POPULATION DYNAMICS, CROP LOSS ESTIMATION AND MANAGEMENT OF LEPIDOPTERAN PESTS OF SUNFLOWER

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CERTIFICATE

This is to certify that the thesis entitled **"POPULATION DYNAMICS, CROP LOSS ESTIMATION AND MANAGEMENT OF LEPIDOPTERAN PESTS OF SUNFLOWER"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY** to the College of Agriculture, Shivamogga. University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Miss. SWATHI G. HEGDE, ID. No. MA1TAF0156** (swathihegdeg@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

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Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower

(SWATHI G. HEGDE)

ABSTRACT

Investigations on lepidopteran pests of sunflower were carried out at College of Agriculture, University of Agricultural and Horticultural sciences, Navile, Shivamogga during 2017. Correlation studies with weather parameters on *Spodoptera litura* (Fabricius), *Thysanoplusia orichalcea* (Fabricius) and *Hyposidra* sp. showed negative correlation with maximum temperature and sunshine hours. The population of *Spilarctia obliqua* (Walker) had negative correlation with minimum temperature and sunshine hours whereas, it had positive correlation with remaining weather parameters. *Helicoverpa armigera* (Hubner) had positive correlation with maximum temperature, morning relative humidity, sunshine hours and negative correlation with rainfall, minimum temperature and evening relative humidity. Crop loss estimation studies revealed maximum yield loss in untreated control by recording 60.43 per cent followed by mechanical method (31.54%), chemical method (16.11%) and chemical + mechanical method (12.11%) compared to caging method. Chlorantraniliprole 18.5 SC and flubendiamide 480 SC were found to be highly effective in managing the lepidopteran pests of sunflower by recording highest yield of 24.66 q/ha and 24.16 q/ha with a C:B ratio of 1:3.09 and 1:3.01, respectively. These were followed by spinosad 45 SC and indoxacarb 14.5 SC in reducing the larval population.

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ಸೂರ್ಯಕಾಂತಿ ಬೆಳೆಯಲ್ಲಿ ಲೆಪಿಡೊಪ್ಟೆರಾ ಕೀಟಗಳ ಕ್ರಿಯಾತ್ಮಕ ಸಂಖ್ಯೆ, ಅಂದಾಜು ಬೆಳೆ ನಷ್ಟ ಹಾಗೂ ಅವುಗಳ ನಿರ್ವಹಣೆ

(ಸ್ವಾತಿ ಜಿ. ಹೆಗಡೆ)

