha), profenphos (750 g a.i/ha), methomyl (250 g a.i/ha), indoxacarb (72.5 g a.i/ha), and endosulfan (350 g a.i/ha) was undertaken for

their bioefficacy against Chickpea pod borer. Novaluron (100 g a.i./ha) registered lower pod damage (4.83%), followed by emamectin benzoate at 11 g a.i./ha (5.13%) and spinosad at 60 g a.i./ha (6.83%) and higher grain yield (Raghvani *et al.*, 2006).

Spinosad (22.5 g a.i./ha) and indoxacarb (21.75 g a.i./ha) were tested against Chickpea pod borer which recorded significantly lower pod damage and higher grain yield (Siddegowda *et al.*, 2006).

Singh and Yadav (2007) studied the efficacy of four insecticides i.e. indoxacarb, thiamethoxam, spinosad and endosulfan; three biopesticides (two *Bacillus thuringiensis* based bioinsecticides) namely halt, biolep and *Ha* NPV and two neem formulations *viz.*, nimbecidine and neemarine. The study showed, Indoxacarb caused maximum larval mortality after one week of two sprayings i.e. 99.4 and 98.3% after first and second spraying of 2005–2006, respectively which was closely followed by thiamethoxam and spinosad. Among biopesticides, the maximum larval mortality after one week of spraying was achieved in halt i.e. 42.2% after first spraying and 42.8% after second spraying which was closely followed by *Ha* NPV. Both the neem based formulations were on par among each other but significantly superior over control.

Siddegowda *et al.* (2006) conducted studies on chickpea pod borer *H. armigera* to evaluate different formulations. Among the different formulations tested, indoxacarb 14.5 SC @ 25 g a.i./ha was highly effective as compared to chlorpyrifos 20 EC @ 250 g a.i./ha.

Yadav and Verma (2007) investigated that spray of quinalphos recorded highest (100 %) mortality of larvae after last spray and maximum grain yield 17.85 q/ha with 6.09 per cent increase in yield over control against *H. armigera* in pigeonpea.

Ashok Kumar and shivaraju (2009) reported that flubendiamide 480 SC @ 48 and 36 g a.i./ha recorded minimum pod damage of 6.04 and 7.62 per cent by *H. armigera*, 2.91 and 3.55 per cent by *E. zinckenella*, respectively in black gram.

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.

Sathyanarayana *et al.* (2010) conducted chemical trials on groundnut against *S. litura*. The results indicated that emamectin benzoate 0.00725% was the most effective treatment followed by indoxacarb 0.0145% and indoxacarb 0.00725%+ novaluron. 0.005%.

Thilagam *et al.* (2010) evaluated that flubendiamide 60 g a.i./ha showed marked reduction in the *Helicoverpa* larval population and recorded up to 96.00 per cent reduction in damage in cotton.

Sahito *et al.* (2012) reported that proclain gave best results against gram pod borer. The overall mean population of *H. armigera* 0.36, 0.44 and 0.49 per plant was

recorded in the plots treated with Proclaim, Radiant and Jatara, respectively as compared to control plot (1.23 larvae per plant) during the first spray. During second spray the overall mean population was 0.33, 0.51 and 0.56 per plant in the plots treated with Proclaim, Radiant and Jatara, respectively as compared to control plot (2.21 larvae per plant). Whereas, during third spray the overall mean population was 0.29, 0.44 and 0.48 per plant was recorded in the plots treated with Proclaim, Radiant and Jatara, respectively as compared to control plot (2.68 larvae per plant).

Singh *et al.* (2012) studied the efficacy of certain new molecules insecticides *viz.*, HaNPV@250 LE/ha, spinosad 45SC@ 100 g *a.i./ha*, fenvalerate 20 EC @ 300 g *a.i./ha*, quinalphos 25EC @ 450 g *a.i./ha*, emamectin benzoate 5SG @ 11 g *a.i./ha*, azadirachtin 1500 ppm@5ml/lit, cartap hydrochloride 50 SP @ 500 g*a.i./ha*, fiproni 15 SC @ 50 g *a.i./ha* and indoxacarb 14.5 EC @ 75 g; these were applied twice at 15 days interval against gram pod borer, *H. Armigera*; spinosad was found best among all the treatments with 81.2% reduction in larval population over control followed by indoxacarb, fipronil, emamectin benzoate, cartap hydrochloride, fenvalerate, quinalphos, azadirachtin and HaNPV.

Mahmudunnabi *et al.* (2013) evaluated different biorational based IPM packages *viz.*, IPM package 1 (P1) comprising pheromone trapping of *H. armigera* along with sequential release of biocontrol agents (*Trichogramma evanescens* @ gm/ha/week + *Bracon hebetor* @ 1 jar (1000-1200 adults)/ha/week) and spraying of *Bacillus thuringiensis* @ 0.4g/ litre of water; IPM package 2 consists of pheromone trapping in addition to sequential release of bio-control agents and spraying of Ha NPV @ 0.1g/litre of water against *H. armigera* in chickpea; results indicated that the IPM package (P2) recorded the best performance reducing 68.20% pod damage over control.

Patil *et al.* (2007) evaluated newer insecticides on *H. armigera viz.*, proclaim 5 SG @ 8, 9 and 11 g.a.i. /ha, novaluron 10 EC @ 50, 75 and 100 g.a.i./ha, spinosad 45 EC @ 60 g.a.i./ha, and profenofos 50 EC @ 750 g.a.i./ha and compared with conventional recommended insecticide, endosulfan 35 EC @ 350 g.a.i./ha. The minimum larval incidence of 1.68 larvae/m row length was recorded in novaluron 10 EC @ 100 g/ha at 3 DAS whereas in profenofos 50 EC @ 750 g/ha, recorded 1.17 larvae/MRL followed by proclaim 05 SG @ 11 g.a.i./ha (1.18 larvae/MRL). The treatment with proclaim 05 SG @ 11 g.a.i./ha was found to be more effective in reducing the pod damage (3.0%) and enhancement in higher grain yield (2346 kg/ha) followed by spinosad 45 SC @ 60 g.a.i./ha which recorded pod damage of 3.3% and grain yield of 2256 kg/ha as compared to endosulfan which was on par. The highest cost: benefit ratio was recorded in endosulfan 35 EC @ 350g a.i./ha (1:15.08).

Hossain *et al.* (2010) reported that lowest pod damage (2.55%) as well as grain yield loss (34.90 kg/ha) was observed in the treatment where lambda cyhalothrin applied three times at 7 days interval from flowering stage. Chickpea seed yield was maximum (1338 kg/ha) with lambda cyhalothrin sprayed thrice which was identical to sprayed twice (1280 kg/ha). Neem seed extract showed a marginal performance to control chickpea pod borer. The highest marginal benefit cost ratio (3.19) was recorded from lambda cyhalothrin sprayed twice.

Singh *et al.* (2010) reported various developmental changes exhibited by *H. armigera* by the treatment of different insect growth regulators (IGRs) *i.e.* lufenuron, novaluron and UPI-106. Among the different concentration of three IGRs used, the most effective IGR was the treatment of UPI-106 (0.08% conc.) while the least effective was Novaluron (0.025% conc.).

Jeewesh *et al.* (2012) Studied the efficacy of five insecticides for the management of *H. armigera* on chickpea; among them, spinosad 45SC @ 90 g a.i/ha was most effective treatment followed by indoxacarb 14.5EC @ 50 g a.i/ha and novaluron 10EC @ 100 g a.i/ha. Endosulfan 35EC @ 700 g a.i/ha was least effective on basis of larval reduction and seed yield. The maximum cost: benefit ratio was obtained from indoxacarb 14.5EC @ 50 g a.i/ha.

Ram *et al.* 2012, conducted field studies to assess the efficacy of moult disruptor's *viz.*, Novaluron, Flufenoxuron, Diflubenzuron, and Teflubenzuron both alone and in combination with Endosulfan (0.07%) against groundnut leafminer, *Aproaerema modicella* during *kharif* seasons of 2006 and 2007 at two *different locations*. Novaluron alone (0.01%) and in combination with Endosulfan (0.07%) was found to be the best treatment based on larval & pupal mortalities, reduction in leaf damage and higher yields.

Babar *et al.* (2012) evaluated ten insecticides against *H. armigera viz.*, emamectin benzoate (Proclaim 5 WG) 0.0025%, thiodicarb (Larvin 75 WP) 0.075%, indoxacarb (Fego 15.5 SC) 0.007%, spinosad (Spintor 45 SC) 0.0135%, novaluron (Remon 10 EC) 0.01%, lufenuron (Match 5 EC) 0.005%, flubendiamide (Fame 480 SC) 0.01%, rynaxypyr (Coragen 20 SC) 0.006% and endosulfan (Thiodan 35 EC) 0.07% in laboratory for their ovicidal and larvicidal action against *H. armigera*. Flubendiamide and thiodicarb recorded more than 70% egg mortality in the laboratory experiment and found most effective as ovicide. Flubendiamide, emamectin, rynaxypyr and spinosad recorded more than 90% larval mortality in the laboratory experiment and found most effective as larvicide. Overall, flubendiamide 0.01% was found most effective treatment followed by emamectin benzoate 0.0025%, rynaxypyr 0.006% and spinosad 0.0135% for the management of pod borer, *H. armigera* in chickpea crop.

Gadhiya *et al.* (2014) reported evaluation of insecticides for the management of *H. armigera* and *Spodoptera litura* infesting groundnut. Insecticides used in experiment were Emamectin benzoate 5 WG @ 0.002%, Thiodicarb 75 WP @ 0.075%, Indoxacarb 14.5 SC @ 0.007%, Spinosad 45 SC @ 0.018%, Novaluron 10 EC @ 0.01%, Lufenuron 5 EC @ 0.005%, Flubendiamide 480 SC @ 0.014%, Chlorantraniliprole 20 SC @ 0.006% and Metaflumizone 22 SC @ 0.044%. Among nine insecticides, chlorantraniliprole (0.006%), spinosad (0.018%) and emamectin benzoate (0.002%) were noticed higher effective and statistically at par with each other in protecting the groundnut crop from the infestation of both pests. Metaflumizone (0.044%) and lufenuron (0.005%) were noticed poor in checking the incidence of *H. armigera* and *S. litura*. Highest cost benefit ratio 1: 3.3 was observed in chlorantraniliprole (0.006%) followed by indoxacarb treatment.

Two field experiments were conducted to evaluate the bio-efficacy and economics of certain new insecticides against gram pod borer, *H. armigera* on

pigeonpea. Experimental results showed that the number of *Helicoverpa* larvae per plant were lowest in plots treated with chlorantraniliprole 20 SC (0.43), flubendiamide 480 SC (0.59) and spinosad 45 SC (0.85) as against untreated control plot (4.17) with 89.7, 85.9 and 79.6 per cent larval reduction over control, respectively. Pod damage due to pod borer, *Helicoverpa* was lowest in plots treated with flubendiamide (1.16%), chlorantraniliprole (1.26%) and spinosad (1.92%) with 88.7, 87.7 and 81.2 per cent reduction over control respectively. The untreated plot has recorded maximum pod damage of 10.22% (Sreekanth *et al.*, 2014).

III. MATERIAL AND METHODS

The present investigation on effect of sex pheromone traps against chickpea pod borer *Helicoverpa armigera* (Lepidoptera: Noctuidae) was carried out to find out standardize trap density, correlation of trap catches and pest infestation and influence of select insecticides on pheromone trap catches of *H. armigera* during, 2013-2014 in and around Bangalore rural district. The materials used and methods followed for different experiments are presented here under.

Bangalore is situated between 13° 5' Latitude and 77° 35' Longitude with an altitude of 930 m above mean sea level in Eastern Dry Zone (Zone 5) of Karnataka. In *kharif* season the monthly mean maximum temperature varies from 29.53°C during July to 29.14°C during October, where as monthly mean minimum temperature varies from 20.36°C during August and 18.73°C during October. The relative humidity fluctuates between 81.72 per cent during July and 83.70 per cent during September. An average rainfall of 74.35 mm, distributed from July to October with peak in October. In *rabi* season the monthly mean maximum temperature varies from 27.39°C during December to 28°C during February, whereas monthly mean minimum temperature varies from 15.67°C during November and 17.4°C during February. The relative humidity fluctuates between 80 per cent during November-December and 72.77 per cent during September. The rainfall distributed well during November and December with peak in November. In *summer* season the monthly mean maximum temperature varies from 28.70°C during February to 31.40°C during April, where as monthly mean minimum temperature varies from 17.40°C during February and 21.67°C during April. The relative humidity fluctuates between 72.77 per cent during February and 68.20 per cent during March. The rainfall is distributed well during March and April with peak in April.

The field trials on the pheromone traps were laid out in the selected Chickpea grower's field in four villages in and around Rajanukunte viz, Chikka madurae, Kodipalya, Agrahara and Byatha and also near Doddballapur viz, Hanabe, Neralaghatta. These Chickpea growers were adopted by Bio-Control Research Laboratory, Sreeramanahalli. The experiments were carried out by following common agronomic practices and for experimental purpose all fields were kept free from plant protection measures and non-host crops viz., banana, arecanut, coconut and eucalyptus were observed for the pest occurrence in and around the field.

Pheromone Sample

The composition of the pheromone components of *H. armigera* is (Z)-11-hexadecenal (Z11-16: Ald) and (Z)-9-hexadecenal (Z9-16: Ald). The pheromone impregnated in the rubber septa was used in these studies; they were manufactured and marketed in the name of Helilure™ and supplied by Pest Control (India) Ltd. Bombay, Division of Biocontrol Research Laboratories, Sreeramanahalli, Arakere post, Bangalore-561203.

Fero-T™ traps

The traps used for study were Fero-T™ traps. It is a funnel trap designed by M/s Pest Control (India) Ltd, Bombay, for mass trapping the pests of crops such as sugarcane borers, paddy stem borer, chickpea pod borer etc. Fero-T™ is easy to assemble on a single pole. The pheromone lure is hung through lure holder fixed in the centre of trap. The pheromone septa were suspended from the lure holder from the centre. Moths attracted to the trap were killed when they fall into the funnel trap (Plate 4, 5 & 6).

3.1. Standardization of trap density per acre for maximum moth catches

Pheromone traps and lures were obtained from Bio-Control Research Laboratory (BCRL), Sreeramanahalli, Bangalore for field studies.

3.1.1. Trap density

In order to standardize the trap density per acre for maximum moth catches, the experiment was carried out in five different fields of one acre each with same chickpea variety in and around Rajankunte, Bangalore North and near Doddballapur. The observations were recorded for moth catches in different fields with different soil type's viz., deep black, black sandy, red and red sandy; and chickpea variety JJ11 was selected for the present investigation and sown between November and December month. The traps with different density were set up in the farmer's field at 25 DAS to get moth catches from the crop. The funnel traps baited with pheromone septa were set up by using wooden pegs. The trap height was maintained at 0.3 m above the canopy level. The traps were installed randomly covering an acre area and the lure was changed at 25 days interval. The Chickpea field selected was not in a compact block/area. The details of the treatments are as follows:

Treatments:

T1- 10 traps per acre

T2- 20 traps per acre

T3- 30 traps per acre

T4- 40 traps per acre

T5- Control (Trap without lure)

The treatments were implemented at four locations; five sites were selected with a distance of one kilo meter apart in each location and it was considered as one replication. The data on moth catches and larval count was transformed to $\sqrt{(X + 0.5)}$ and the data on pod damage by the pest was converted into per cent values and transformed to Arc sin before analysis by RCBD.



Plate 4. General plot view (Farmers field)



Plate 5. *H. armigera* male moth caught in funnel trap



Plate 6. Funnel trap with trapped *H. armigera* male moths

Observation on number of moths trapped was recorded at weekly intervals; besides, observations were also made on defoliating symptom during early stage, number of damaged pods due to pest and total number of pods, at an interval of seven days on plants selected randomly from each of the field.

3.2. Correlation between trap catches and pest infestation of *H. armigera*

A study was conducted to know the Correlation between trap catches and pest infestation of *H. armigera* on chickpea pod borer; the studies were conducted in few villages near by Rajanukunte viz, Chikka madurae, Kodipalya, Agrahara and Byatha and also few villages near Doddballapur viz., Hanabe, Neralaghatta during *rabi* 2013-14. The incidence of chickpea pod borer was recorded during *rabi* season. Observations were recorded from 25 DAS of the crop to the time the crop attained senescence. The observations were recorded on plants showing damage symptoms like defoliation during early stage and presence of circular hole on the pods in later stages; besides, larvae were also collected on 30 tagged and untagged plants selected randomly from each field and calculated the infestation.

3.2.1. Moth count

The observations were recorded on number of moths caught in each trap at 7 days interval from each field. The lure was changed at 25 days interval.

3.2.2. Larval count

The observations were recorded on number of larvae present on plants at 7 days interval from each field.

3.2.3. Pods infestation

Later, observations were also made and recorded on pods showing big circular holes due to pod borer damage and total number of pods per plant in the plant at an interval of one week on randomly selected 30 plants from each of the field on tagged and untagged plants. The data on the incidence of pod borer were converted to per cent value. The per cent pod damage was worked out for 30 plants

$$i.e., \% \text{ pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

3.2.4. Yield

The grain yield of chickpea was recorded from each plot. It was converted in to quintal per hectare before statistical analysis.

3.2.5. Abiotic Factors

Abiotic factors like maximum and minimum temperature, relative humidity, wind speed and rainfall were recorded from Indian Institute of Horticultural research

(IIHR), Hessaraghatta, Bangalore during the study period (all the seasons). The meteorological data was recorded to correlate the moth catches and pest infestation. The data was subjected to correlation and regression analysis.

3.3. Influence of select insecticides on pheromone trap catches

In order to study the influence of selected insecticides on pheromone trap catches of *H. armigera*, an experiment was conducted at four locations (Multi-location Trials) in and around Rajanukunte. For this study, 25 chickpea growing farmers were chosen from Bangalore North. Later, the farmers were interviewed regarding the insecticides used in chickpea using a standard questionnaire/proforma. The insecticides sprayed against *H. armigera* in chickpea ecosystem were identified based on farmers interview; accordingly, the most commonly used insecticides were Indoxacarb (Avaunt) 14.5%SC, Quinolphos (Ekalux) 25EC, Chlorantraniliprole (Coragen) 18.5%SC and Novaluron (Rimon) 10 EC. The crop stage selected was 25 days after sowing and the experiment was carried out for a period of one month with single spray of insecticide. Details of the treatment modules followed in the experiment are as follows.