ಸಾರಾಂಶ

ಸೂರ್ಯಕಾಂತಿ ಬೆಳೆಯಲ್ಲಿ ಲೆಪಿಡೊಪ್ಟೆರಾ ಕೀಟಗಳ ಈ ಅಧ್ಯಯನವನ್ನು ಕೃಷಿ ಕಾಲೇಜು, ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕಾ ವಿಶ್ವವಿದ್ಯಾಲಯ, ನವಿಲೆ, ಶಿವಮೊಗ್ಗದಲ್ಲಿ ೨೦೧೭ ರಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಕೀಟಗಳ ಕ್ರಿಯಾತ್ಮಕ ಸಂಖ್ಯೆ ಅಧ್ಯಯನದಲ್ಲಿ *ಸ್ಪೊಡೊಪ್ಟೆರಾ ಲಿಟುರಾ* (ಫ್ಯಾಬ್ರಿಶಿಯಸ್), *ಥೈಸನೊಪ್ಲುಸಿಯಾ ಒರಿಚಾಲ್ಸಿಯಾ* (ಫ್ಯಾಬ್ರಿಶಿಯಸ್) ಮತ್ತು *ಹೈಪೊಸಿಡ್ರಾ* ಎಸ್‌ಪಿ. ಗಳ ಸಂಖ್ಯೆಯು ಗರಿಷ್ಠ ತಾಪಮಾನ ಮತ್ತು ಸೂರ್ಯ ಧನತಾಪಕಗಳ ಜೊತೆ ನಕಾರಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿದೆ. *ಸ್ಪೈಲಾರ್ಕ್ಟಿಯಾ ಆಬ್ಲಿಕ್ವಾ* (ವಾಕರ್) ದ ಸಂಖ್ಯೆಯು ಕನಿಷ್ಠ ತಾಪಮಾನ, ಸೂರ್ಯ ಧನತಾಪಕಗಳ ಜೊತೆ ನಕಾರಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹಾಗೆಯೇ ಉಳಿದ ನಿಯತಾಂಕಗಳ ಜೊತೆ ಸಕಾರಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿದೆ. *ಹೆಲಿಕೊವರ್ಪಾ ಆರ್ಮಿಜೆರಾ* (ಹಬ್ನರ್) ದ ಸಂಖ್ಯೆಯು ಗರಿಷ್ಠ ತಾಪಮಾನ, ಮುಂಜಾನೆ ಸಾಪೇಕ್ಷ ಆರ್ದ್ರತೆ, ಸೂರ್ಯ ಧನತಾಪಕಗಳ ಜೊತೆ ಸಕಾರಾತ್ಮಕ ಮತ್ತು ಮಳೆ, ಕನಿಷ್ಠ ತಾಪಮಾನ, ಸಂಜೆ ಸಾಪೇಕ್ಷ ಆರ್ದ್ರತೆ ಜೊತೆ ನಕಾರಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿದೆ. ಅಂದಾಜು ಬೆಳೆ ನಷ್ಟ ಅಧ್ಯಯನದಲ್ಲಿ ಪರದೆ ವಿಧಾನಕ್ಕಿಂತ, ಯಾವುದೇ ನಿರ್ವಹಣಾ ಕ್ರಮ ಕೈಗೊಳ್ಳದ ತಾಕುಗಳಲ್ಲಿ ಪ್ರತಿಶತ ೬೦.೪೩ ರಷ್ಟು ಅತಿ ಹೆಚ್ಚು ಇಳುವರಿ ನಷ್ಟ ದಾಖಲಾಗಿದ್ದು ಇದರ ನಂತರದಲ್ಲಿ ಯಾಂತ್ರಿಕ ವಿಧಾನ (೩೧.೫೪ ಶೇ), ರಾಸಾಯನಿಕ ವಿಧಾನ (೧೬.೧೧ ಶೇ) ಮತ್ತು ರಾಸಾಯನಿಕ + ಯಾಂತ್ರಿಕ ವಿಧಾನದಲ್ಲಿ (೧೨.೧೧ ಶೇ) ಇಳುವರಿ ನಷ್ಟ ದಾಖಲಾಗಿವೆ. ಕ್ಲೊರಾಂಟ್ರನಿಲಿಪ್ರೊಲ್ ೧೮.೫ ಎಸ್.ಸಿ. ಮತ್ತು ಫ್ಲುಬೆಂಡಿಮೈಡ್ ೪೮೦ ಎಸ್.ಸಿ. ಕೀಟನಾಶಕಗಳು ಸೂರ್ಯಕಾಂತಿಯಲ್ಲಿನ ಲೆಪಿಡೊಪ್ಟೆರಾ ಕೀಟಗಳ ನಿರ್ವಹಣೆಯಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಪರಿಣಾಮಕಾರಿಯಾಗಿದ್ದು, ಇವುಗಳಲ್ಲಿ ಕ್ರಮವಾಗಿ ೨೪.೬೬ ಕ್ವಿಂ. ಪ್ರತಿ ಹೆಕ್ಟೇರ್‌ಗೆ ಮತ್ತು ೨೪.೧೬ ಕ್ವಿಂ. ಪ್ರತಿ ಹೆಕ್ಟೇರ್‌ಗೆ ಇಳುವರಿ ದಾಖಲಾಗಿವೆ ಹಾಗೆಯೇ ಕ್ರಮವಾಗಿ ೧:೩.೦೯ ಮತ್ತು ೧:೩.೦೧ ರಷ್ಟು ವೆಚ್ಚ ಮತ್ತು ಲಾಭ ದಾಖಲಾಗಿದೆ. ಕ್ಲೊರಾಂಟ್ರನಿಲಿಪ್ರೊಲ್ ೧೮.೫ ಎಸ್.ಸಿ. ಮತ್ತು ಫ್ಲುಬೆಂಡಿಮೈಡ್ ೪೮೦ ಎಸ್.ಸಿ. ಗಳ ನಂತರದಲ್ಲಿ ಸ್ಪೈನೊಸ್ಯಡ್ ೪೫ ಎಸ್.ಸಿ. ಮತ್ತು ಇಂಡಾಕ್ಸಾಕಾರ್ಬ್ ೧೪.೫ ಎಸ್.ಸಿ. ಗಳು ಮರಿಹುಳುಗಳ ಸಂಖ್ಯೆಯನ್ನು ಕಡಿಮೆಮಾಡುವಲ್ಲಿ ಪರಿಣಾಮಕಾರಿಯಾಗಿವೆ.

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CONTENTS

LIST OF TABLES

LIST OF PLATES

INTRODUCTION

I INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a large annual forb of the genus *Helianthus* which is grown as a crop for its edible oil and edible fruits. The genus *Helianthus* comprising about 70 species in the family Asteraceae. In Greek, helios means sun and anthos means flower. The flower is actually a head of numerous flowers crowded together. The outer flowers, which resemble petals, are the ray florets and are yellow, orange, maroon or other colours. These flowers are sterile. The flowers that fill the circular head inside the ray flowers are called disc florets. During growth, a young sunflower's flower head faces the sun to receive the sunlight it needs for photosynthesis. Heliotropism is the term for a plant's ability to follow the sun. That ability allows a sunflower to move with the sun as it arcs across the sky from east to west and the sunflower's bloom always faces the sun. When the sunflower plant matures, the neck of its stem no longer grows and tracking of the sun's arc ceases.

Although it was commonly accepted that the sunflower was first domesticated in what is now the southeastern US, roughly 5000 years ago, there is evidence that it was first domesticated in Mexico around 2600 BC. Sunflower seeds were brought to Europe from America in the 16^{th} century, where, along with sunflower oil, they become a widespread cooking ingredient (Blackman *et al.*, 2011).

Basically, the crop sunflower is relatively a recent introduction in India, which was first reached in the southern part of the country to improve oilseed production in 1969. Initially, Russian varieties were preferred for cultivation in the region and the hybrids were introduced in 1980 (Krishna, 2010). In the Indian subcontinent the sunflower crop is one of the edible oilseed crops making rapid strides in the oilseed scenario due to its wide adaptability to different agro-ecological niches and cropping systems. It is a rich source of edible oil (40-52 %) and polyunsaturated fatty acids (20-30 % oleic acid and 55-65 % linoleic acid) which is good for health.

Sunflower is being cultivated in India over an area of 0.47 mha with a production of 0.33 mt and the productivity is 697 kg/ ha. Karnataka, Maharashtra, Andhra Pradesh, Haryana and Tamil Nadu are the major sunflower growing states in our country. Karnataka with the production of 0.17 mt and productivity of 503 kg/ha, in an area of 0.33 mha stands as the leading state (Anonymous, 2016).

The production of this crop is quite low despite the release of several high yielding varieties and hybrids. Various biotic and abiotic stresses are responsible for lower productivity in this crop. Crop attacked by large number of insect pests (biotic stress) at different stages of crop growth is an alarming feature for lesser productivity. Sunflower acts as a host for wide array of insect pests, as many as 251 insect species use this crop as food across the world (Rajamohan, 1976).

During different stages of its growth sunflower is attacked by seedling pests, sucking pests, soil insects and defoliators among which defoliators are the important one. In the Indian subcontinent, though more than fifty insect species have been reported on sunflower, cutworms (*Agrotis* spp.), sucking pests, leaf and plant hoppers (*Amrasca biguttula biguttula* Ishida, *Empoasca* spp.), thrips (*Thrips palmi* Karny), whitefly (*Bemisia tabaci* Gennadius), defoliators (*Spilosoma obliqua* Walker, *Spodoptera litura* Fabricius, and *Plusia orichalcea* Fab.) and capitulum borer (*Helicoverpa armigera* Hubner) are major pests of economic concern. In Karnataka the cabbage semilooper (*Thysanolpusia orichalcea* Fabricius), Bihar hairy caterpillar [*Spilarctia*(=*Spilosoma*) *obliqua* Walker], tobacco cutworm (*Spodoptera litura* Fab.) and the grasshoppers [*Attractomorpha crenulata* Fab. and *Cyrtacantha crisranacea* (Stoll)], the weevils [*Myllocerus discolor* Fab., *M. dentifer* Fab., *M. viridanus* Fab. and *Ptochus ovulum* Fab.] and the beetles [*Monolepta signata* Fab., *Aulocophora foveicollis* Lucas] were reported to feed on sunflower in different crop growth stages (Rajanna, 1995).

All insect pests attacking the sunflower are injurious to it and they are grouped into sucking pests, defoliators and the head borer. Loss of seed yield due to sucking pests was lower compared to the defoliator pests, which inturn was lower when compared to the head borer. Sucking and defoliator pests together caused a yield loss of 24.30 per cent. The cumulative yield loss due to these three kinds of pests was 40.36 per cent. Twenty two species of defoliator pests distributed in three orders and eight families were recorded on sunflower. Based on feeding potential and economic importance lepidoptera is considered as the most important defoliator pests in sunflower (Rajanna, 1995). Sunflower head borer or capitulum borer, *Helicoverpa armigera* caused an extent of loss 30-60 per cent in sunflower (Daliwal and Arora, 1994). Non-insect pests such as rabbits, parakeets, doves, house sparrows, crows, rats *etc*., also have been reported to cause damage sunflower crop (Basappa, 1995). Lepidopteran pests are considered as one of the important production constraints in sunflower. Hence the present investigation ‘Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower’ was executed with the following objectives:

1. To study population dynamics of lepidopteran pests of sunflower
2. To asses crop loss estimation due to lepidopteran pests of sunflower
3. To manage the lepidopteran pests of sunflower

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The review related to the experiment entitled 'Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower' are presented below

2.1 Population dynamics of lepidopteran pests of sunfower

Rangarajan *et al.* (1975) during the study on pest complex of sunflower reported that while the leafhopper, *Amrasca biguttula biguttula* was found associated with the crop throughout the year, other pests like *Aphis gossypii, Nezara viridula, Dolycoris indicus, Scirtothrips dorsalis* and *Spodoptera littoralis* were noticed in both winter and summer crops. Others like *Bemisia tabaci, Oxycetonia versicolor, Thysanoplusia orichalcea* and *Helicoverpa armigera* were active in winter season.

Sethi *et al.* (1978) reported that four major pests of sunflower under Delhi conditions *viz., A. gossypii, B. tabaci, A. biguttula biguttula* and *Phytomyza atricornis* Meigen increased their numbers in *Rabi* season with steady increase in temperature and prevailing humid conditions around 65 per cent. During 1979, they recorded that mean air temperature around 30±1°C and relative humidity of 30±5 per cent, with declining sunshine hours, favoured the population build-up of *B. tabaci*, which attained its peak in third week of May. The agromyzid fly (*Agromyza* sp.) behaved in a similar way as *B. tabaci*. With the rise in temperature and high wind velocity by the middle of June the population of all the pests declined during the later stages of the crop.