3.3.1. Details of insecticides and traps (Treatment modules) used

T1	Indoxacarb 14.5%SC @ 0.5ml/l + 20 pheromone traps per acre
T2	Chlorantraniliprole 18.5%SC @ 0.3ml/l + 20 pheromone traps per acre
T3	Quinolphos 25%EC @ 2ml/l + 20 pheromone traps per acre
T4	Novaluron 10 EC @ 1ml/l + 20 pheromone traps per acre
T5	Control (Unsprayed area+20 pheromone traps per acre)

The pre-treatment observations were made before spraying on moth catches in pheromone traps, larvae/plant and per cent pod damage. Further, observations were recorded on number of moths trapped at 7 days intervals and also the number of damaged pods and total number of pods per plant on tagged and untagged plants at 7, 14, 21 and 28 days after spraying. However, observation on larvae/plant was made at 4 days after spraying in first observation; further, subsequent observation were recorded at 7 days interval. The data was transformed to $\sqrt{X + 0.5}$ before analysis by one way ANOVA. The data on pod damage by the pest was converted into per cent values and transformed to Arc sin transformation before analysis by one way ANOVA (Snedecor and Cochran, 1956).

IV. EXPERIMENTAL RESULTS

The results of the present investigation on “Effect of sex pheromone traps against chickpea pod borer *Helicoverpa armigera*” (Lepidoptera: Noctuidae) with special reference to trap density, correlation between trap catches and pest infestation and influence of select insecticides on pheromone trap catches of *H. armigera* are presented in this chapter.

4.1. Trap density standardization for maximum *H. armigera* moth catches

4.1.1. Density of traps and moth catches

For optimizing trap density per unit area of cultivated chickpea, densities at four different trap numbers were evaluated under field conditions in and around Maduræ (Rajanukunte). Observations on moth catches, larval count and pod infestation were recorded for 10 weeks (From December 1st week). The effect of different trap densities on moth catches was statistically tested using RCBD. Maximum trap catches (13.60 overall mean) were recorded at trap density of 20/acre which was statistically superior to other trap densities (Table 1). This was followed by the trap density at 40 traps/acre, where a maximum trap catches (12.07 overall mean) were recorded per acre. Statistical significant results were obtained and this was on par with trap density of 20/acre (Table 1).

There was no direct and positive relationship between trap densities tested and moth catches realized. This was possibly because the population size of *H. armigera* moths varied from one chickpea field to another. The important point here is that traps have to be placed at peak moth activity, so as to trap maximum number of moths occurring under field conditions. Timing of the placement of trap in the field and phenology of crop therefore is crucially important besides trap density.

The data on larval count in chickpea fields at Maduræ is presented in Table 2. The larval count was also compared using RCBD statistical analysis. Out of these treatments in 10 traps/acre and 40 traps/acre was showed statistical positive significant differences with respect to per cent defoliation and pod damage. Chickpea field where traps @ 20 /acre and 30/acre were placed recorded the least *H. armigera* larval count (0.81).The next highest was obtained at trap density 40 traps/acre where, overall mean of 1.00 larval count was recorded and in control, maximum overall mean of 1.39 larval count was recorded.

The trap densities of 20 traps/acre and 30 traps/acre were statistically negative significant in chickpea pod borer larval count. This suggests that as moth catches are higher, lower will be the larval count (Table 2). This is expected, as the maximum number of moths were trapped, hence the pest population not be there to cause infestation.

Table 1. Effect of trap density on moth catches/ week at Madurae

Treatments	Standard weeks										Overall mean
	49	50	51	52	1	2	3	4	5	6	
10 traps	0.25 (0.83) ^a	1.5 (1.38) ^a	2.00 (1.54) ^b	5.00 (2.34) ^a	4.50 (2.22) ^a	10.50 (3.15) ^a	7.25 (2.69) ^{ab}	3.50 (1.97) ^{ab}	3.00 (1.84) ^a	2.00 (1.53) ^a	3.95 (2.00) ^c
20 traps	0.50 (0.96) ^a	2.25 (1.63) ^a	5.25 (2.34) ^a	6.25 (2.51) ^a	6.50 (2.60) ^a	14.75 (3.59) ^a	79.00 (6.80) ^a	9.50 (2.78) ^a	8.50 (2.63) ^a	3.50 (1.81) ^a	13.60 (3.26) ^a
30 traps	0.25 (0.83) ^a	1.75 (1.41) ^a	5.50 (2.38) ^a	6.25 (2.56) ^a	6.00 (2.44) ^a	9.00 (2.91) ^a	67.75 (6.17) ^a	5.25 (2.25) ^{ab}	4.25 (2.13) ^a	2.00 (1.54) ^a	10.55 (2.93) ^b
40 traps	1.00 (1.06) ^a	2.25 (1.54) ^a	5.25 (2.31) ^a	5.50 (2.42) ^a	6.00 (2.49) ^a	8.75 (2.98) ^a	64.00 (7.92) ^a	17.75 (3.64) ^a	6.75 (2.48) ^a	3.50 (1.81) ^a	12.07 (2.45) ^b
Control (Trap without lure)	0.00 (0.70) ^a	0.25 (1.83) ^a	0.00 (0.70) ^c	0.25 (0.83) ^b	0.00 (0.70) ^b	0.00 (0.70) ^b	0.00 (0.70) ^b	0.00 (0.70) ^b	0.25 (0.83) ^b	0.25 (0.83) ^b	0.10 (0.77) ^d
SEM±	0.14	0.13	0.15	0.10	0.13	0.26	1.10	0.36	0.22	0.13	0.31
F- test	NS	NS	*	*	*	*	*	*	*	*	*
CD @ 0.05	-	-	0.42	0.28	0.41	0.80	3.37	1.19	0.70	0.41	0.95

*Average of four replications/treatment/week; **Mean of ten weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; **Significant at 1%; NS= Non-Significant

Table 2. Effect of trap density on larvae/plant/week at Madurae

Treatments	Standard weeks										Overall mean
	49	50	51	52	1	2	3	4	5	6	
10 traps	0.75 (1.11) ^a	0.92 (1.19) ^{bc}	1.05 (1.24) ^b	1.15 (1.28) ^b	1.18 (1.29) ^b	1.13 (1.26) ^b	0.75 (1.11) ^b	0.59 (1.04) ^b	0.46 (0.97) ^b	0.38 (0.93) ^b	0.84 (1.16) ^b
20 traps	0.59 (1.04) ^a	0.77 (1.12) ^c	1.16 (1.27) ^b	1.14 (1.27) ^b	1.19 (1.29) ^b	1.17 (1.28) ^b	0.74 (1.10) ^b	0.58 (1.04) ^b	0.43 (0.96) ^b	0.33 (0.90) ^b	0.81 (1.14) ^b
30 traps	0.79 (1.13) ^a	0.99 (1.21) ^b	1.19 (1.29) ^b	1.44 (1.37) ^b	1.34 (1.35) ^b	1.15 (1.27) ^b	0.81 (1.13) ^b	0.56 (1.02) ^b	0.48 (0.99) ^b	0.44 (0.96) ^b	0.92 (1.19) ^b
40 traps	0.81 (1.13) ^a	1.11 (1.26) ^b	1.33 (1.34) ^b	1.33 (1.34) ^b	1.35 (1.36) ^b	1.28 (1.32) ^b	1.04 (1.23) ^b	0.76 (1.11) ^b	0.54 (1.01) ^b	0.40 (0.94) ^b	1.00 (1.36) ^a
Control (Trap without lure)	0.95 (1.19) ^a	1.37 (1.36) ^a	1.70 (1.46) ^a	1.93 (1.54) ^a	1.84 (1.52) ^a	2.22 (1.63) ^a	1.45 (1.39) ^a	1.00 (1.22) ^a	0.74 (1.11) ^a	0.64 (1.06) ^a	1.39 (1.36) ^a
SEm±	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.02
F- test	NS	*	*	*	*	*	*	*	*	*	*
CD @ 0.05	-	0.06	0.06	0.08	0.08	0.08	0.10	0.06	0.06	0.04	0.05

*Average of four replications/treatment/week; **Mean of ten weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%, **Significant at 1%; NS= Non-Significant

4.1.3. Relationship between *H. armigera* moth catches and pod infestation

The pod infestation was recorded when pod formation has been initiated i.e., from 51st standard week and continued up to 6th week. The study plots with trap densities @ 10, 20, 30 and 40 traps/acre showed positive and non-significant association between moth catches and pod infestation. The overall data of the field experiment revealed positive relationship between moth catches and pod infestation in the field. This was consistently observed throughout 10 weeks in the study plots and across the four trap densities. The correlation analysis revealed significant differences between the two parameters. Chickpea field where traps @ 20 /acre recorded the least pod infestation (6.60%). The next highest was obtained at trap density 40 traps/acre where overall mean of 6.78% pod infestation was recorded and in control, maximum overall mean of 9.20% pod infestation was recorded (Table 3).

4.2. Correlation between moth catches and pest infestation

The data on trap catches of *H. armigera* and mean weather parameters were subjected to correlation analysis. Correlation matrix between moth catches and larval count were recorded and it was found negative at trap density 20 and 30/acre; whereas in 10 and 40 traps/acre positive relationship was observed (Table 4).

The appearance of chickpea pod borer occurred (0.08 moths/trap) during 49th standard week (December 1st week). The incidence increased as the plants put forth new tender shoots, flowers and pods. One peaks of moth catches were observed during 3rd standard week (8.52 moths/trap). The trapping decreased and ceased as the crop attained senescence with the minimum number of moths (0.51 moths/trap) observed in traps during 6th standard week (Table 5).

During *rabi* 2013-14, the incidence of chickpea pod borer in terms of damage was recorded by defoliation with larval count (0.78/week) during 49th standard week. Three peak larval counts was observed during 52nd (1.26), 1st (1.28) and 2nd (1.21) week with a maximum temperature of 26.85^oC and declined gradually. Treatments in 10 traps/acre and 40 traps/acre showed statistical positive significant differences between moth catches and larval count. Chickpea field where traps @ 20 /acre and 30/acre placed recorded the least *H. armigera* larval count (0.81). (i.e., negative relation) (Table 5). The pod infestation was also noticed during 51st standard week (2.30%) and increased gradually up to 6th standard week i.e., 52nd (4.02%) standard week, 1st (6.78%) standard week, 2nd (7.47%) standard week, 3rd (8.34%) standard week, 4th (8.90%) standard week, 5th (8.92%) standard week and 6th (8.78%) standard week. Maximum (8.92%) pod damage was recorded during 5th standard week; further, the decreasing trend as the crop attained senescence (Table 5). The data on trap catches of *H. armigera* and mean weather parameters were subjected to simple correlation analysis. The correlation matrix between the trap catches and weather parameters are presented below.

The chickpea trap catches exerted a positive association with maximum temperature ($r=0.538$), minimum temperature ($r=0.188$), afternoon relative humidity ($r=0.047$), evaporation ($r=0.072$) and wind speed ($r=0.033$), negative relation with morning relative humidity ($r=-350$) and rainfall ($r=-251$).

Table 3. Effect of trap density on pod borer infestation/week at Madurrae

Treatments	Standard weeks										Overall mean
	49	50	51	52	1	2	3	4	5	6	
10 traps	-	-	2.10 (8.27) ^a	4.10 (11.71) ^a	6.70 (14.92) ^b	7.03 (15.34) ^b	8.50 (16.94) ^b	8.79 (17.22) ^b	8.65 (17.09) ^c	8.71 (17.16) ^b	6.82 (15.13) ^b
20 traps	-	-	2.20 (8.54) ^a	4.15 (11.74) ^a	6.60 (14.83) ^b	6.64 (14.74) ^b	8.39 (16.80) ^b	8.28 (16.70) ^b	8.63 (17.04) ^c	7.87 (16.25) ^c	6.60 (14.83) ^c
30 traps	-	-	2.45 (8.92) ^a	4.30 (8.99) ^a	7.12 (15.15) ^b	8.35 (16.57) ^b	8.46 (16.87) ^b	8.90 (17.30) ^c	9.45 (17.84) ^b	9.88 (18.30) ^b	7.33 (15.67) ^b
40 traps	-	-	2.45 (8.99) ^a	3.55 (10.85) ^a	6.70 (14.83) ^b	7.87 (16.18) ^b	8.04 (16.43) ^b	8.10 (16.50) ^c	8.97 (17.38) ^b	8.69 (17.10) ^b	6.78 (15.03) ^b
Control (Trap without lure)	-	-	2.77 (9.53) ^a	4.65 (12.38) ^a	9.85 (18.08) ^a	10.85 (19.10) ^a	10.67 (19.01) ^a	11.37 (19.63) ^a	11.77 (20.04) ^a	11.65 (19.92) ^a	9.20 (17.63) ^a
SEm±	-	-	0.21	0.28	0.46	0.50	0.31	0.41	0.36	0.36	0.19
F- test	-	-	NS	NS	*	*	*	*	*	*	*
CD @ 0.05	-	-	-	-	1.43	1.52	0.98	1.22	1.18	1.13	0.60

*Average of four replications/treatment/week; **Mean of ten weeks; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; **Significant at 1%; NS= Non-Significant

Table 4. Chickpea pod borer moth catches in relation to damage in field at Maduraj in 4 different trap density

Standard weeks	Trap density/acre											
	10			20			30			40		
	Mean No. of moth catches /week*	Mean no of larvae/plant /week**	Mean no. of larvae/plant /week**	Mean No. of moth catches /week*	Mean no. of larvae/plant /week**	Mean No. of moth catches /week*	Mean no. of larvae/plant /week**	Mean No. of moth catches /week*	Mean no. of larvae/plant /week**	Mean No. of moth catches /week*	Mean no. of larvae/plant /week**	
49	0.25	0.75	0.59	0.5	0.59	0.25	0.79	1.00	0.81	1.00	0.79	0.81
50	1.50	0.72	0.77	2.25	0.77	1.75	0.99	2.25	1.11	2.25	0.99	1.11
51	2.00	1.05	1.16	5.25	1.16	5.50	1.19	5.25	1.33	5.25	1.19	1.33
52	5.00	1.15	1.14	6.25	1.14	6.25	1.44	5.50	1.33	5.50	1.44	1.33
1	4.50	1.18	1.19	6.50	1.19	6.00	1.34	6.00	1.35	6.00	1.34	1.35
2	10.50	1.13	1.17	14.75	1.17	9.00	1.15	8.75	1.28	8.75	1.15	1.28
3	7.25	0.75	0.74	79.00	0.74	67.75	0.81	64.00	1.04	64.00	0.81	1.04
4	3.50	0.59	0.58	9.50	0.58	5.25	0.56	17.75	0.76	17.75	0.56	0.76
5	3.00	0.46	0.43	8.50	0.43	4.25	0.48	6.75	0.54	6.75	0.48	0.54
6	2.00	0.38	0.33	3.50	0.33	2.00	0.44	3.50	0.40	3.50	0.44	0.40
Total	39.5	8.16	8.10	136	8.10	108	9.19	120	8.59	120	9.19	8.59
Mean	3.95	0.82	0.81	13.6	0.81	10.80	0.92	12.00	0.86	12.00	0.92	0.86
r- value	0.456			-0.016			-0.040			0.031		

* Mean number of moth catches per week; ** Mean number of larvae per plant per week from 30 plants for seven days

Table 5. Chickpea pod borer moth catches and pod damage (%) in relation to meteorological variables in field at Madurae, rabi, 2013-14

Standard weeks	**Mean No. of moth catches/trap/week	Mean No. of larva/plant/week***	Pod infestation (%)** *	Weather factors						
				Temperature (°C)		Relative Humidity (%)		Evaporation (mm)	Wind Speed (Km/h)	Rainfall all (mm)
				Max	Min	Morning	After noon			
49	0.08	0.78	-	27.42	17.42	76.00	45.75	4.85	4.20	8.20
50	0.38	0.94	-	27.71	15.85	80.50	50.71	5.90	4.36	0.00
51	0.82	1.18	2.30	26.71	17.00	75.87	50.50	5.82	4.27	0.00
52	1.14	1.26	4.02	26.85	15.42	76.75	57.50	5.65	4.25	0.00
1	1.12	1.28	6.78	26.75	15.40	78.00	49.10	5.10	3.55	6.80
2	2.30	1.21	7.47	27.25	15.45	78.80	49.40	5.32	3.61	0.00
3	8.52	0.83	8.34	28.00	16.90	74.00	48.45	5.60	4.20	0.00
4	1.45	0.62	8.50	27.30	16.71	79.52	48.50	5.75	4.41	0.00
5	1.03	0.48	8.92	27.00	16.00	75.00	43.70	5.75	3.90	0.00
6	0.51	0.38	8.78	27.50	16.15	74.10	43.00	5.65	3.94	0.00

*Average of 7 days; ** Mean number of moths and ***Mean number of larvae for seven days; *** Per cent pod damage for seven days in 30 plants

However, the influence of maximum temperature on trap catches was found to be significant. When the data was subjected to linear regression analysis, it revealed that the pest damage and moth catches were influenced by maximum temperature to an extent of 79 per cent ($R^2=0.79$). This suggested that maximum temperature is a critical factor influencing the moth catches (Table 6).

The larval count of *H. armigera* per plant and mean weather parameters were subjected to simple correlation analysis. The per cent pod damage by chickpea pod borer exerted a negative association with maximum temperature ($r=-0.454$), minimum temperature ($r=-0.380$), evaporation ($r=-0.224$) and wind speed ($r=0.207$) and positive relation with morning relative humidity ($r=0.388$), afternoon relative humidity ($r=0.782$) and rainfall ($r=0.174$). However, the influence of these factors was found to be non-significant (Table 7). It may be the combined effect of the chosen weather parameters together influenced the mean larval count/plant. When the data was subjected to linear regression analysis it revealed that, 97 per cent ($R^2=0.97$) of mean larval count was influenced by factors other than those chosen or it might be a combination of all the chosen weather parameters (Table 7).

The per cent pod damage by *H. armigera* and mean weather parameters were subjected to simple correlation analysis. The pod damage by chickpea pod borer was positively correlated with maximum temperature ($r=0.033$) and evaporation ($r=0.147$) and negatively correlated with minimum temperature ($r=-0.252$), morning relative humidity ($r=-0.230$), afternoon relative humidity ($r=-0.365$), wind speed ($r=-0.444$) and rainfall ($r=-0.352$). However, there was a significant association found with maximum temperature and highly significant with evaporation (Table 8). When the data was subjected to linear regression analysis it revealed that, 56 per cent ($R^2=0.56$) of pod damage was influenced by weather parameters such as wind speed and afternoon relative humidity (Table 8).