Basavaraja (1990) reported the occurrence of eight important pests distributed throughout the cropping season and damaging at various stages of sunflower during *Kharif.* Eight important pests were namely *Amrasca biguttala biguttala, Aphis craccivora, Tetranychus ludeni, Myllocerus discolor, Spodaptera litura, Spilosoma obliqua, Thysanoplusia orichalcea and Heliothis armigera* (Hb.), in relation to population trends, period of occurence and per cent incidence were studied.

Dubey *et al.* (1995) studied the population dynamics of *Helicoverpa armigera* on various crops and recorded its peak activity in February and March during two years in Madhya Pradesh.

Keyhanian (2000) reported in sunflower crop that mean population of cutworm *Agrotis* spp. fluctuated between 0.06 and 0.22 larva and 0.04 and 0.16 larva per one meter row length (MRL), mean population of semilooper fluctuated from 0.3 to 0.96 larva and 0.1 to 2.62 larvae/plant, mean population of sunflower caterpillar, *S. exigua* ranged between 0.06 and 0.64 larva and 0.06 and 0.54 larva/plant and the mean population of capitulum borer, *H. armigera* ranged between 0.16 and 2.1 larvae and 0.32 and 1.86 larvae/plant.

Higher eggs and larval populations as well as leaf damage caused by *Spodoptera litura* to castor plants was found in the third and fourth week of November, whereas the lower population and leaf damage was observed in the first and second week of October in middle Gujarat agroclimatic condition. Among the various abiotic factors minimum temperature, vapour pressure (morning & evening) and RH (evening) were found most influencing factors showed negative effect on oviposition behaviour and larval development of *Spodoptera litura*. The maximum temperature showed significant negative influence on oviposition by *Spodoptera litura* (Thanki *et al.*, 2003).

Patel *et al.* (2015) studied on the population dynamics of chickpea pod borer (*Helicoverpa armigera* Hubner) in relation to abiotic factors and reported that the pest commenced from 2nd week of November, which remained till 4th week of February with its peak activity during 1st and 2nd week of December. The correlation studies indicated significant negative association between larval population of *Helicoverpa armigera* and evaporation (-0.551). The non-significant effect was observed between larval population of *Helicoverpa armigera* and maximum temperature, evening relative humidity, evening vapour pressure and wind speed.

Yadav *et al.* (2015) conducted an experiment at Pantnagar to know the effect of weather parameters on sucking pests, tobacco caterpillar, *Spodoptera litura*, semilooper, *Trichoplusia ni* and bihar hairy caterpillar, *Spilosoma obliqua* in black gram. Rainfall and wind velocity showed non-significant negative correlation while temperature (minimum and maximum), relative humidity (morning and evening) and sunshine showed a non-significant positive correlation with the population of *Spodoptera litura*. Population of *Trichoplusia ni* had significant positive correlation with minimum temperature and evening relative humidity. Rainfall and wind velocity with *Spilosoma obliqua* population showed significant negative correlation.

Helicoverpa armigera incidence on tomato fruits started in the last week of August after that, population increased gradually and reached to its peak in the fourth week of October with a mean of 7.6 larvae per five plants. The correlation between fruit borer population and maximum temperature was positive but non-significant. While, non-significant negative correlation was recorded with minimum temperature and significant negative correlation with relative humidity (Arjun, 2016).

A study was carried out at Banswara to find out the effect of various weather parameters on the occurrence of major defoliators in soybean crop. Semilooper larval population was recorded on late July/early August and among the weather factors, morning relative humidity showed significant (r = 0.954) and positively, highly influence on the larval population per meter row length whereas evening humidity (r = -0.644) and sunshine hrs (r = -0.367) negatively and significantly influence the larval population per meter row length. The moth catches of *Spodoptera litura* increased from late-August to late-September and this trend was almost similar in different *Kharif* seasons observed. Larval population of *Spodoptera litura* positively correlated with pheromone trap catches (Babu *et al.,* 2017).

Naresh *et al.* (2017) conducted a study at Tirupati to know the effect of abiotic factors on population dynamics of *Spodoptera litura* in groundnut. Weather parameters like maximum temperature, minimum temperature, sun shine hours and wind speed showed negative correlation with *Spodoptera litura* incidence and morning and evening relative humidity showed positive correlation with *Spodoptera litura* damage in groundnut.

Effect of different sowing dates (15th October, 30th October, 15th November, 30th November and 15th December in cropping seasons) was evaluated on the population dynamics of *Helicoverpa armigera* for three cropping systems in chickpea. In early sown crop (15th October) larval count and pod damage was not recorded up to 96 DAS, whereas, initial infestation was higher in late sown crop (15th December). Pod damage was 44.56 per cent on 15th October sown crop, while 59.16 per cent on 15th December sown crop. Thus, it was concluded that the average yield loss was lowest in the early sown crop than to late sown crop (Ahmad *et al.,* 2018).