4.3. Effect of application of select insecticides on pheromone trap catches of chickpea pod borer and pod damage

The field experiment was conducted at four locations by using statistical analysis of one way ANOVA to know the effect of application of select insecticides on trap catches of chickpea pod borer, their effect on pod damage and per cent protection provided by the combination of insecticides and pheromone traps over control. This study was carried out by selecting 4 different insecticides viz., chlorantraniliprole, indoxacarb, novaluran and quinalphos used by farmers against chickpea pod borer. Along with insecticides application, 20 pheromone traps were installed in each field to record the moth catches. The untreated field was maintained as control with pheromone traps to record the moth catches. The field's treated with insecticides alone on larval count and per cent pod infestation also recorded and statistically done by RCBD. The results obtained from the study are presented here under.

Table 6. Relationship between the Chickpea pod borer moth catches and meteorological variables, Madurae, 2013-14

Parameters	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇
Y- Trap catches	0.538*	0.188	-0.350	0.047	0.072	0.033	-0.251
X ₁ - Max. Temperature	1.00	0.325	-0.080	-0.295	0.079	0.308	-0.163
X ₂ - Min. Temperature		1.00	-0.368	-0.352	-0.093	0.568	0.195
X ₃ -Morning RH (%)			1.00	0.406	0.054	0.072	0.012
X ₄ -Afternoon RH (%)				1.00	0.172	0.276	-0.177
X ₅ -Evaporation (mm)					1.00	0.482	-0.886
X ₆ -Wind speed(km/h)						1.00	-0.281
X ₇ -Rainfall (mm)							1.00

N=10; *Significant at 5% (p<0.05); R²=0.790;

$$Y = -186.74 + 5.227X_1 + 3.385X_2 - 0.305X_3 + 0.643X_4 + 5.322X_5 - 11.391X_6 + 0.114X_7$$

Table 7. Relationship between the Chickpea pod borer larval count and meteorological variables, Madurac, 2013-14

Parameters	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇
Y- Larval count	-0.454	-0.380	0.388	0.782*	-0.224	-0.207	0.174
X ₁ - Max. Temperature	1.00	0.325	-0.080	-0.295	0.070	0.308	-0.163
X ₂ - Min. Temperature		1.00	-0.368	-0.352	-0.093	0.568	0.195
X ₃ -Morning RH (%)			1.00	0.406	0.054	0.072	0.012
X ₄ -Afternoon RH (%)				1.00	0.172	0.276	-0.177
X ₅ -Evaporation (mm)					1.00	0.482	-0.886
X ₆ -Wind speed(km/h)						1.00	-0.281
X ₇ -Rainfall (mm)							1.00

N=10; *Significant at 5% ($p \leq 0.05$); $R^2=0.970$;

$$Y = -12.623 + 0.081X_1 + 0.366X_2 - 0.029X_3 + 0.108X_4 + 0.591X_5 - 1.362X_6 + 0.047X_7$$

Table 8. Relationship between the pod infestation by *H. armigera* and meteorological variables, Madurae, 2013-14

Parameters	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇
Y- Pod infestation	0.033	-0.252	-0.230	-0.365	0.147	-0.444	-0.352
X ₁ - Max. Temperature	1.00	0.325	-0.080	-0.295	0.079	0.308	-0.163
X ₂ - Min. Temperature		1.00	-0.368	-0.352	-0.093	0.568	-0.163
X ₃ -Morning RH (%)			1.00	0.406	0.054	0.072	0.012
X ₄ -Afternoon RH (%)				1.00	0.172	0.276	-0.177
X ₅ -Evaporation (mm)					1.00	0.482	-0.886
X ₆ -Wind speed(km/h)						1.00	-0.281
X ₇ -Rainfall (mm)							1.00

N=10; *Significant at 5% ($p \leq 0.05$); $R^2 = 0.560$;

$$Y = 95.955 - 0.419X_1 - 0.559X_2 - 0.243X_3 - 0.310X_4 - 3.498X_5 - 3.783X_6 - 0.888X_7$$

4.3.1. Effect on pheromone trap catches of *H. armigera*

Before insecticide application at first location the moth catches of *H. armigera* in pheromone traps ranged from 0.95 to 1.15 moths/trap in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.00 moth/trap was recorded at pre-treatment observation (Table 9).

At 7 DAS, minimum number of moths (0.30/trap) was recorded in the treatment module I (*i.e.*, chlorantraniliprole + pheromone trap), treatment module II and treatment module III also recorded minimum number of moth catches (0.45 and 0.55/trap *i.e.*, indoxacarb + pheromone trap and novaluran + pheromone trap) respectively which were statistically on par followed by other treatment module *viz.*, quinalphos + pheromone trap (0.7 moths/trap). Significantly higher number of moths were trapped in the control (1.30 moths/trap).

At 14 DAS, there was a significant difference observed in all the treatment modules and control field with respect to number of moths caught/trap. Significantly lower number of moths (0.21, 0.40 and 0.50 moths/trap) were trapped in the treatment module I, II and III (*i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluran + pheromone trap) respectively which were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (1.10 moths/trap). Maximum moth catches (1.25 moths/trap) were recorded in control field (untreated + pheromone trap alone).

At 21 DAS and 28 DAS, similar trend was noticed in all the treatment modules. Module I and II (chlorantraniliprole + pheromone and indoxacarb + pheromone trap) recorded 0.20 and 0.25 moths/trap and 0.40 and 0.50 moths/trap against 1.40 and 1.60 moths/trap respectively in control field (untreated + pheromone trap alone).

Observations indicated that there were significant differences noticed in all the treatment modules regarding mean number of moths trapped compared to control during the study period (Table 9). The treatment module I and II (*i.e.*, chlorantraniliprole + pheromone and indoxacarb + pheromone trap) were on par because the mean number of moths recorded per trap against control (1.60 moths/trap) was significantly lower. This was followed by module III and IV (novaluran + pheromone trap and quinalphos + pheromone traps).

In second location the moth catches of *H. armigera* in pheromone traps ranged from 1.1 to 1.35 moths/trap in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.40 moths/trap was recorded at pre-treatment observation (Table 10).

At 7 DAS, minimum number of moths (0.40/trap) was recorded in the treatment module I *i.e.*, chlorantraniliprole + pheromone trap, in module II, in module III and in module IV also recorded minimum number of moth catches (0.60, 0.75 and 0.80/trap) *i.e.*, indoxacarb + pheromone trap, novaluran + pheromone trap and quinalphos + pheromone trap respectively which were statistically on par. Significantly higher number of moths were trapped in the control (1.65 moths/trap).

Table 9. Effect of insecticides and traps on moth catches/trap/week (First location)

Treatment modules	Mean No. of moth catches/trap/week*				
	Prespray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	0.95 (1.13) ^a	0.30 (0.86) ^d	0.21 (0.81) ^b	0.20 (0.81) ^c	0.25 (0.84) ^d
Indoxacarb + 20 traps/acre	1.15 (1.20) ^a	0.45 (0.93) ^c	0.40 (0.91) ^b	0.40 (0.91) ^c	0.50 (0.96) ^{cd}
Novaluron + 20 traps/acre	1.05 (1.16) ^a	0.55 (0.98) ^c	0.50 (0.97) ^b	0.60 (1.00) ^{bc}	0.75 (1.07) ^{bc}
Quinalphos + 20 traps/acre	1.10 (1.20) ^a	0.70 (1.05) ^b	1.10 (1.22) ^a	1.05 (1.18) ^{ab}	1.20 (1.25) ^{ab}
Untreated + 20 traps/acre	1.00 (1.13) ^a	1.30 (1.27) ^a	1.25 (1.27) ^a	1.40 (1.33) ^a	1.60 (1.41) ^a
F-test	NS	*	*	*	*
SEm ±	0.10	0.08	0.06	0.07	0.07
CD @ P=0.05	-	0.21	0.18	0.20	0.20

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

Table 10. Effect of insecticides and traps on moth catches/trap/week (Second location)

Treatment modules	Mean No. of moth catches/trap/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	1.30 (1.24) ^a	0.40 (0.91) ^b	0.25 (0.84) ^c	0.35 (0.89) ^c	0.15 (0.78) ^c
Indoxacarb + 20 traps/acre	1.15 (1.23) ^a	0.60 (1.01) ^b	0.45 (0.94) ^{bc}	0.50 (0.97) ^{bc}	0.35 (0.89) ^{bc}
Novaluron + 20 traps/acre	1.35 (1.31) ^a	0.75 (1.07) ^b	0.60 (1.00) ^{bc}	0.55 (0.98) ^{bc}	0.40 (0.91) ^{bc}
Quinalphos + 20 traps/acre	1.10 (1.22) ^a	0.80 (1.10) ^b	0.70 (1.66) ^b	0.85 (1.14) ^b	0.65 (1.04) ^b
Untreated + 20 traps/acre	1.40 (1.33) ^a	1.65 (1.43) ^a	1.90 (1.52) ^a	2.05 (1.58) ^a	1.50 (1.35) ^a
F-test	NS	*	*	*	*
SEm±	0.08	0.07	0.06	0.05	0.07
CD @ 0.05	-	0.19	0.18	0.16	0.18

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%, NS= Non-Significant

At 14 DAS, there was a significant difference observed in treatment module I (*i.e.*, chlorantraniliprole + pheromone trap); significantly lower number of moths (0.25 moths/trap) were trapped; further treatment modules II and III (indoxacarb + pheromone trap and novaluran + pheromone trap) also recorded lower moth catches (0.45 and 0.65 moths/trap) respectively which were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (0.70 moths/trap); Maximum moth catches (1.90 moths/trap) were recorded in control field (untreated + pheromone trap alone).

At 21 and 28 DAS, similar trend was noticed in all the treatment modules; however module I (chlorantraniliprole + pheromone) recorded 0.35 and 0.15 moths/trap; further treatment modules II and III recorded 0.50, 0.35 and 0.55, 0.40 moths/trap; whereas in treatment module IV recorded 0.85 and 0.65 moths/trap against 2.05 and 1.50 moths/trap respectively in control field (untreated + pheromone trap alone).

In third location the moth catches of *H. armigera* in pheromone traps ranged from 1.30 to 1.45 moths/trap in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.35 moths/trap was recorded at pre-treatment observation (Table 11).

At 7 DAS, minimum number of moths (0.40/trap) was recorded in the treatment module I (chlorantraniliprole + pheromone trap), treatment module II and in treatment module III also recorded minimum number of moth catches (0.65 and 0.80/trap) *i.e.*, indoxacarb + pheromone trap and novaluran + pheromone trap respectively which were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (0.95 moths/trap). Significantly higher number of moths were trapped in the control (1.60 moths/trap).

At 14 DAS, there was a significant difference observed in treatment modules I, II and III (*i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluran + pheromone trap); further, significantly lower number of moths (0.25, 0.50 and 0.55 moths/trap) were trapped respectively, which were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (1.05 moths/trap). Maximum moth catches (1.85 moths/trap) were recorded in control field (untreated + pheromone trap alone).

At 21 DAS and 28 DAS, similar trend was noticed in all the treatment modules; module I (chlorantraniliprole + pheromone) recorded 0.35 and 0.20 moths/trap; while treatment modules II and III recorded 0.70, 0.45 and 0.80, 0.60 moths/trap; whereas treatment module IV recorded 1.20 and 0.95 moths/trap against 2.05 and 1.65 moths/trap respectively in control (untreated + pheromone trap alone).

In fourth location the moth catches of *H. armigera* in pheromone traps ranged from 0.55 to 0.75 moths/trap in the first four treatment modules over control (untreated + pheromone trap alone) in which 0.80 moths/trap was recorded at pre-treatment observation (Table 12).

Table 11. Effect of insecticides and traps on moth catches/trap/week (Third location)

Treatment modules	Mean No. of moth catches/trap/week*				
	Prespray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	1.45 (1.35) ^a	0.40 (0.91) ^c	0.25 (0.84) ^c	0.35 (0.89) ^c	0.20 (0.81) ^d
Indoxacarb + 20 traps/acre	1.30 (1.28) ^a	0.65 (1.02) ^{bc}	0.50 (0.96) ^c	0.70 (1.05) ^{bc}	0.45 (0.94) ^{cd}
Novaluron + 20 traps/acre	1.40 (1.32) ^a	0.80 (1.09) ^{bc}	0.55 (0.99) ^c	0.80 (1.11) ^{bc}	0.60 (1.02) ^{bc}
Quinalphos + 20 traps/acre	1.35 (1.29) ^a	0.95 (1.16) ^b	1.05 (1.21) ^b	1.20 (1.26) ^b	0.95 (1.16) ^b
Untreated + 20 traps/acre	1.35 (1.29) ^a	1.60 (1.39) ^a	1.85 (1.49) ^a	2.05 (1.54) ^a	1.65 (1.41) ^a
F-test	NS	*	*	*	*
SEm±	0.09	0.08	0.07	0.08	0.07
CD @ 0.05	-	0.22	0.19	0.22	0.19

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

Table 12. Effect of insecticides and traps on moth catches/trap/week (Fourth location)

Treatment modules	Mean No. of moth catches/trap/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	0.60 (0.99) ^a	0.25 (0.84) ^b	0.20 (0.81) ^c	0.30 (0.86) ^b	0.15 (0.78) ^c
Indoxacarb + 20 traps/acre	0.65 (1.01) ^a	0.40 (0.91) ^b	0.30 (0.86) ^c	0.45 (0.93) ^b	0.25 (0.84) ^{bc}
Novaluron + 20 traps/acre	0.55 (0.98) ^a	0.40 (0.91) ^b	0.35 (0.89) ^{bc}	0.50 (0.96) ^b	0.40 (0.91) ^{abc}
Quinalphos + 20 traps/acre	0.75 (1.07) ^a	0.60 (1.01) ^{ab}	0.65 (1.04) ^b	0.70 (1.05) ^{ab}	0.55 (0.98) ^{ab}
Untreated + 20 traps/acre	0.80 (1.06) ^a	0.85 (1.11) ^a	1.05 (1.21) ^a	1.10 (1.20) ^a	0.75 (1.06) ^a
F-test	NS	*	*	*	*
SEm±	0.08	0.06	0.05	0.07	0.06
CD @ 0.05	-	0.18	0.16	0.20	0.17

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

At 7 DAS, minimum number of moths (0.25, 0.40 and 0.40 moths/trap) was recorded in the treatment module I; treatment module II and treatment module III *i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluran + pheromone trap were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (0.60 moths/trap). Significantly higher number of moths were trapped in the control (0.85 moths/trap).

At 14 DAS, there was a significant difference observed in treatment module I, treatment module II (*i.e.*, chlorantraniliprole + pheromone trap and indoxacarb + pheromone trap) were trapped significantly lower number of moths (0.20 and 0.30 moths/trap respectively), which were statistically on par followed by other treatment modules such as novaluron + pheromone trap (0.35 moths/trap), quinalphos + pheromone trap (0.65 moths/trap). Maximum moth catches (1.05 moths/trap) were recorded in control field (untreated + pheromone trap alone).

At 21 DAS, minimum number of moths (0.30, 0.45 and 0.50 moths/trap) were recorded in the treatment module I; while treatment module II and treatment module III (*i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluran + pheromone trap) were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (0.70 moths/trap). Significantly higher numbers of moths were trapped in the control (1.15 moths/trap).

At 28 DAS, the treatment module I (*i.e.*, chlorantraniliprole + pheromone trap) was recorded lower number of moths (0.15 moths/trap). The module I followed by other treatment modules such as indoxacarb + pheromone trap (0.25 moths/trap), novaluron + pheromone trap (0.40 moths/trap) and quinalphos + pheromone trap (0.55 moths/trap). Significantly higher number of moths were trapped in the control (0.75 moths/trap).

4.3.2. Effect on larval count

The effect of application of select insecticides on larval count of *H. armigera* on chickpea is presented in Table 13. The larval count ranged from 1.20 to 1.30 per plant in the first four treatment modules compared to control (1.37 larvae/plant) at pre-treatment observation in first location.

At 4 DAS, significantly lower larval count was recorded in all the treatment (0.47, 0.63, 0.83 and 0.97 larvae/plant) *i.e.*, chlorantraniliprole + pheromone trap and indoxacarb + pheromone trap, novaluron + pheromone trap and quinalphos + Pheromone trap whereas control plot recorded maximum (1.63 larvae/plant).

At 7 DAS, lower larval count was recorded in the treatment module I, II and III (0.33, 0.50, 0.67 larvae/plant) *i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluron + Pheromone trap which were statistically on par followed by other treatment modules such as quinalphos + pheromone trap (1.13 larvae/plant), while control plot recorded maximum (1.93 larvae/plant).

Table 13. Effect of insecticides and traps on larval count/plant (First location)

Treatment modules	Mean No. of larva/plant/week*				
	Pre spray	4 DAS	7 DAS	14 DAS	21 DAS
Chlorantraniliprole + 20 traps/acre	1.27 (1.26) ^a	0.47 (0.94) ^b	0.33 (0.88) ^c	0.40 (0.91) ^c	0.27 (0.85) ^c
Indoxacarb + 20 traps/acre	1.20 (1.24) ^a	0.63 (1.00) ^b	0.50 (0.94) ^c	0.63 (1.01) ^c	0.47 (0.92) ^c
Novaluron + 20 traps/acre	1.30 (1.27) ^a	0.83 (1.10) ^b	0.67 (1.04) ^c	0.73 (1.08) ^c	0.57 (1.00) ^{bc}
Quinalphos + 20 traps/acre	1.30 (1.27) ^a	0.97 (1.14) ^b	1.13 (1.23) ^b	1.33 (1.32) ^b	0.93 (1.15) ^b
Untreated + 20 traps/acre	1.37 (1.30) ^a	1.63 (1.39) ^a	1.93 (1.51) ^a	2.27 (1.62) ^a	1.90 (1.52) ^a
F-test	NS	*	*	*	*
SEm±	0.08	0.07	0.06	0.06	0.05
CD @ 0.05	-	0.20	0.17	0.16	0.15

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

At 14 DAS and 21 DAS, similar trend was noticed in the treatment module I, II and III (0.40 and 0.27, 0.63 and 0.47, 0.73 and 0.57 larvae/plant) which were statistically on par followed by other treatment modules such as and quinalphos + pheromone trap (1.33 and 0.93 larvae/plant), whereas control plot recorded maximum (2.27 and 1.90 larvae/plant).

In second location the larval count of *H. armigera* in pheromone traps ranged from 1.23 to 1.40 larvae/plant in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.47 larvae/plant was recorded at pre-treatment observation (Table 14).

At 4 DAS, 7 DAS and 14 DAS significantly lower larval count (0.50, 0.40 and 0.53 larvae/plant) was recorded in the treatment module I (*i.e.*, chlorantraniliprole + pheromone trap) followed by treatment module II (0.87, 0.63 and 0.70 larvae/plant), treatment module III (0.90, 0.77 and 0.73 larvae/plant) and treatment module IV (0.97, 0.83 and 1.00 larvae/plant) which were statistically on par but differ significantly with control plot, which recorded maximum (1.63, 1.77 and 2.13 larvae/plant).

At 21 DAS, the treatment module I (*i.e.*, chlorantraniliprole + pheromone trap) was recorded lower number of larval count (0.27 larvae/plant) which was statistically significant; This was followed by other treatment module such as indoxacarb + pheromone trap (0.47 larvae/plant), novaluron + pheromone trap (0.53 larvae/plant), which were statistically on par followed by other treatment module *i.e.*, quinalphos + pheromone trap (0.83 larvae/plant); whereas control plot recorded maximum (1.77 larvae/plant).

In third location the larval count of *H. armigera* in pheromone traps ranged from 1.30 to 1.47 larvae/plant in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.53 larvae/plant was recorded at pre-treatment observation (Table 15).

At 4 DAS, significantly lower larval count was recorded in the treatment module I (0.47 larvae/plant), treatment module II (0.67 larvae/plant), and III (0.83 larvae/plant), which were statistically on par but differed significantly with treatment module IV (1.03 larvae/plant), whereas control plot recorded maximum (1.87 larvae/plant).

At 7, 14 and 21 DAS significantly lower larval count was recorded in the treatment module I (0.30, 0.37 and 0.37 larvae/plant), module II (0.43, 0.47 and 0.40 larvae/plant), module III (0.60, 0.73 and 0.67 larvae/plant), which were statistically on par followed by other treatment module (*i.e.*, quinalphos + Pheromone trap 1.20, 1.43 and 1.13 larvae/plant); whereas control plot recorded maximum (2.23, 2.40 and 2.03 larvae/plant).

In fourth location the larval count of *H. armigera* in pheromone traps ranged from 0.93 to 1.17 larvae/plant in the first four treatment modules over control (untreated + pheromone trap alone) in which 1.27 larvae/plant was recorded at pre-treatment observation (Table 16).

Table 14. Effect of insecticides and traps on larval count/plant (Second location)

Treatment modules	Mean No. of larva/plant/week*				
	Pre spray	4 DAS	7 DAS	14 DAS	21 DAS
Chlorantraniliprole + 20 traps/acre	1.37 (1.26) ^a	0.50 (0.96) ^b	0.40 (0.91) ^b	0.53 (0.97) ^b	0.27 (0.85) ^c
Indoxacarb + 20 traps/acre	1.40 (1.29) ^a	0.87 (1.11) ^b	0.63 (1.00) ^b	0.70 (1.03) ^b	0.47 (0.93) ^{bc}
Novaluron + 20 traps/acre	1.23 (1.24) ^a	0.90 (1.13) ^b	0.77 (1.08) ^b	0.73 (1.05) ^b	0.53 (0.97) ^{bc}
Quinalphos + 20 traps/acre	1.33 (1.36) ^a	0.97 (1.14) ^b	0.83 (1.08) ^b	1.00 (1.16) ^b	0.83 (1.08) ^b
Untreated + 20 traps/acre	1.47 (1.33) ^a	1.63 (1.41) ^a	1.77 (1.46) ^a	2.13 (1.57) ^a	1.77 (1.43) ^a
F-test	NS	*	*	*	*
SEM±	0.09	0.07	0.06	0.07	0.07
CD @ 0.05	-	0.19	0.18	0.19	0.19

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

Table 15. Effect of insecticides and traps on larval count/plant (Third location)

Treatment modules	Mean No. of larva/plant/week*				
	Pre spray	4 DAS	7 DAS	14 DAS	21 DAS
Chlorantraniliprole + 20 traps/acre	1.47 (1.35) ^a	0.47 (0.95) ^c	0.30 (0.86) ^c	0.37 (0.89) ^c	0.37 (0.89) ^c
Indoxacarb + 20 traps/acre	1.37 (1.29) ^a	0.67 (1.02) ^{bc}	0.43 (0.92) ^c	0.47 (0.93) ^c	0.40 (0.91) ^c
Novaluron + 20 traps/acre	1.40 (1.30) ^a	0.83 (1.07) ^{bc}	0.60 (0.98) ^c	0.73 (1.05) ^c	0.67 (1.02) ^c
Quinalphos + 20 traps/acre	1.30 (1.27) ^a	1.03 (1.18) ^b	1.20 (1.24) ^b	1.43 (1.34) ^b	1.13 (1.22) ^b
Untreated + 20 traps/acre	1.53 (1.35) ^a	1.87 (1.48) ^a	2.23 (1.60) ^a	2.40 (1.65) ^a	2.03 (1.53) ^a
F-test	NS	*	*	*	*
SEm±	0.08	0.07	0.06	0.06	0.06
CD @ 0.05	-	0.19	0.18	0.18	0.18

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

Table 16. Effect of insecticides and traps on larval count/plant (Fourth location)

Treatment modules	Mean No. of larva/plant/week*				
	Pre spray	4 DAS	7 DAS	14 DAS	21 DAS
Chlorantraniliprole + 20 traps/acre	0.93 (1.14) ^a	0.40 (0.91) ^c	0.30 (0.86) ^b	0.43 (0.93) ^b	0.37 (0.82) ^c
Indoxacarb + Pheromone	1.03 (1.17) ^a	0.57 (0.98) ^{bc}	0.48 (0.93) ^b	0.60 (1.99) ^b	0.53 (0.96) ^b
Novaluron + 20 traps/acre	0.97 (1.14) ^a	0.60 (0.99) ^{bc}	0.53 (0.95) ^b	0.70 (1.02) ^b	0.57 (0.97) ^b
Quinalphos + 20 traps/acre	1.17 (1.22) ^a	0.87 (1.09) ^b	1.00 (1.15) ^a	1.20 (1.24) ^a	1.03 (1.17) ^a
Untreated + 20 traps/acre	1.27 (1.26) ^a	1.33 (1.30) ^a	1.43 (1.33) ^a	1.67 (1.40) ^a	1.47 (1.34) ^a
F-test	NS	*	*	*	*
SEm±	0.07	0.06	0.06	0.07	0.07
CD @ 0.05	-	0.18	0.18	0.20	0.19

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

At 4 DAS, significantly lower larval count was recorded in the treatment module I *viz.*, chlorantraniliprole + pheromone trap (0.40 larvae/plant), in treatment module II (0.57 larvae/plant), treatment module III (0.60 larvae/plant) which were statistically on par and differed significantly with treatment module IV (0.87 larvae/plant), whereas control plot recorded maximum (1.33 larvae/plant).

At 7 and 14 DAS significantly lower larval count was recorded in the treatment module I (0.30 and 0.43 larvae/plant), module II (0.48 and 0.60 larvae/plant), and module III (0.53 and 0.70 larvae/plant) which were statistically on par. Other treatment modules such as and quinalphos + Pheromone trap (1.00 and 1.20 larvae/plant) and control plot recorded maximum (1.43 and 1.67 larvae/plant) which were also statistically on par.

At 21 DAS, significantly lower larval count was recorded in the treatment module I (0.37 larvae/plant), treatment module II (0.53 larvae/plant), treatment module III (0.57 larvae/plant) which were statistically on par; further treatment module IV (1.03 larvae/plant) and control plot recorded maximum (1.47 larvae/plant) which were also statistically on par.

4.3.3. Effect on pod infestation by *H. armigera*

The effect of application of select insecticides on pod infestation by *H. armigera* on chickpea is presented in Table 17. The pod infestation ranged from 8.87 to 9.03 per cent/week in the first four treatment modules compared to control (9.27 per cent/week) at pre-treatment observation in first location.

At 7 DAS, lowest pod infestation (7.50, 7.63, 7.90 and 8.10 per cent pod infestation/week) was recorded in the treatment module I, treatment module II, treatment module III and treatment module IV *i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap, novaluran + pheromone trap and quinalphos + pheromone trap which were statistically on par. Significantly highest pod infestation was recorded in the control (10.07 per cent pod infestation/week).

At 14 DAS, lowest pod infestation (5.23% pod infestation/week) was recorded in the treatment module I, followed by module II (5.67% pod infestation/week), module III (6.30% pod infestation/week) and module IV (7.73% pod infestation/week). Significantly highest pod infestation were recorded in the control (10.77% pod infestation/week).

At 21 and 28 DAS, lowest pod infestation (4.40% and 3.80%, 4.80% and 4.13% pod infestation/week) was recorded in the treatment module I and in treatment module II *i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap which were statistically on par but differed significantly with and other treatment modules *viz.*, novaluran + pheromone trap (5.63% and 4.87% pod infestation/week) and quinalphos + pheromone trap (8.03% and 8.37% pod infestation/week). Significantly highest pod infestation were recorded in the control (11.63% and 12.10% pod infestation/week).

Table 17. Effect of insecticides and traps on pod infestation/week (First location)

Treatment modules	Per cent pod infestation/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	8.90 (17.22) ^a	7.50 (15.83) ^b	5.23 (13.02) ^d	4.40 (11.11) ^d	3.80 (11.03) ^d
Indoxacarb + 20 traps/acre	8.87 (17.21) ^a	7.63 (15.96) ^b	5.67 (13.61) ^{cd}	4.80 (12.44) ^d	4.13 (11.53) ^d
Novaluron + 20 traps/acre	9.03 (17.39) ^a	7.90 (16.26) ^b	6.30 (14.37) ^c	5.63 (13.58) ^c	4.87 (12.65) ^c
Quinalphos + 20 traps/acre	8.97 (17.27) ^a	8.10 (16.45) ^b	7.73 (16.02) ^b	8.03 (16.37) ^b	8.37 (16.71) ^b
Untreated + 20 traps/acre	9.27 (17.50) ^a	10.07 (18.30) ^a	10.77 (19.03) ^a	11.63 (19.82) ^a	12.10 (20.24) ^a
F-test	NS	*	*	*	*
SEm±	0.43	0.35	0.42	0.40	0.37
CD @ 0.05	-	0.97	1.16	1.12	1.05

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

In second location the select insecticides on pod infestation by *H. armigera* on chickpea is presented in Table 18. The pod infestation ranged from 9.33 to 9.87 per cent/week in the first four treatment modules compared to control (10.70 per cent/week) at pre-treatment observation.

At 7 DAS, lowest pod infestation (6.73, 7.07, and 7.17% pod infestation/week) was recorded in the treatment module I, treatment module II, treatment module III *i.e.*, chlorantraniliprole + pheromone trap, indoxacarb + pheromone trap and novaluran + pheromone trap which were statistically on par. Significantly highest pod infestation was recorded in the control (10.53% pod infestation/week).

At 14 and 21 DAS, significant lowest pod infestation (5.30% and 4.50% pod infestation/week) was recorded in the treatment module I, followed by module II (6.00% and 5.17% pod infestation/week); while treatment module III (6.47% and 5.53% pod infestation/week) and module IV (8.07% and 8.20% pod infestation/week) were on par and recorded little higher percent pod infestation. Significantly highest pod infestation was recorded in the control (11.20% and 11.60% pod infestation/week).

At 28 DAS, lowest pod infestation (3.87% pod infestation/week) was recorded in the treatment module I which differed significantly with other treatment modules; while module II and III (4.83% and 5.30% pod infestation/week) were statistically on par; and differed significantly with module IV *i.e.*, other module *i.e.*, quinalphos + pheromone trap (8.47% pod infestation/week). However significantly highest pod infestation was recorded in the control (12.20% pod infestation/week).

In third location the select insecticides on pod infestation by *H. armigera* on chickpea is presented in Table 19. The pod infestation ranged from 8.97 to 9.27 per cent/week in the first four treatment modules compared with control (9.23 per cent/week) at pre-treatment observation in first location.

At 7 DAS, lowest pod infestation (6.50% pod infestation/week) was recorded in the module I, followed by treatment module II (7.40% pod infestation/week); treatment module III and IV (7.53% and 8.20% pod infestation/week) which were statistically on par. Significantly highest pod infestation were recorded in the control (10.03% pod infestation/week).

At 14, 21 and 28 DAS, lowest pod infestation (5.37%, 4.53% and 3.83% pod infestation/week) was recorded in the treatment module I, followed by module II and module III (6.47%, 5.97%, 4.83% and 6.73% 6.33%, 5.86% pod infestation/week) which were statistically on par; but differs significantly with module IV (8.47%, 8.80% and 9.23% pod infestation/week). Further significantly highest pod infestation was recorded in the control (10.77%, 10.07% and 10.36% pod infestation/week).

In fourth location the select insecticides on pod infestation by *H. armigera* on chickpea is presented in Table 20. The pod infestation ranged from 7.57 to 7.73 per cent/week in the first four treatment modules compared to control (8.03 per cent/week) at pre-treatment observation in first location.

Table 18. Effect of insecticides and traps on pod infestation/week (Second location)

Treatment modules	Per cent pod infestation/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	9.87 (18.14) ^a	6.73 (14.89) ^c	5.30 (13.07) ^d	4.50 (12.14) ^d	3.87 (11.24) ^d
Indoxacarb + 20 traps/acre	9.70 (17.85) ^a	7.07 (15.26) ^c	6.00 (14.00) ^{cd}	5.17 (13.01) ^{cd}	4.83 (12.60) ^c
Novaluron + 20 traps/acre	9.37 (17.63) ^a	7.17 (15.43) ^c	6.47 (14.64) ^c	5.53 (13.51) ^c	5.30 (13.20) ^c
Quinalphos + 20 traps/acre	9.33 (17.71) ^a	8.40 (16.77) ^b	8.07 (16.39) ^b	8.20 (16.51) ^b	8.47 (16.82) ^b
Untreated + 20 traps/acre	10.70 (18.33) ^a	10.53 (18.82) ^a	11.20 (19.46) ^a	11.60 (19.83) ^a	12.20 (20.37) ^a
F-test	NS	*	*	*	*
SEM±	0.50	0.37	0.40	0.34	0.32
CD @ 0.05	-	1.04	1.10	0.96	0.88

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant

Table 19. Effect of insecticides and traps on pod infestation/week (Third location)

Treatment modules	Per cent pod infestation/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	9.27 (17.56) ^a	6.50 (14.65) ^c	5.37 (13.28) ^d	4.53 (12.19) ^d	3.83 (11.20) ^d
Indoxacarb + 20 traps/acre	8.97 (17.31) ^a	7.40 (15.67) ^{bc}	6.47 (14.56) ^c	5.97 (13.95) ^c	4.83 (12.43) ^c
Novaluron + 20 traps/acre	9.07 (17.42) ^a	7.53 (15.81) ^b	6.73 (14.88) ^c	6.33 (14.38) ^c	5.86 (13.87) ^c
Quinalphos + 20 traps/acre	9.10 (17.42) ^a	8.20 (16.53) ^b	8.47 (16.83) ^b	8.80 (17.17) ^b	9.23 (17.61) ^b
Untreated + 20 traps/acre	9.23 (17.53) ^a	10.03 (18.35) ^a	10.77 (19.08) ^a	10.07 (18.43) ^a	10.36 (18.71) ^a
F-test	NS	*	*	*	*
SEm±	0.42	0.37	0.37	0.37	0.36
CD @ 0.05	-	1.04	1.03	1.03	1.00

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are arc sine transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; *Significant at 5%; NS= Non-Significant

Table 20. Effect of insecticides and traps on per cent pod infestation/week (Fourth location)

Treatment modules	Per cent pod infestation/week*				
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS
Chlorantraniliprole + 20 traps/acre	7.70 (16.01) ^a	5.17 (12.97) ^c	4.03 (11.37) ^d	3.20 (10.18) ^d	2.87 (9.63) ^d
Indoxacarb + 20 traps/acre	7.57 (15.80) ^a	6.03 (13.99) ^{bc}	5.20 (12.89) ^c	4.17 (11.40) ^c	3.63 (10.64) ^{cd}
Novaluron + 20 traps/acre	7.63 (15.96) ^a	6.20 (14.22) ^b	5.63 (13.58) ^c	4.00 (11.41) ^c	3.70 (11.00) ^c
Quinalphos + 20 traps/acre	7.73 (16.07) ^a	6.83 (15.04) ^b	7.20 (15.47) ^b	7.40 (15.71) ^b	6.60 (14.67) ^b
Untreated + 20 traps/acre	8.03 (16.38) ^a	8.40 (16.76) ^a	8.77 (17.11) ^a	9.00 (17.34) ^a	7.97 (16.23) ^a
F-test	NS	*	*	*	*
SEm±	0.34	0.41	0.41	0.38	0.41
CD @ 0.05	-	1.14	1.15	1.07	1.14

* Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; *Significant at 5%; NS= Non-Significant

At 7 DAS, significantly lowest pod infestation (5.17% pod infestation/week) was recorded in the module I, followed by module II (6.03% pod infestation/week); treatment module III and IV (6.20% and 6.83% pod infestation/week) were statistically on par. Significantly highest pod infestation was recorded in the control (8.46% pod infestation/week).

At 14 and 21 DAS, lowest pod infestation (4.03% and 3.20% pod infestation/week) was recorded in the module I, followed by treatment module II and module III (5.20%, 4.17% and 5.63%, 4.00% pod infestation/week) which were statistically on par but differ significantly with module IV (7.20% and 7.40% pod infestation/week). Significantly highest pod infestation was recorded in the control (8.77% and 9.00% pod infestation/week).

At 28 DAS, lowest pod infestation (2.87% pod infestation/week) was recorded in the module I, followed by module II (3.63% pod infestation/week), treatment module III and IV (3.70% and 6.60% pod infestation/week) were statistically on par. Significantly highest pod infestation was recorded in the control (7.97% pod infestation/week).

4.4. Effect of insecticides on larval count and pod infestation

The effect of application of select insecticides on larval count of *H. armigera* on chickpea is presented in Table 21. The larval count ranged from 1.37 to 1.45 per plant in the first four treatment modules compared to control (1.44 larvae/plant) at pre-treatment observation.