2.2 Crop loss estimation due to lepidopteran pests of sunflower

Lewin *et al.* (1973) pointed out that *Helicoverpa armigera* caused more than 50 per cent loss to the maturing seed of sunflower.

Thontadarya and Jayaramaiah (1973) reported that the larvae of *Helicoverpa armigera* made irregular hole in calyxes, ray florets, leaves and caused damage on seeds in the capitulum.

Singh and Singh (1975) reported that young larvae of *Helicoverpa armigera* nibbled on various parts of sunflower till they reached flower buds or fruits to bore into capitulum. The early stage larvae caused negligible damage.

The yield loss due to *Helicoverpa* and defoliators was 469 kg/ha whereas losses due to *Helicoverpa* and defoliators separately were 112 and 268 kg/ha, respectively in sunflower (Panchabhavi and Krishnamoorthy, 1978).

Diacrisia casigneta Kollars, the hairy caterpillar caused extensive defoliation (70-90 per cent) of sunflower variety EC-68414 resulting into substantial loss in seed quality and yield (Banerjee and Haque, 1984).

Margal (1990) reported that cultivars mean of losses (per cent) in yield due to larval stage a for the larval densities 1, 2, 4, 6, 8, 12 and 16 were found to be 6.49, 10.58, 15.71, 20.93, 25.97, 31.45 and 35.90 respectively.

Sindagi and Virupakshappa (1990) reported that when sunflower crop was sprayed with endosulfan (0.1%) against capitulum borer at Bangalore, the yield increased by 23 to 25 per cent, whereas, at Akola weekly spraying of this insecticide resulted in 135 per cent increase in the yield.

Srivastava and Srivastava (1990) conducted field studies in Rajasthan and reported that the mean pod damage to chickpea (*Cicer arietinum*) caused by *Heliothis armigera* [*Helicoverpa armigera*] in protected and unprotected plots was 0.9 and 5.9 per cent, respectively, in 1984 and 1.0 and 6.4 per cent, respectively, in 1985. The loss in grain yield in the unprotected plot compared to the protected plot was 115 kg/ha (avoidable loss = 16.7 %) in 1984, and 128 kg/ha (avoidable loss = 18 %) in 1985.

Dhir *et al.* (1992) carried out field studies in Orissa, during the *Rabi* season 1990-91 and showed that one larva of *Spodoptera litura* per groundnut plant at the seedling and flowering stages could cause a significant yield loss. At the seedling stage, one larva per plant consumed about 54.7 per cent leaf area and reduced pod yield by 25.8 per cent. At flowering, one larva per plant consumed 49.1 per cent leaf area and reduced the yield by 19 per cent. At pegging, one larva per plant consumed about 38.8 per cent leaf area and resulted in a yield loss of 5.7 per cent.

Karuppuchamy *et al.* (1993) conducted the field experiment at Coimbatore in the rainy season of 1991 to investigate the yield losses of sunflower caused by *Helicoverpa armigera*. The economic injury level was 0.92 larva/plant.

In sunflower, seed yield loss due to sucking pests was lower compared to defoliator pests, which in return was lower when compared to head borer. The sucking and defoliator pests together caused a yield loss of 24.3 per cent. The cumulative yield loss due to three kinds of pests amounted to 40.36 per cent, compared to the plants totally protected (Rajanna, 1995).

Shyam *et al.* (1999) observed that the yield losses in sunflowers due to insect-pests in Uttar Pradesh, India were 11.64 per cent in the *Zaid* (Spring-Summer) crop and 16.34 per cent in the *Rabi* crop.

Keyhanian (2000) reported that estimated reduction in seed yield in sunflower by all the insect-pests combined was 15.65 per cent. Maximum reduction was recorded due to cutworms (5.69 %) followed by capitulum borer (5.59 %), sucking pests (3.18 %) and early and later defoliators (2.26 %).

Shivaramu and Kulakarni (2008) studied chilli yield loss assessment due to the fruit borer *Helicoverpa armigera* (Hubner) at Dharwad in green house and field conditions. In field experiment, it was revealed that the fruit damages were zero, 11.68, 18.84, 25.00, 31.25, 40.27 and 50.00 at 0, 1, 2, 3, 4, 5 and 6 larvae per plant respectively. The yield reduction for 1, 2, 3, 4, 5 and 6 larvae per plant was zero, 2.49, 3.61, 4.72, 6.94, 8.05 and 11.11 q/ha respectively.

Yield loss assessment studies were carried out in Madenur, Hassan and Beekanahalli, Chikmagalur during 2004 and 2005 on potato pests. Aphids, *Myzus persicae* caused on an average 6 per cent loss in yield at Madenur and 3 per cent loss in Beekanahalli. The yield loss due to *Spodoptera litura* was 8 per cent at Madenur and 4 per cent at Beekanahalli. The yield loss due to potato tuber moth, *Phthoremaea operculella* was 9 per cent at Madenur while it was 6 per cent at Beekanahalli. The yield loss due to mite, *Polyphagotarsonemus latus* was 26.80 per cent at Madenur and it was 4 per cent at Beekanahalli (Basavaraju *et al.*, 2009).