At 4 DAS, significantly lower larval count was recorded in all the treatments (0.62, 0.68, 0.80 and 1.06 larvae/plant) *i.e.*, chlorantraniliprole, and indoxacarb, novaluron and quinalphos. Whereas control plot recorded maximum (1.77 larvae/plant).

At 7 DAS, lower larval count was recorded in the treatment module I, II and III (0.61, 0.63 and 0.76 larvae/plant) *i.e.*, chlorantraniliprole, indoxacarb and novaluron which were statistically on par followed by other treatment module such as quinalphos (1.13 larvae/plant), while control plot recorded maximum (2.02 larvae/plant).

At 14 and 21 DAS, similar trend was noticed in the treatment module I, II and III (0.71 and 0.76, 0.73 and 0.76, 0.88 and 0.91 larvae/plant). Treatment module II and III which were statistically on par. The other treatment module such as and quinalphos (1.25 and 1.30 larvae/plant), whereas control plot recorded maximum (2.07 and 2.32 larvae/plant).

With respect to overall mean larvae/plant, chlorantraniliprole recorded significantly lower larvae/plant (0.68) followed by indoxacarb (0.70 larvae/plant), novaluron (0.83 larvae/plant) and quinalphos (1.18 larvae/plant) against 2.04 larvae/plant in control (untreated). The treatment modules I and II were statistically on par. Overall, observations indicated that there was significant difference in mean larvae/plant among various treatment modules.

Table 21. Effect of insecticides on larval count/plant

Treatment modules	Mean No. of larva/plant/week*						Overall mean
	Pre spray	4 DAS	7 DAS	14 DAS	21 DAS		
Chlorantraniliprole	1.45 (1.39) ^a	0.62 (1.05) ^c	0.61 (1.10) ^c	0.71 (1.14) ^c	0.76 (1.16) ^c	0.68 (1.08) ^d	
Indoxacarb	1.37 (1.36) ^a	0.68 (1.08) ^{bc}	0.63 (1.12) ^c	0.73 (1.16) ^{bc}	0.76 (1.18) ^{bc}	0.70 (1.09) ^d	
Novaluron	1.40 (1.38) ^a	0.80 (1.14) ^{bc}	0.76 (1.17) ^{bc}	0.88 (1.17) ^{bc}	0.91 (1.21) ^{bc}	0.83 (1.15) ^c	
Quinalphos	1.37 (1.37) ^a	1.06 (1.25) ^b	1.13 (1.32) ^b	1.25 (1.33) ^b	1.30 (1.34) ^b	1.18 (1.29) ^b	
Control	1.44 (1.39) ^a	1.77 (1.51) ^a	2.02 (1.60) ^a	2.07 (1.62) ^a	2.32 (1.68) ^a	2.04 (1.59) ^a	
F-test	NS	*	*	*	*	*	
SEm±	0.01	0.02	0.01	0.02	0.02	0.01	
CD @ 0.05	-	0.07	0.06	0.06	0.06	0.04	

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are $\sqrt{x+0.5}$ transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; *Significant at 5%; NS= Non-Significant

The effect of application of insecticides on pod infestation by *H. armigera* on chickpea is presented in Table 22. The pod infestation ranged from 9.50 to 9.68 per cent/week in the first four treatment modules compared to control (9.71 per cent/week) at pre-treatment observation.

At 7 DAS, lowest pod infestation (7.02%) was recorded in the module I, followed by module II (7.42% pod infestation/week), module III (7.48% pod infestation/week) and module IV (8.40% pod infestation/week); Treatment module II and III were statistically on par; significantly highest pod infestation was recorded in control (11.18% pod infestation/week).

At 14 DAS, lowest pod infestation (6.90%) was recorded in the module I, followed by module II (7.10% pod infestation/week), module III (7.10% pod infestation/week) and module IV (8.45% pod infestation/week); treatment module I, II and III were statistically on par; significantly highest pod infestation was recorded in control (11.80% pod infestation/week).

At 21 and 28 DAS, lowest pod infestation (7.20% and 7.32% pod infestation/week) was recorded in the module I, followed by module II and module III (7.30%, 7.37% and 7.30%, 7.48% pod infestation/week). Treatment module II and III were statistically on par; but differed significantly with module IV (8.68% and 8.78% pod infestation/week). Further, significantly highest pod infestation was recorded in the control (12.17% and 12.42% pod infestation/week).

With respect to overall mean per cent pod infestation, chlorantraniliprole module recorded significantly lower pod infestation (7.11%) followed by indoxacarb (7.29%), novaluron (7.34%) and quinalphos (8.58%) against 11.89 per cent pod infestation in control (untreated). The treatment modules II and III were statistically on par. Overall, observations indicated that there was significant difference in mean per cent pod infestation among various treatment modules.

4.5. Trap density and chickpea yield

The fields installed with 20 traps/acre were recorded the maximum yield (460.9 kg) followed by 40 traps (430.3 kg), 30 traps (404.2 kg) and 10 traps (390.6 kg). Significantly lower yield was recorded in the control fields (311.6 kg) (Table 23).

4.6. Combination of insecticide and pheromone traps on chickpea yield

The pheromone trap fields treated with chlorantraniliprole were recorded the maximum yield (583.9 kg) followed by indoxacarb (549.4 kg), novaluron (505.2 kg) and quinalphos (440.7 kg). Significantly lower yield was recorded in the untreated fields (409.3 kg) (Table 24).

Table 22. Effect of insecticides on pod infestation/week

Treatment modules	Per cent pod infestation/week*						Overall mean
	Pre spray	7 DAS	14 DAS	21 DAS	28 DAS		
Chlorantraniliprole	9.68 (18.11) ^a	7.02 (15.34) ^c	6.90 (15.20) ^c	7.20 (15.55) ^c	7.32 (15.69) ^c	7.11 (15.44) ^d	
Indoxacarb	9.50 (17.94) ^a	7.42 (15.80) ^{bc}	7.10 (15.44) ^c	7.30 (15.66) ^{bc}	7.37 (15.75) ^{bc}	7.29 (15.65) ^c	
Novaluron	9.66 (18.09) ^a	7.48 (15.86) ^{bc}	7.10 (15.44) ^c	7.30 (15.67) ^{bc}	7.48 (15.85) ^{bc}	7.34 (15.70) ^c	
Quinalphos	9.67 (18.12) ^a	8.40 (16.83) ^b	8.45 (16.88) ^b	8.68 (17.11) ^b	8.78 (17.22) ^b	8.58 (17.02) ^b	
Control	9.71 (18.14) ^a	11.18 (19.52) ^a	11.80 (20.07) ^a	12.17 (20.41) ^a	12.42 (20.63) ^a	11.89 (20.12) ^a	
F-test	NS	*	*	*	*	*	
SEm±	0.03	0.18	0.19	0.10	0.08	0.05	
CD @ 0.05	-	0.56	0.58	0.31	0.24	0.16	

*Average of four replications/treatment/week; ** Mean of five weeks; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; *Significant at 5%; NS= Non-Significant

Table 23. Influence of different trap densities on chickpea yield

SI No.	Trap density/acre	Yield (Kg/acre)	Yield (q/ha)
1	10 traps	390.6	9.77
2	20 traps	460.9	11.52
3	30 traps	404.2	10.10
4	40 traps	430.3	10.75
5	Control	311.6	7.79

Table 24. Influence of combination of select insecticides and pheromone trap density on chickpea yield

SI No.	Insecticides + Traps	Yield (Kg/acre)	Yield (q/ha)
1	Chlorantraniliprole + 20 traps/acre	583.9	14.60
2	Indoxacarb + 20 traps/acre	549.4	13.73
3	Novaluron + 20 traps/acre	505.2	12.63
4	Quinalphos + 20 traps/acre	440.7	11.01
5	Untreated + 20 traps/acre	409.3	10.23

V. DISCUSSION

The results of the present investigation on “Effect of sex pheromone traps against chickpea pod borer *Helicoverpa armigera* (Lepidoptera: Noctuidae)” with special reference to trap density, correlation between trap catches and pest infestation and influence of select insecticides on pheromone trap catches of *H. armigera* are discussed in this chapter.

With the increasing realization of the importance of sustainable agriculture, the concept of IPM is gaining a firmer foothold with the chemicals being pushed to the background. In the recent past, entomologists and farmers have identified IPM methods that are ecologically non-disrupting and stable. Insect sex pheromones have been recognized as one of the important components for imparting sustainability to agricultural ecosystems through improved IPM practices (Jayaraj *et al.*, 1995).

In India, *H. armigera* and many other major lepidopteran insect sex pheromones are widely recommended in a variety of cropping systems. The insect sex pheromones were considered efficient in the eighties and the effectiveness of the pheromone trap catches depend on trap height, density of traps per unit area and the application of insecticides. Weather factors and seasons also play an important role in effectiveness of the pheromone traps.

Hence, the present investigation was aimed at standardization of trap density, correlation between trap catches and pest infestation; besides, influence of select insecticides on pheromone trap catches of *H. armigera* are discussed here under.

5.1. Trap density

It is important to optimize the number of traps per unit area for the deployment of traps and also to maximize the moth catch per unit time for the mass trapping of *H. armigera* moths. Density of pheromone traps in the field is influenced by the size of pest population in the field. Rodriguez-Saona and Stelinski (2008) reported that the utility of mass trapping as a practical application in IPM programs has been very limited given that the technique is density dependent. The following is an attempt to optimize the trap density per acre for Chickpea pod borer.

The results of field experiment on trap density per acre showed that maximum trap catches (13.60 moths) was recorded at trap density of 20 traps/acre compared to other trap densities (Fig. 1). The next maximum number of moth catches (12.07 moths) was recorded at 40 traps/acre. Statistical significant results were obtained and this was on par with trap density 20/acre. Present study suggest that 20 traps per acre appear to be the most effective and convenient trap density to use in a Chickpea pod borer integrated management program. Therefore the trap density of 20 trap/acre proved to be as efficient and more economical.

The above findings are almost in agreement with Giampiero (1993), who compared the trap densities for male moth capture rate and suggests 40 traps/ha was found to be more effective for mass collection; similarly, Shah *et al.* (2009) who reported that 40/ha is the optimum trap density for mass collection of chickpea pod

borer; but the present study slightly differed with Singh *et al.* (2009) who suggests that 20 traps per hectare was found to be effective. Similarly Sarwar *et al.* (2009) reported as a part of integrated pest management, installing pheromone traps @ 10/ha can monitor pest build up to take decision on timely control measures.

The study carried out by Balasubramanian (1979), Cork *et al.* (2005) and Larrain *et al.* (2009), reported 20, 20 and 20-40 traps/ha recorded maximum moth catches against pink boll worm in cotton, yellow stem borer of rice and potato tuber moth respectively. Similarly, Jenn-sheng (2000), reported 40 traps/ha was effective in managing the sweet potato weevil.

Overall, trap catches may give an indication of population size in a field but not infestation level in a particular field. Hence, the results suggested that traps have to be placed at peak moth activity period to trap maximum number of moths. Along with trap density timing of placement of trap and phenology of crop are crucial in IPM of chickpea pod borer.

5.1.2. Density of traps and larval count

Trap density of 20 traps/acre recorded the lower number of larvae/plant (0.81 larvae/plant) and high moth catches followed by 10 traps/acre (0.84 larvae/plant), 30 traps/acre (0.92 larvae/plant) and 40 traps/acre (1.00 larvae/plant) (Fig. 1). This suggests that as moth catches are higher, lower will be the larval count.

5.1.3. *H. armigera* moth catches and pod infestation during rabi, 2013-14

The chickpea pod borer moth catches started in the 49th standard week (1st week of December) and attained peak (218 moths/week) during 3rd standard week (3rd week of January). Minimum moth catches (11 moths/week) was observed during 6th standard week (1st week of February). The least per cent pod damage (6.60%) was recorded in fields installed with 20 traps followed by 40 traps/acre (6.78%). Significantly highest per cent pod damage (9.20%) was recorded in control (Fig. 1). Similarly the present study was supported by Hossain (2008), who reported that, gram pod borer moth catching in pheromone traps was started between 3rd week of January to 2nd week of February depending on the climatic conditions of the year.

The present study slightly differed with Sah *et al.* (1988) who reported that, the male moth population was peak during 3rd week of February to 1st week of March in chickpea; In Nepal, Prasad and Newpane (1992) reported that maximum number of moth trapping was observed during last week of February and first week of April. Similarly Reena *et al.* (2009) reported that *H. armigera* catches in pheromone traps was peak during 14-15 standard week due to the pest preference to oviposit more on leaves, flowers and pods. These variations may be due to change of location, crop and weather parameters. However, Mahmudunnabi *et al.* (2013) who reported that least per cent pod damage (5.19%) was recorded in the fields with pheromone traps and highest pod damage (16.32%) was in control.

In a similar study Wakil *et al.* (2005) studied the effectiveness of bio-rational approach and compared with control the result suggested that low percent damage due to chickpea pod borer compared to control (15.71%).

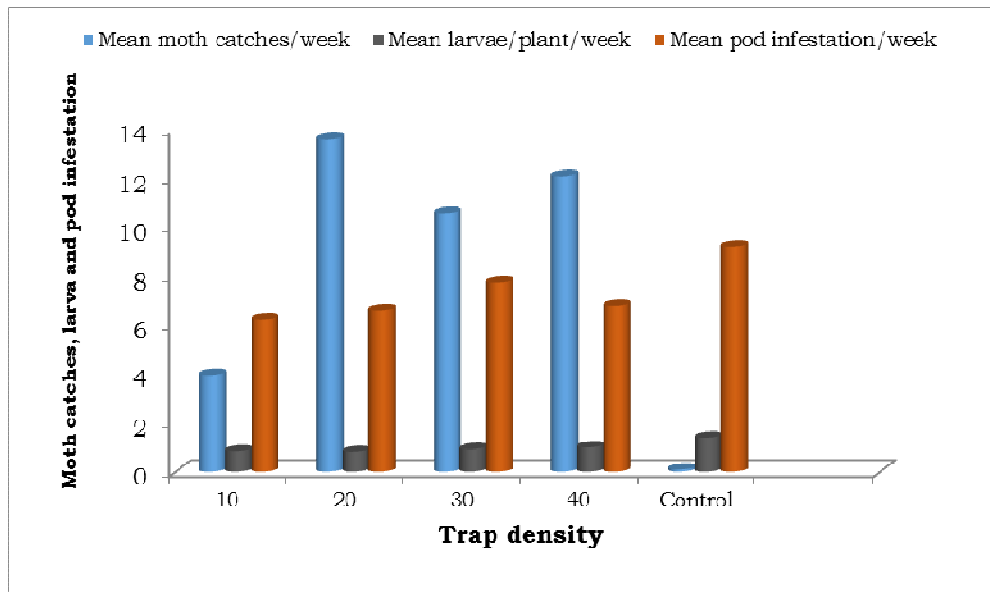


Fig 1: Comparison of different trap densities and number of *H. armigera* moth catches, larval count and pod infestation

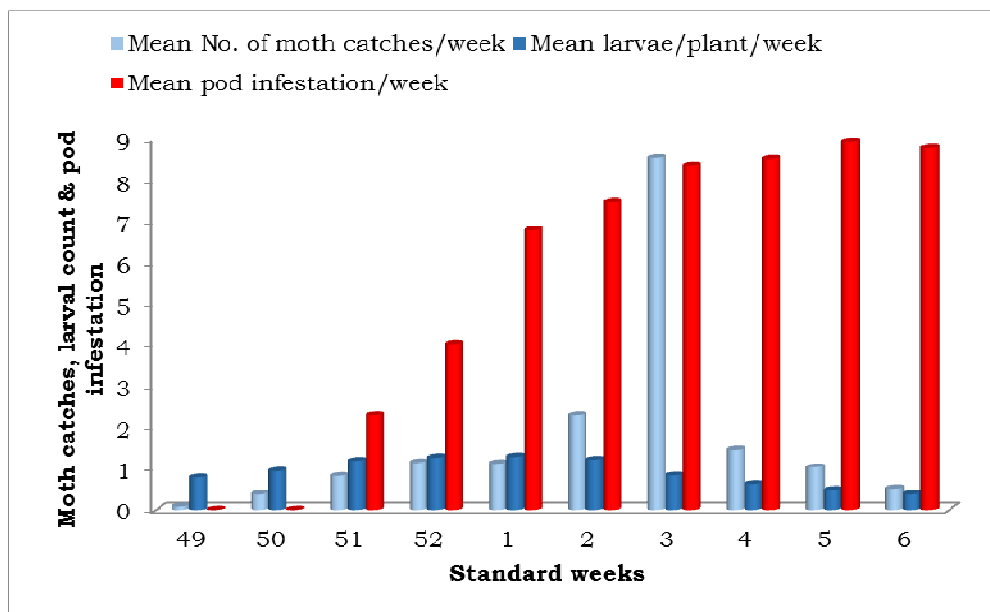


Fig 2: Relationship between moth catches, larval count and pod infestation

5.2. Correlation between trap catches and pest infestation

Positive relation ($p \leq 0.05$) existed between *H. armigera* moth catches and per cent pod infestation at trap density 10, 20, 30 and 40 per acre. However, negative relation ($p \leq 0.05$) existed between *H. armigera* moth catches and larvae per plant at trap density 20 and 30 per acre, whereas at trap density of 10 and 40 per acre positive relationship was observed. The incidence of chickpea pod borer was began during 51st standard week (3rd week of December) with mean per cent pod damage 2.30 and keep increase with increasing pod formation; infestation reached maximum (8.92 per cent) during 5th standard week and declined in subsequent week (Fig 2).

The correlation matrix between moth catches and weather parameters showed that the moth catches was found to have significant association with maximum temperature, morning RH, afternoon RH, evaporation and wind speed (Fig 3). While negative relation was found with minimum temperature, and rainfall. Jayaramiah and Babu (1990) attributed rainfall in the influencing factor on moth emergence of *H. armigera* and showed a positive correlation. The present findings are in conformity with Anwar *et al.* (1992) who have reported rapid increase of pheromone trap catches from February to march with rise in temperature. Sharma *et al.* (2012) reported that moth catches are positively correlated ($r=0.77$ and $r=0.63$) with maximum and minimum temperatures, while it was negatively correlated ($r= -0.79$) with relative humidity. Basavaraj *et al.* (2013) reported the correlation between the pheromone trap catches with the weather parameters of preceding week was significant and positively correlated with minimum temperature ($r= 0.580^{**}$) and negatively with morning relative humidity ($r=-0.533^*$). The sunshine hours ($r=0.413$) and number of rainy days ($r=0.297$) was non-significant positive correlation and total rainfall ($r=-0.313$), afternoon relative humidity ($r=-0.225$) and maximum temperature ($r=-0.125$) showed a non-significant negative relationship with the pheromone trap catches of *H. armigera*.

Sonkar *et al.* (2012) reported that population of *H.armigera* moth was first trapped in 2nd fortnight of December with an average of 2.55 moths /trap and showed two peaks i.e., in 1st fortnight of January and 2nd fortnight of March, respectively and mean relative humidity was found to be positively significant, while correlation with maximum temperature, minimum temperature, and sun shine hours was found negative but non-significant. These findings almost corroborated with the present findings.

The incidence of chickpea pod borer began on vegetative parts (leaves) during 49th standard week (1st week of December) with mean larvae 0.78 per plant reaches maximum (1.28 larvae/plant) during 1st standard week and reached minimum (0.38 larvae/plant) during 6th standard week (1st week of February). This variation was due to that the pest was at higher levels initially and as soon as the traps were placed in the field, the moths were attracted and trapped by the pheromone traps. Hence, there was a decline in the incidence on tender parts and pods. Larval count was negatively correlated with maximum temperature, minimum temperature, morning RH, evaporation and wind speed (Fig 4); whereas afternoon RH and rainfall was found to be positively correlated. Incidence of pod borer on pods starts from 51st standard week (2.30%), increased as pod bearing was increased and reached maximum (8.92%)

during 5th standard week due to availability of young pods and declined once pod get matured in the subsequent week (8.78%).

The pod damage was found to be positively associated with maximum temperature and evaporation (Fig 5); whereas minimum temperature, morning relative humidity, afternoon relative humidity, wind speed, and rainfall were found to be negative *i.e.*, non-significant in association with pod damage. These findings are corroborated with Upadhyay *et al.* (1989) who reported positive correlation of weather parameters and infestation with maximum temperature ($r=0.63$), minimum temperature ($r=0.67$) and as well as relative humidity($r=0.59$).

5.3. Influence of select insecticides on pheromone trap catches of *H. armigera* at different locations.

5.3.1. Effect of insecticides and trap catches (moth catches per trap)

Generally chickpea growers in and around Bangalore and adjacent districts do not resist from applying insecticides irrespective of the execution or implementation of other management tools. Therefore, commonly used insecticides by chickpea growers were selected to determine the interaction effect between *H. armigera* moth catches and insecticide application. Quinalphos 20 EC and Novaluran 10EC were commonly used to control pod borer on chickpea. So, an attempt was made to know the effect and compatibility of application of insecticides on moth catches, larval count and per cent pod damage.

The results of the experiment showed that the minimum number of moth catches was obtained in chlorantraniliprole sprayed plots (0.25 moths/trap/week respectively) followed by indoxacarb and novaluron up to 21 DAS (0.40 and 0.6 moths/trap), which were statistically on par; and quinalphos found to be the least effective (1.20 moths/trap) however, immediately after spraying moderate efficacy has been observed (0.70 moths/week) in first location (Fig 6). Further, the reduction in moth catches was noticed in all the insecticide treated plots after spraying.

In second location also significant difference was observed in treatment module 1 *i.e.*, Chlorantraniliprole; which was found to be more effective and minimum number of moth catches was obtained (0.15 moths/trap), followed by indoxacarb and novaluron, which recorded lower moth catches up to 28 DAS (0.35 and 0.40 moths/trap) respectively which were statistically on par followed by other treatment modules such as Quinalphos (0.50 moths/trap), (Fig 7).

Third and fourth locations also showed significant difference in treatment modules Chlorantraniliprole, which was found to be more effective and minimum number of moth catches was obtained (0.20 and 0.15 moths/trap), followed by indoxacarb and novaluron (0.45, 0.25 and 0.60, 0.40 moths/trap respectively), which were statistically on par followed by other treatment module *i.e.*, Quinalphos (0.95 and 0.55 moths/trap). Significantly higher number of moths were trapped in the control 2.05 and 1.10 moths/trap (Fig 8 and 9).

These findings were supported by Gadhiya *et al.* (2014), who reported that Chlorantraniliprole was more effective against pod borer and obtained minimum

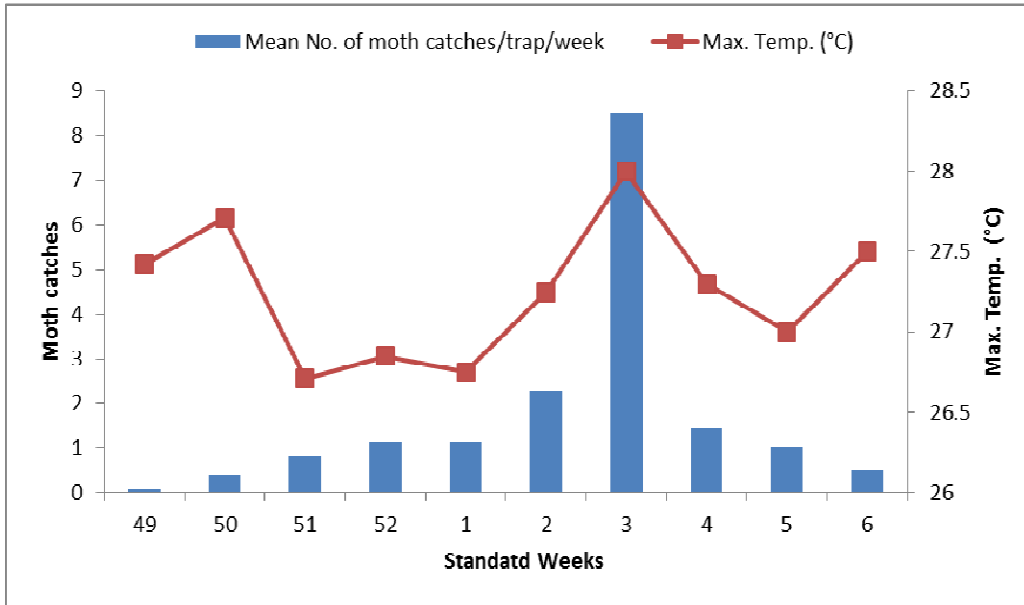


Fig 3: Influence of weather factors on *H. armigera* borer moth catches

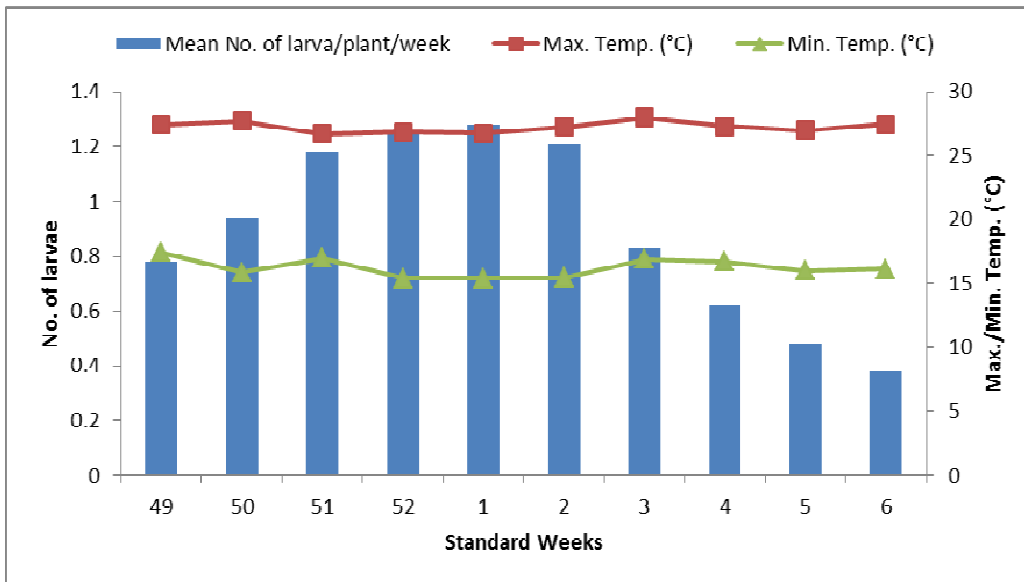


Fig 4: Influence of weather factors on *H. armigera* borer larval count

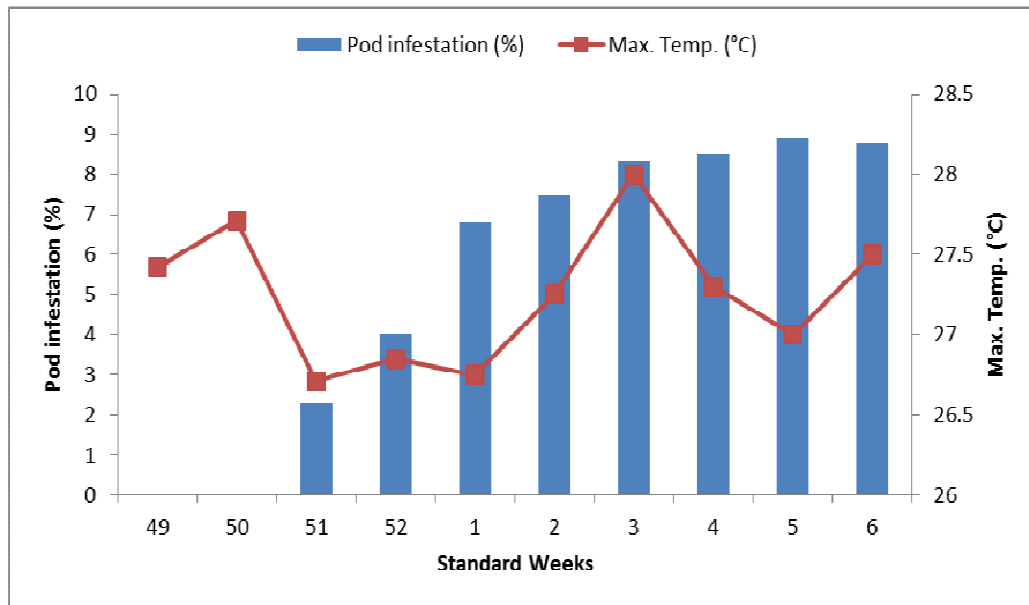


Fig 5: Influence of weather factors on *H. armigera* borer pod infestation

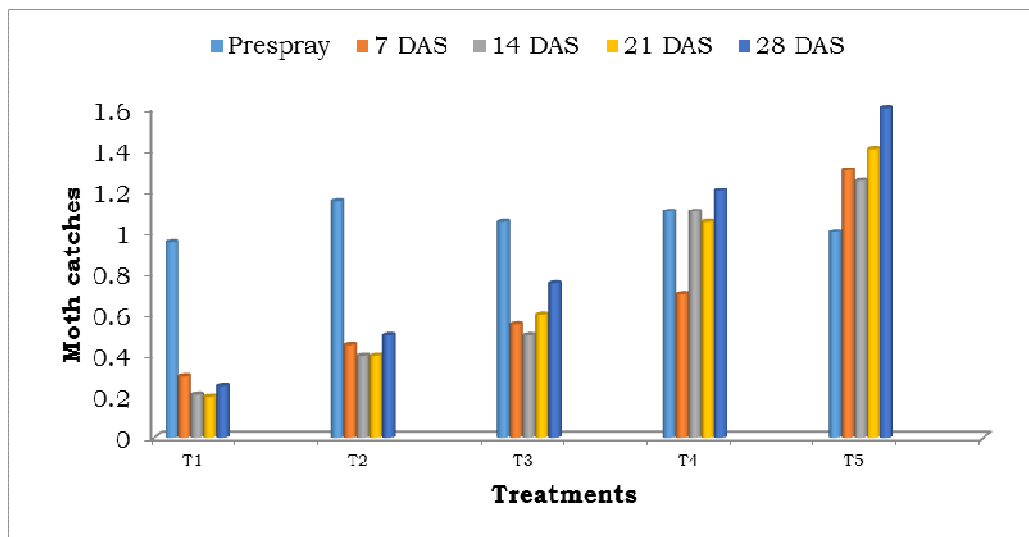


Fig 6: Influence of insecticides on *H. armigera* moth catches in first location

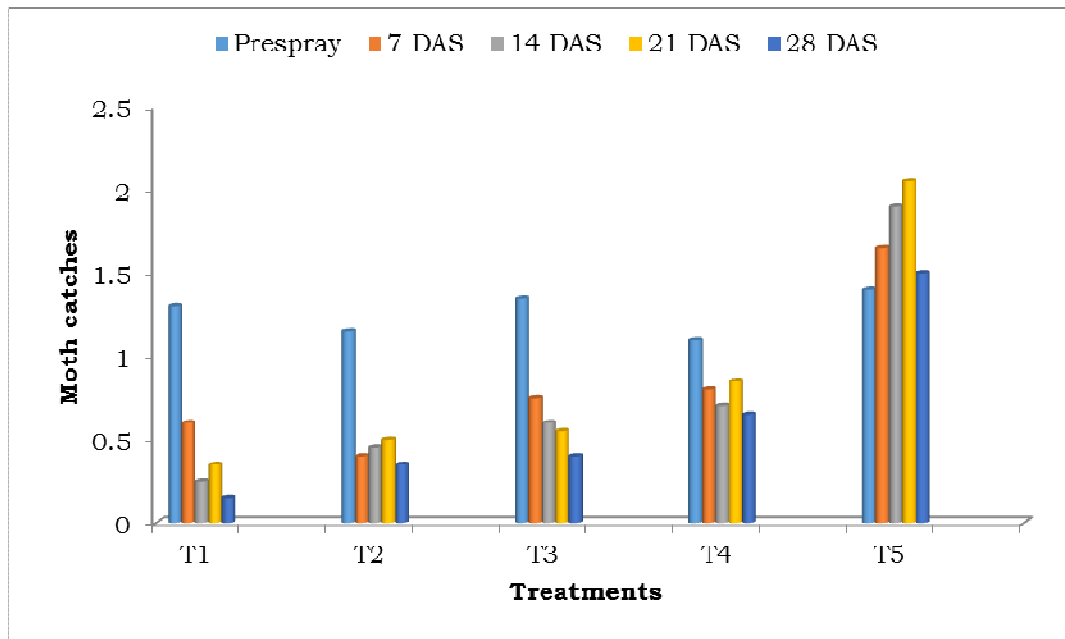


Fig 7: Influence of insecticides on *H. armigera* moth catches in second location

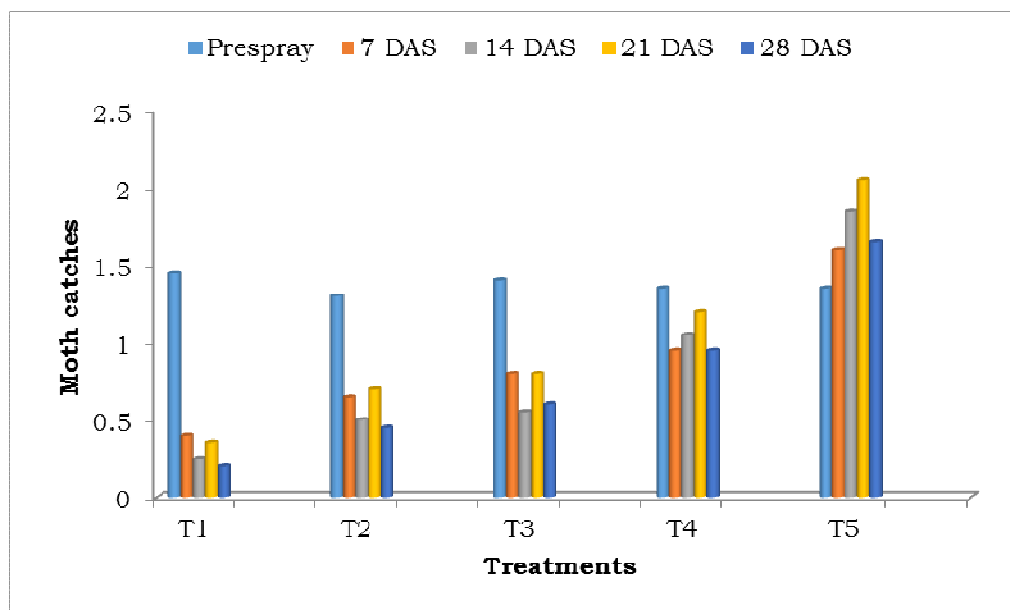


Fig 8: Influence of insecticides on *H. armigera* moth catches in Third location

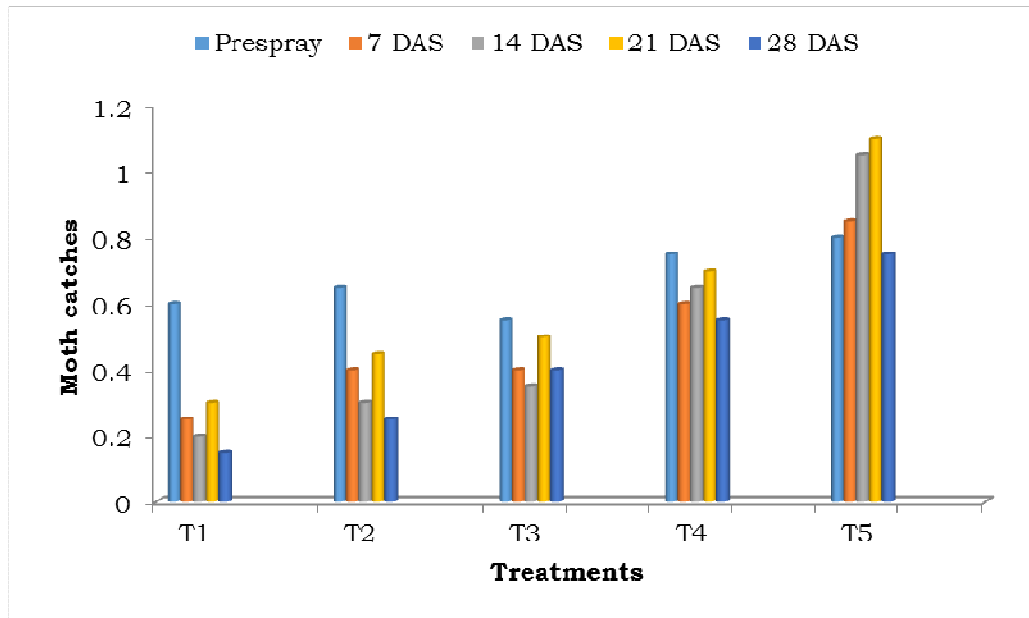


Fig 9: Influence of insecticides on *H. armigera* moth catches in Fourth location

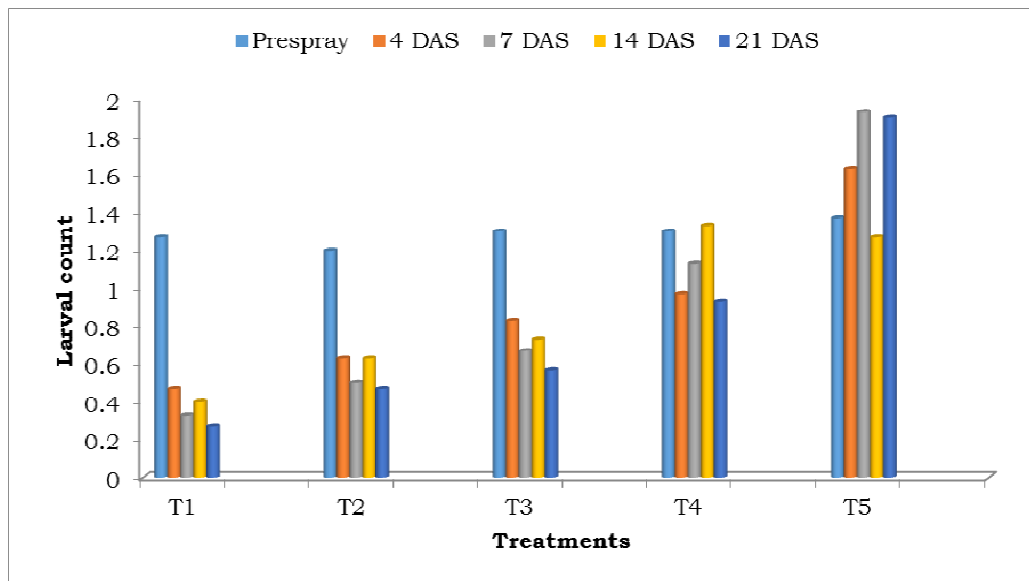


Fig 10: Influence of insecticides on *H. armigera* larval count in First location

number of moth catches followed by indoxacarb. Similarly, novaluron alone (0.01%) was found to be the best treatment and recorded lower moth catches due to larval & pupal mortalities (Ram and Raja, 2012).