Jayewar *et al.* (2017) conducted a study at Maharashtra to assess the relative abundance and extent of damage caused by the various pests attacking sunflower. The mean population of defoliators in protected plot was 0.99 larvae/plant which was significantly less of that 1.90 larvae/plant in unprotected plot. As a result of which crop left unprotected recorded significantly less yield *i.e.*, 1759 kg/ha as compared to crop protected through chemicals *i.e.*, 2127 kg/ha which means unprotected plot recorded a yield loss of 368 kg/ha. Similarly significant yield reduction to the extent of 17.30 per cent was recorded in unprotected treatment.

2.3 Management of lepidopteran pests of sunflower

Rabindra *et al.* (1990) reported that two applications of NPV at 250 LE/ha to sunflower heads at three days interval reduced the larval population substantially.

Basavaraja (1990) studied the efficacy of certain insecticides including cypermethrin EC, fenvalerate EC, methyl parathion EC, endosulfan EC, phosalone EC, malathion EC, neem oil, argemone oil and pongamia oil were evaluated in sunflower ecosystem against the head borer under field conditions. All the insecticides were effective in reducing head damage. Cypermethrin EC, endosulfan EC, fenvalerate EC and methyl parathion were more effective in reducing per cent head damage with maximum yield and high cost benefit ratio over other treatments.

Use of African tall variety of marigold Golden Age afforded maximum reduction of both eggs and larvae of *Helicoverpa armigera* in the intercropped tomato with a consequent reduction in the number of bored fruits. The percent of fruits damaged in 10, 12, 14, 16, 18 and 20 intercropped rows of tomato were 6.0, 7.1, 10.3, 10.4, 14.1 and 14.5 respectively. Two sprays of 0.07 % endosulfan applied at 28 and 35 DAP on the intercropped tomato in the planting pattern of 16 rows of tomato alternated with one row of marigold reduced fruit borer infestation to less than 6 per cent (Srinivasan *et al.*, 1994).

Singh (1995) studied certain aspects of pest management of sunflower at New Delhi and reported that among the four insecticides evaluated, fenvalerate (0.02 %) and endosulfan (0.07 %) recorded the lowest pest population and lower predator population as compared to other treatments. However, basal application of carbofuran and foliar spray of neemark had no adverse impact on the activity of the predators. The seed yield in fenvalerate treated plots was maximum, followed by endosulfan. Carbofuran and neemark registered higher seed yields over untreated control and intercropping systems.

Balikai and Sattigi (2000) reported that two applications of HaNPV at 500 LE/ha recorded lowest damage to sunflower heads (31.6 %) and highest seed yield of 3.1 q/ha followed by two applications of HaNPV at 250 LE/ha + Btk at 0.5 kg/ha and two sprays of HaNPV at 250 LE/ha + endosulfan 35 EC at 0.5 lit/ha. Two applications of HaNPV at 250 LE/ha failed to give an appreciable control.

Hussain and Bilal (2007) evaluated the efficacy of six insecticides at farmers field against *Helicoverpa armigera* infesting tomato. Among the treatments imidacloprid at 0.03 per cent proved more effective followed by deltamethrin and fluvalinate. The spraying of these insecticides on tomato resulted in significantly higher reduction of larval population. The field data showed that imidacloprid gave significantly higher increase in yield (>78 %) over control followed by deltamethrin. Imidacloprid (0.03 %) avoided 46 per cent yield loss on tomato crop.

Kumar (2007) tested the efficacy of four different synthetic pyrethroids namely, deltamethrin, cypermethrin, fenvalerate and permethrin against *Thysanoplusia orichalcea* in sunflower ecosystem. The results indicated that the LC_{50} and LD_{50} for deltamethrin was 0.000095 % and 0.03496 µg/g of body weight of third instar larvae respectively. Similarly LC_{50} for cypermethrin, fenvalerate and permethrin was 0.00027, 0.00095 and 0.00111 7 % respectively whereas LD_{50} was 0.07878, 0.1196 and 0.1502 µg/g of body weight respectively. The data of LD_{50} reveals that the deltamethrin is the most toxic and permethrin is least toxic against *Thysanoplusia orichalcea*. The order of relative efficacy based on LT_{50} values of these insecticides were deltamethrin 0.001 %, cypermethrin 0.01 %, fenvalerate 0.01 % and permethrin 0.05 %.

Patil and Basappa (2009) carried out field study during *Kharif* divulged that thiodicarb 75 WP at (0.075 %) was working more effectively against defoliators *T. ni* and *S. litura* and spinosad 45 % SC at (0.018 %) against capitulum borer *H. armigera* whereas application of endosulfan 35 % EC at (0.07 %) proved to be effective against stem borer in sunflower.

Ranganatha (2009) conducted laboratory study and reported that nimbecidine (0.5 %) recorded 82.67, 85.00 and 76.67 per cent larval mortality of *S. litura*, *T. orichalcea* and *Cydia ptychora* after 72 hrs of treatment, respectively. The next best treatments were NSKE (5 %) and cristol 74 GL (1 %). Further studied the bio-efficacy of organic components and it was found that, nimbecidine (0.5 %) recorded maximum larval reduction of *S. litura* and *T. orichalcea* (72.74, 85.11 and 73.43, 86.50 % respectively after first and second spray) and least per cent pod damage (24.80 %) and seed damage (16.37 %) with higher seed yield (21.71 q/ha) and B:C ratio (2.96). The next best treatments were NSKE (5 %) and cristol 74 GL (1 %).