Trap catches of pink bollworm increased after the applications of the two organophosphate insecticides and decreased after the applications of the permethrin in the cotton field (Bariola, 2001).

The study showed the reduction in trap catches due to the application of insecticides killed the chickpea pod borer larvae by their contact action; this indicated that the insecticides can be used with the pheromone traps which reduced future population build-up of *H. armigera*.

5.3.2. Effect of insecticides and larval count (larvae per plant)

The results of first location showed that treatment I (chlorantraniliprole) significantly reduced the larvae/plant followed by other treatments (indoxacarb, novaluron and quinalphos), which are statistically on par, suggested that all four insecticides exhibiting similar influence on larval count. However, significantly more larvae/plant was recorded in control (Fig 10).

Second location also recorded lower number of larvae per plant in all the treatments with combination of pheromone traps and insecticides up to 21 days after spraying; later, treatment I significantly recorded the least number of larvae/plant followed by other treatments (Fig 11).

While in third and fourth locations, treatment I (chlorantraniliprole) recorded significantly least number of larvae/plant immediately after spraying followed by other treatments. Later (*i.e.*, 14 and 21 DAS) results in treatment I, II and III were statistically on par, but treatment IV recorded significantly higher number of larvae/plant (Fig 12 and 13).

The above findings are supported by Chabra *et al.* (1984) who reported quinalphos (0.05%) was promising insecticides in controlling the pod borer complex of pigeonpea. Quinalphos showed only low ovicidal activity (Hargreaves and Cooper, 1984). Quinalphos were most effective up to 3 DAS (Aslam *et al.* 2004). Vekaria and Vyas (1985) showed ovicidal toxicity of quinalphos 0.05 per cent; Dubey *et al.* (1991), reported the effectiveness of quinalphos 0.03 per cent recorded significantly higher mortality of 93.12 per cent.

Similarly, indoxacarb at 75 g a.i/ha recorded lower bollworm incidence (Bheemanna and Patil, 1999); Suhas Yelshetty *et al.* (1999) reported that indoxacarb at 75 g a.i/ha was effective in suppressing the pod borer, *H.armigera*; Giraddi *et al.* (2002) reported the effectiveness of indoxacarb 14.5SC in reducing *H. armigera* population.

Novaluron 0.01 per cent recorded the lowest number of surviving *H. armigera* larvae/plant on chickpea (Chaudhari *et al.* 2003). Similarly Murthy and

Maruthi ram 2003, evaluated the efficacy of novaluron (1ml/lit) against American bollworm by recording higher yield and lower larval population.

Srinivasan *et al.* 2004 and Udikeri *et al.* 2004 reported the most effectiveness of indoxacarb 15SC (@50 and 75g a.i/ha) against cotton bollworm. Similarly Singh and Yadav (2007) who studied the efficacy of four insecticides, among them indoxacarb caused maximum larval mortality after one week of two sprayings i.e. 99.4 and 98.3% after first and second spraying.

Yadav and Verma (2007) investigated the efficacy of quinalphos and recorded highest (100 %) mortality of larvae after last spray. Further, Hanafy and Sayed (2013) reported the more effectiveness of chlorantraniliprole followed by indoxacarb against *H. armigera* in chickpea. Chlorantraniliprole recorded more than 90% larval mortality in the laboratory experiment and found most effective as larvicide (Babar *et al.* 2012). Similarly, Sreekanth *et al.* (2014) recorded the lowest number (0.43) of *H. armigera* larvae/plant and also lowest per cent pod damage in chickpea.

Chamberlain *et al.* (1993) reported that there was no infestation of flower by larvae of *P. gossypiella* in the pheromone + insecticide plot and low infestations in both the insecticide and untreated plots.

5.3.3. Effect of insecticides and per cent pod damage

In first location results obtained from the study regarding effect of application of select insecticides + pheromone traps on pod damage revealed that the minimum per cent pod damage was recorded in the chlorantraniliprole and indoxacarb sprayed plots followed by novaluron and quinalphos treated plots, which recorded comparatively more per cent pod damage. Among the select insecticides, maximum per cent pod damage was recorded in quinalphos treated plots. However highest per cent pod damage (12.10%) was recorded in control (Fig 14).

In second location significantly low per cent pod infestation was recorded in treatment module I, followed by treatment II, III and IV whereas highest per cent damage (12.20%) in control plots (Fig 15).

Almost similar results were found in third and fourth location. Among them the treatment 1 (chlorantraniliprole + pheromone) was more superior followed by treatment II (indoxacarb + pheromone), treatment III (novaluron + pheromone) and treatment IV (quinalphos + pheromone) sprayed plots. However maximum per cent pod damage was recorded in untreated plots (Fig 16 and 17).

The above study was supported by Balikai *et al.* (2001) who reported that effectiveness of quinalphos 25 EC (0.05%) against pod borer. Siddegowda *et al.* (2004 and 2006), who tested the bio efficacy of three insecticides on *H. armigera*, among them novaluron found to be more effective and lower per cent pod damage was recorded. Similarly Raghvani *et al.*, (2006) who tested the efficacy of 5 different insecticides, among them novaluron recorded the least pod damage (4.83%); Sreekanth *et al.* (2014) reported lower pod damage due to *Helicoverpa* in plots treated with chlorantraniliprole 20 SC (1.26%). This suggests that chlorantraniliprole is superior over other tested insecticides. This was followed by indoxacarb, novaluron and quinalphos. Further, Hossain *et al.* (2010) reported the effectiveness of lambda cyhalothrin against pod borer and recorded the lowest per cent pod damage and the grain yield loss of 34.90 kg/ha.

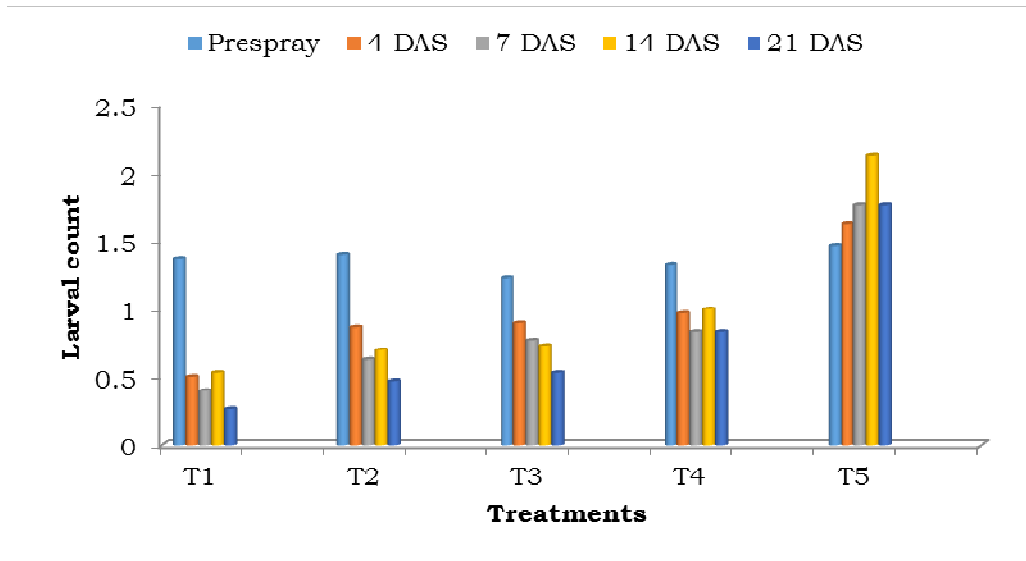


Fig 11: Influence of insecticides on *H. armigera* larval count in Second location

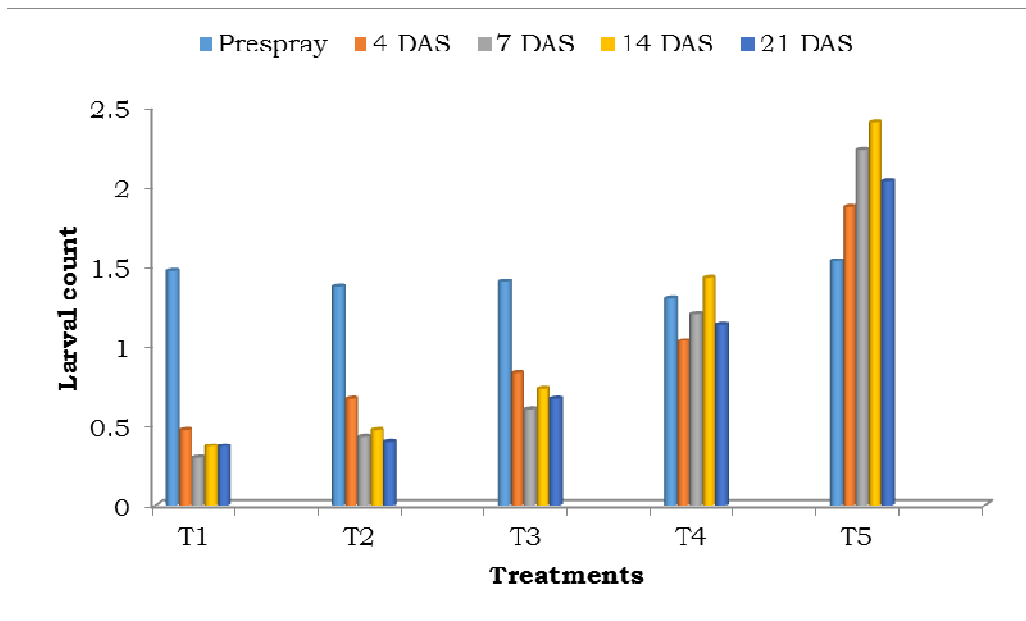


Fig 12: Influence of insecticides on *H. armigera* larval count in Third location

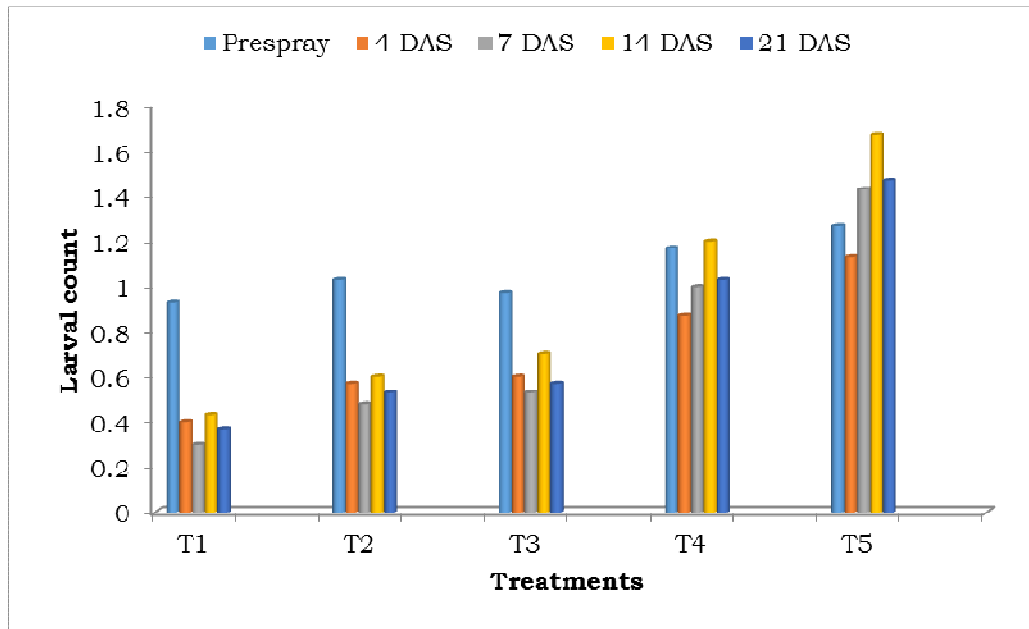


Fig 13: Influence of insecticides on *H. armigera* larval count in Fourth location

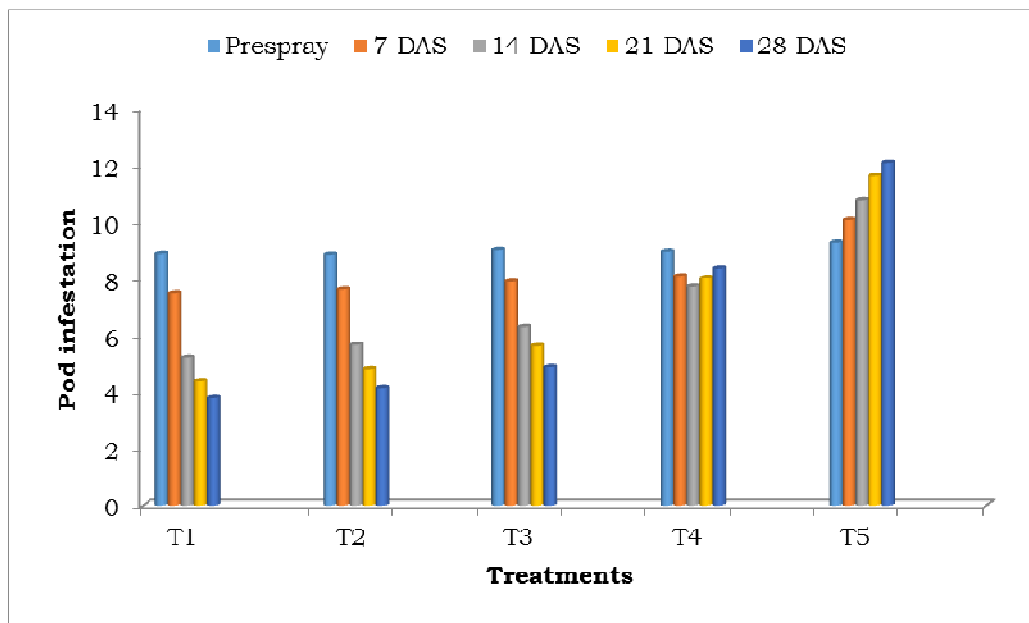


Fig 14: Influence of insecticides on *H. armigera* pod infestation in First location

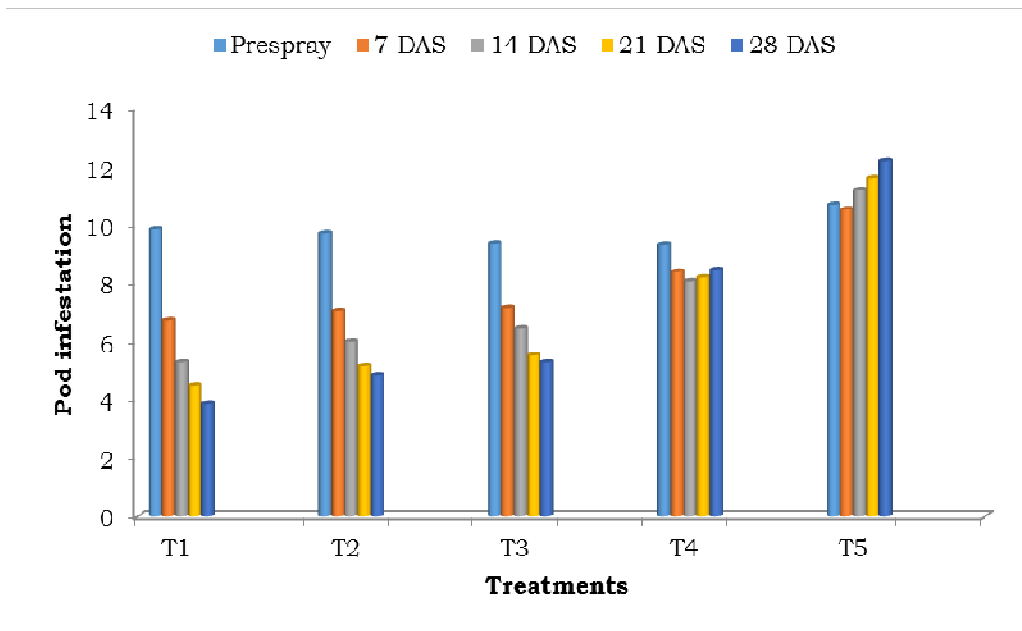


Fig 15: Influence of insecticides on *H. armigera* pod infestation in Second location