Dhaka *et al.* (2010) conducted a field trail on the efficacy of different novel insecticides namely, novaluron 10 EC, indoxacarb 14.5 SC, bifenthrin 10 EC, lambda cyhalothrin 5 EC, and biopesticides *viz*., HaNPV, *Bacillus thuringiensis* var. kurstaki and neemarin, against *Helicoverpa armigera* on tomato in comparison with sequential application of conventional insecticide *i.e*., endosulfan 35 EC and untreated control. Results showed that among different sequential application of insecticides, indoxacarb with lowest fruit infestation of 2.53 and 2.83 and highest yield of 39.45 and 38.85 q/ha were recorded during both the seasons, respectively. While among the biopesticides, neemarin followed by Bt and NPV with mean fruit yield of 30.27 and 29.60, 28.17 and 27.61 and 26.70 and 26.11 q/ha were obtained in two seasons, respectively.

Jagadish *et al.* (2010) evaluated six bio-pesticides, under field conditions, for their efficacy against major defoliators and capitulum borer, *Helicoverpa armigera* Hub. infesting sunflower. All the six bio-pesticides *viz.*, *Spodoptera* NPV at 2×10^8 POB/ml, *Helicoverpa* NPV at 2×10^8 POB/ml, *Pongamia* Seed Kernel Extract at 5 %, Neem gold 0.03EC (300 ppm) (0.5 %), Neem Seed Kernel Extract at 5 % and Prosopan at 10 ml/L were on par with the insecticidal checks (endosulphan 35 EC at 0.07 % and profenophos 50EC at 0.05 %) and they were found to be significantly superior than untreated check in the suppression of defoliators, 50 days after sowing.

Pal *et al.* (2010) conducted a field trial to study the management of major insect pests (*Amrasca biguttula biguttula, Bemisia tabaci* and *Helicoverpa armigera*) of summer sunflower and reported that phorate + two sprayings of endosulfan at 0.05 % after 45 and 60 days of sowing was found most effective treatment to minimizing the population of *A. biguttula biguttula, Bemisia tabaci* and *Helicoverpa armigera*, respectively. However, basal application of phorate with two foliar sprayings of monocrotophos at 0.05 % registered highest crop yield and it was as high as 1380.00 kg/ ha.

Ten insecticides emamectin benzoate 0.0025 %, thiodicarb 0.075 %, indoxacarb 0.007 %, spinosad 0.0135 %, novaluron 0.01 %, lufenuron 0.005 %, flubendiamide 0.01 %, rynaxypyr 0.006 % and endosulfan 0.07 % were evaluated in both laboratory and field conditions against *Helicoverpa armigera* (Hubner) Hardwick infesting chickpea. Flubendiamide, emamectin, rynaxypyr and spinosad recorded more than 90 per cent larval mortality in the laboratory experiment and found most effective as larvicide. In the field experiment 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, *Helicoverpa armigera* in chickpea crop (Babar *et al.*, 2012).

Chakravarthy *et al.* (2012) initiated a study to explore the potential of CdS, Nano-Ag and Nano-TiO2 nanoparticles in causing adverse effects on *Spodptera litura*. CdS nanoparticle caused higher larval mortality of 21.41 to 93.79 per cent at 150 and 2400 ppm, respectively. The Nano-TiO2 showed maximum of 73.79 per cent larval mortality at 2400 ppm and the least was 18.50 per cent at 150 ppm. Nano-Ag caused maximum 56.89 per cent mortality at 2400 ppm followed by 46.89 and 33.44 per cent mortality at 1200 and 600 ppm, respectively. Hence, all the three nanoparticles used were effective against *Spodoptera litura* larvae.

Basavaraj (2014) evaluated the effect of bio-rational formulations on capitulum borer, *Helicoverpa armigera*, in sunflower ecosystem. Among the bio-rational formulation used, spinosad was significantly superior against *Helicoverpa armigera*, it recorded 100 per cent mortality at 48 HAT and 72 HAT and it was followed by profenophos.

Gadhiya *et al.* (2014) studied on the evaluation of insecticides for the management of *Helicoverpa armigera* (Hubner) Hardwick and *Spodoptera litura* (Fabricius) infesting groundnut. They used nine insecticides in the experiment. 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 *Helicoverpa armigera* and *Spodoptera litura*. Highest cost benefit ratio 1:3.3 was observed in chlorantraniliprole (0.006 %) followed by indoxacarb treatment.

A study was conducted for the evaluation of novel insecticides for the management of *Spodoptera litura* (Fabricius) and *Chrysodeixis acuta* (Walker) infesting soybean. Among the treatments used, chlorantraniliprole (30 g a.i./ ha), methomyl (300 g a.i./ ha) and spinosad (75 g a.i./ ha) were found effective and statistically at par with each other in protecting the soybean crop from the infestation of both lepidopteran pests. Chlorantraniliprole provided consistent protection from defoliation to soybean crop from *Spodoptera litura* and *Chrysodeixis acuta* with highest cost benefit ratio among the tested insecticides (Patil *et al.,* 2014).