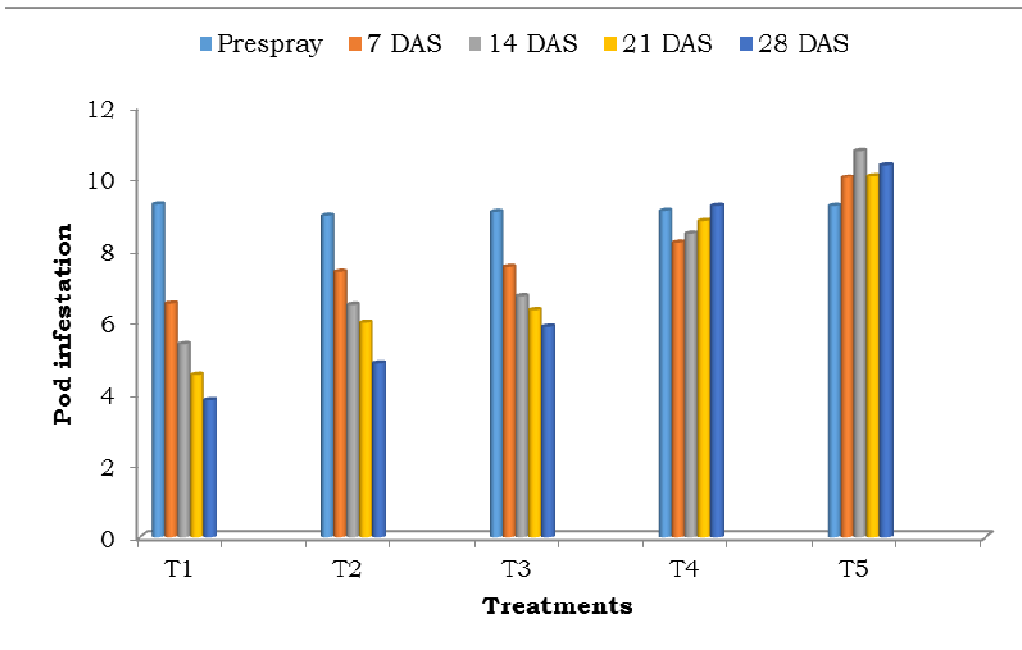


Fig 16: Influence of insecticides on *H. armigera* pod infestation in Third location

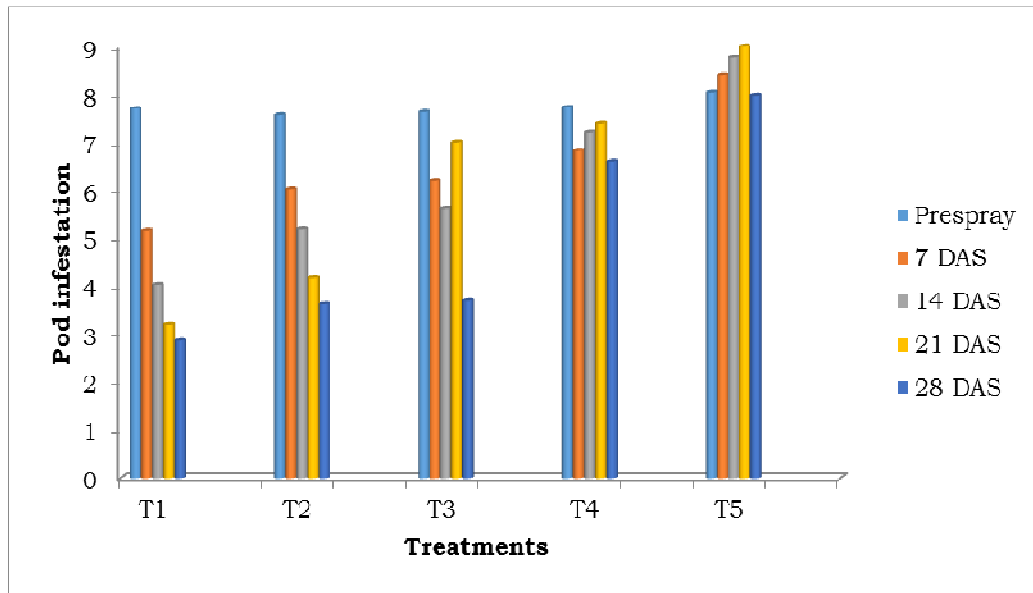


Fig 17: Influence of insecticides on *H. armigera* pod infestation in Fourth location

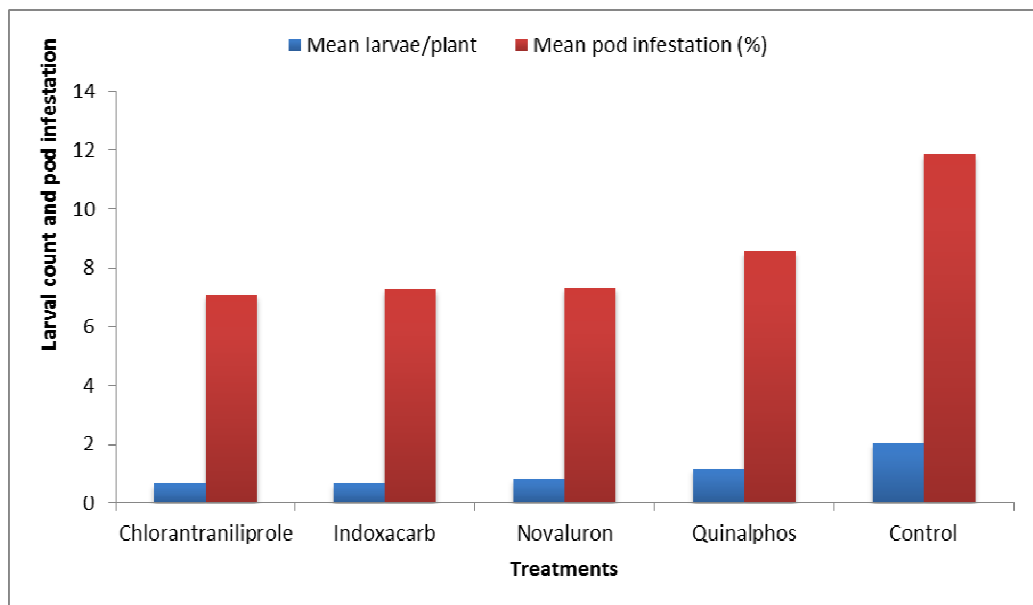


Fig 18: Influence of insecticides alone on larval count pod infestation

All the studies suggest that the combined use of insecticides and pheromone traps can be used in the IPM programme. The insecticides effectively reduce the infestation on pods while pheromone traps attract the adult male moths and reduce the population. Further, both insecticides and pheromone traps have greater impact on future generations of pest.

5.4. Effect of insecticides alone on larval count and pod infestation

The results showed that lower number of larvae/plant/week was obtained in chlorantraniliprole, indoxacarb and novaluron sprayed plots (0.68, 0.70 and 0.83 respectively). Significantly higher larvae/plant/week was recorded in quinalphos treated plots (1.18). The reduction in larval count was noticed in all the insecticide treated plots after spraying of insecticides (Fig.18). The results suggest that quinalphos had less effect on the reduction of larval numbers compared to chlorantraniliprole, indoxacarb and novaluron.

The results of the experiment showed that lower number of per cent pod infestation was obtained in chlorantraniliprole, indoxacarb and novaluron sprayed plots (7.11, 7.29 and 7.34 per cent pod infestation). Significantly higher per cent pod infestation was recorded in quinalphos treated plots (8.58). The results suggest that quinalphos was less effective compared to remaining treatments.

5.5. Effect of pheromone trap density on chickpea yield

Twenty pheromone traps installed fields recorded the maximum yield of 460.6 kg/acre followed by 40 traps (430.9 kg/acre), 30 traps (404.2 kg/acre), 10 traps/acre (390.3 kg/acre) and in control fields low yield of 311.6 kg/acre was recorded (Fig 19).

5.6. Effect of standardized pheromone trap and insecticides on chickpea yield

Combination of 20 pheromone traps/acre with chlorantraniliprole treated plots recorded the maximum yield of 583.9 kg/acre, followed by indoxacarb treated plots (549.4 kg/acre), novaluron treated plots (505.2 kg/acre) and quinalphos treated plots (440.7 kg/acre). The insecticides and pheromone traps found significantly superior over the untreated control with pod damage and yield of 409.3 kg/acre (Fig 20.)

The present study was supported by Chaudhari *et al.* (2003) who reported that novaluron recorded the lowest number of surviving *H. armigera* larvae/plant on chickpea and also highest yield of 16.73 q/ha. Similarly, Yadav and Verma (2007) who reported that spray of quinalphos recorded maximum grain yield 17.85 q/ha. Sreekanth *et al.* (2014) obtained maximum yield of 743.1 kg/ha plots treated with chlorantraniliprole.

5.7. Natural enemies in the chickpea field

General observations were made on the occurrence of natural enemies such as Indian myna bird, egg parasitoid *Trichogramma* sp. and *Campoletis chlorideae*. These were recorded only in the pheromone operated fields; while these were not observed

in fields where only insecticides were used for the management of chickpea pod borer.

5.8. Factors responsible for *H. armigera* optimum moth catches

The optimum trap catches of *H. armigera* moths are influenced by various factors viz., trap density, pheromone lure, dispenser type used, insecticides application and finally weather parameters.

The pheromone trap density is an important factor in mass trapping techniques. Evaluation of trap density per unit area indirectly shows the effect of trap catches on the reduction of pod damage caused by larvae. The results of trap density trial suggests that 20 traps/acre is best for optimum *H. armigera* moth catches.

The weather parameters are responsible for optimum moth catches of *H. armigera*. The results showed that temperature, relative humidity and rainfall had a greater influence on the moth catches and pod damage, also the response by moths to pheromone traps was good in the field provided favourable environment to disseminate the pheromone component in the air. Besides, the wind speed also played a major role in optimum pheromone trap catches.

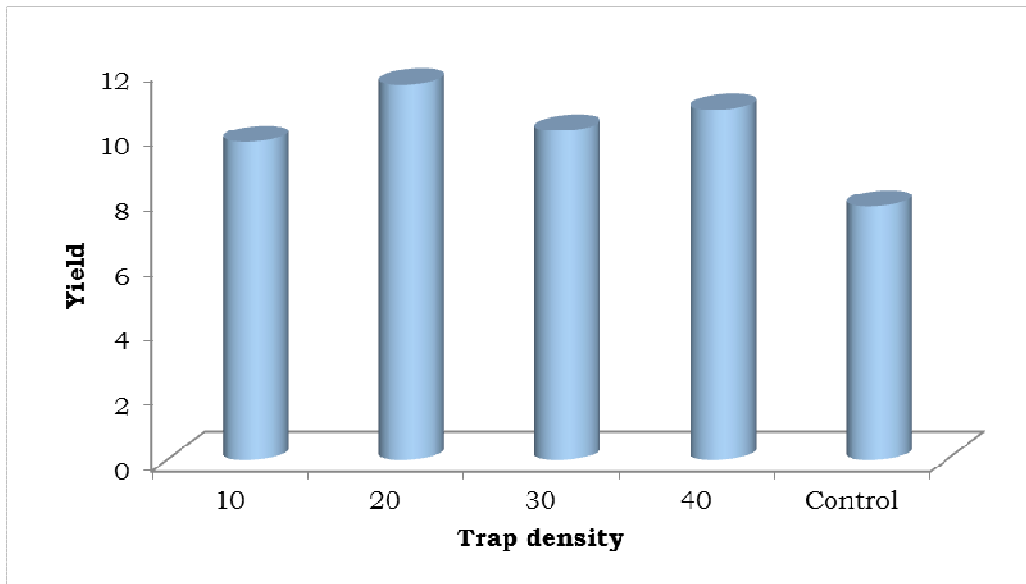


Fig 19: Comparison of pheromone trap densities on chickpea yield

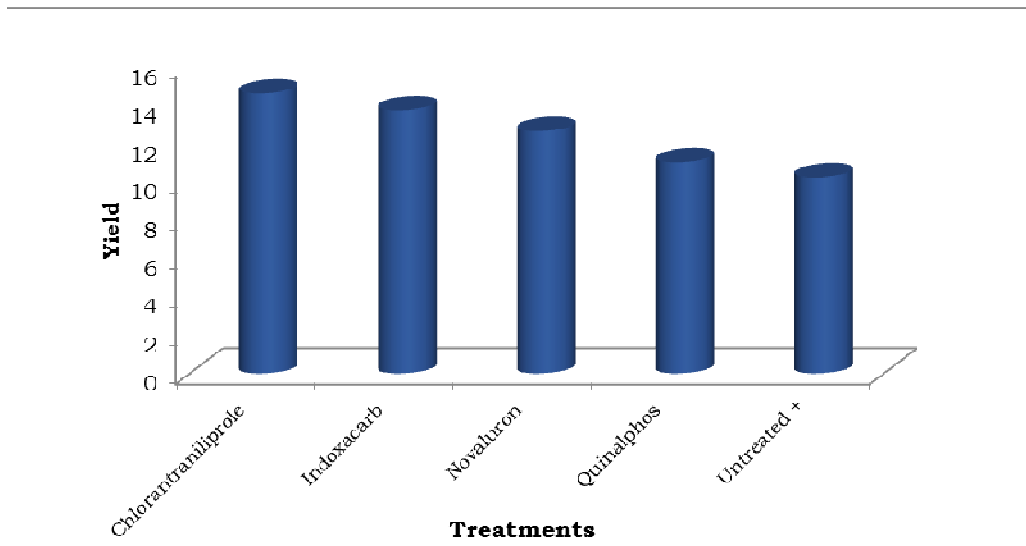


Fig 20: Comparison of insecticides and pheromone traps on chickpea yield

VI. SUMMARY

The most widespread and successful applications of sex pheromones concern their use in detection and population monitoring. Captures in traps baited with synthetic pheromone lures accurately show whether a specific insect is present, and when its seasonal flight period starts. Studies were conducted on standardization of pheromone trapping plans for the eco-friendly management of chickpea pod borer during 2012-13 in the farmers' fields in and around Madurae, Banaglore district. The results of the investigation are summarized below.

The results of the study showed that traps placed at 20 traps/acre recorded maximum moth catches (13.60 moths/week), least larval count (0.81 larvae/plant) and less pod damage (6.60%). Field observations on incidence of *H. armigera* revealed that peak moth catches were observed during 3rd week January. So, the placement of traps during these period will realize maximum moth catches.

The moth catches was significantly influenced by maximum temperature ($r=0.538$), minimum temperature (0.188) and evaporation (0.072). Rainfall ($r=-0.251$) and morning relative humidity ($r=-0.350$) had adverse effect on the activity of moths and on pheromone trap catches. Whereas morning relative humidity, afternoon relative humidity and rainfall influence positively and maximum temperature, minimum temperature, evaporation and wind speed negatively influenced on larval count. Pod infestation was positively influenced by maximum temperature and Rainfall. Whereas minimum temperature, morning relative humidity, afternoon relative humidity and wind speed influenced negatively.

These pheromone traps can be used as monitoring and mass trapping tool for chickpea pod borer. The use of pheromone traps will be effective when there is a peak moth activity. The relationship between moth catches/week, larval count/plant/week was found to be positive at 10 and 40 traps/acre, while it was negative at 20 and 30 traps/acre.

Four insecticides were evaluated against chickpea pod borer along with pheromone traps. chlorantraniliprole, indoxacarb and novaluron were found superior against chickpea pod borer in reducing the pod infestation when executed with pheromone traps.

The insecticides were used in the field experiment *i.e.*, chlorantraniliprole, indoxacarb and novaluron are newer insecticides having different modes of action and specificity and the routine insecticide used by farmers to managing the chickpea pod borer *i.e.*, quinalphos. Among them chlorantraniliprole was statistically significant with respect to moth catches, larval count and pod infestation followed by indoxacarb and novaluron. Hence, the use of these insecticides in combination with pheromone traps is effective in chickpea pod borer.

In 20 pheromone traps installed fields were recorded the maximum yield of 460.6 kg/acre followed by 40 traps (430.9 kg/acre). Whereas in combination of 20 pheromone traps/acre with chlorantraniliprole treated plots recorded the maximum

yield of 583.9 kg/acre, followed by indoxacarb treated plots (549.4 kg/acre), novaluron treated plots (505.2 kg/acre) and quinalphos treated plots (440.7 kg/acre).

The C:B ratio of only pheromone operated field was 1:2.1; whereas in combination of insecticides and pheromone traps operated field was 1:2.8.

This study has also shown that pheromone traps located near chickpea fields can be an effective tool for facilitating the early detection of *H. armigera* oviposition on chickpea by providing a means to time egg scouting. Initiating insecticide applications when oviposition begins in chickpea would eliminate unnecessary early-season Insecticide applications.

The use of pheromone trap with insecticides will reduce the cost of pest management to about 40-50 per cent (4-5 thousand). The pheromone traps reduced the number of insecticide sprays from 3-4 sprays/month to 1-2 sprays/month throughout the cropping season of chickpea crop.

The use of pheromone traps in pest management is economical, environment friendly and the activity of natural enemies will also be sustained in the chickpea cultivated ecosystem.

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APPENDIX

Meteorological variables at Maduræ (Rajanukunte), during *rabi* 2013-14

Month	Standard week	Temperature ($^{\circ}$ C)		Relative Humidity (%)		Evaporation (mm)	Wind Speed (Km/h)	Rainfall (mm)
		Max.	Min.	Morning	Afternoon			
December 2013	49	27.42	17.42	76.00	45.75	4.85	4.20	8.20
	50	27.71	15.85	80.50	50.71	5.90	4.36	0.00
	51	26.71	17.00	75.87	50.50	5.82	4.27	0.00
	52	26.85	15.42	76.75	57.50	5.65	4.25	0.00
January 2014	1	26.75	15.40	78.00	49.10	5.10	3.55	6.80
	2	27.25	15.45	78.80	49.40	5.32	3.61	0.00
	3	28.00	16.90	74.00	48.45	5.60	4.20	0.00
	4	27.30	16.71	79.52	48.50	5.75	4.41	0.00
	5	27.00	16.00	75.00	43.70	5.75	3.90	0.00
February 2014	6	27.50	16.15	74.10	43.00	5.65	3.94	0.00