Shreekanth *et al.* (2014) evaluated the bio-efficacy and economics of certain new insecticides against gram pod borer, *Helicoverpa armigera* (Hubner) on pigeonpea. They reported that the number of larvae/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. The cost effectiveness of chlorantraniliprole and flubendiamide was also high and very favourable with incremental cost-benefit ratios of 1:4.64 and 1:4.50 respectively, followed by indoxacarb (1:3.67), emamectin benzoate (1:3.13) and spinosad (1:2.97).

Thodsare and Srivastava (2014) examined the bioefficacy of abamectin (0.1, 0.09, 0.08, 0.07 and 0.06 %) and emamectin benzoate (0.04, 0.009, 0.006 and 0.002 %) against 10 days old larvae of *Spodoptera litura* by leaf dip bioassay method. Emamectin benzoate proved to be more toxic than abamectin with the LC_{30}, LC_{50} and LC_{90} values of 0.001, 0.007 and 0.45 % respectively at 12 hours after exposure (HAE). At 24 HAE the LC_{50} value of emamectin benzoate and abamectin were 0.002 and 0.02 % respectively. Emamectin benzoate showed 10 times more toxicity than abamectin at LC_{50} and was quick in causing mortality than abamectin.

Jayewar and Sonkamble (2015) tested different biopesticides against the natural incidence of the capitulum borer *Helicoverpa armigera* on sunflower with seven treatments *viz*., *B. bassiana* SC formulation at 250 mg/L, DOR *Bacillus thuringiensis* (Bt) formulation at 2.5 g/L, HaNPV (DOR isolate) at 2 x 10^8 POBs/mL, commercial neem formulation 0.5 %, NSKE 5 %, PSE 5%, Profenophos 0.05 % and UTC. Larval incidence was lowest in plots sprayed with profenophos. However the next best treatments in the order of effectiveness for the control of *Helicoverpa* were HaNPV at 2 x 10^{8} POBs/mL, NSKE 5 %, DOR *B. bassiana* 250 mg, DOR Bt 5 at 2.5 gm/litre, PSE 5 % and neem formulation 0.5 %.

A field trail was conducted to evaluate the efficacy of novaluron 5.25 %+ indoxacarb 4.5 % SC at different concentrations against *Spodoptera litura* (Fab.) and *Helicoverpa armigera* (Hubner) on tomato. The mean data of the two seasons revealed that novaluron 10 EC at 750 ml/ha and indoxacarb 14.5 % SC at 500 ml/ha were significantly superior in managing *Spodoptera litura* and *Helicoverpa armigera* over rest of the treatments. Lowest fruit damage and higher fruit yield was recorded in the treatment novaluron 5.25 % + indoxacarb 4.5 % at 875 ml/ha treatment and was significantly superior over other treatments followed by novaluron 5.25 % + indoxacarb 4.5 % at 825 ml/ha (Katti and Surpur, 2015).

Matti and Deotale (2015) conducted an experiment to determine the efficacy of different insecticides against semilooper *Thysanoplusia orichalcea* (Fab.) in soybean ecosystem. Fenvalerate 20 EC at 0.50 ml/l, indoxacarb 15.8 EC at 0.60 ml/l, spinosad 45 SC at 0.25 ml/l were found to be most effective treatments which recorded highest yield of 21.05 q/ha, 20.10 q/ha and 19.02 q/ha, respectively. From the seed production point of view fenvalerate 20 EC at 0.50 ml/l, indoxacarb 15.8 EC at 0.60 ml/l, spinosad 45 SC at 0.25 ml/l were most effective in recording highest yield.

Patra *et al.* (2015) evaluated the efficacy of three novel insecticides namely, pyridalyl, indoxacarb and chlorfenapyr along with two standard checks chlorpyriphos and triazophos and untreated control. Pyridalyl and indoxacarb were found to be very effective insecticides against *Helicoverpa armigera* (3.10 and 2.60 % fruit damage) and *Spodoptera litura* (3.34 and 3.59 % fruit damage) with 211.21 and 209.59 q/ha marketable yield, respectively.

In tomato against fruit borer, *Helicoverpa armigera,* chlorantraniliprole (0.005 %) proved most effective insecticide followed by flubendiamide (0.19 %). Quinalphos (0.05 %) proved least effective followed by lambda cyhalothrin (0.005 %) among the tested insecticides. The maximum yield of marketable tomato fruit and minimum avoidable loss was obtained in chlorantraniliprole followed by flubendiamide. The highest benefit cost ratio obtained in the profenophos treatment (18.98: 1) followed by quinalphos (9.95: 1) due to low cost of chemicals, while, lowest was in novaluron (3.67: 1) followed by indoxacarb (4.15: 1) (Arjun, 2016).

Chandra Shekhara *et al.* (2017) evaluated the efficacy of certain chemicals and neem products against pod borer, *Helicoverpa armigera* (Hubner) on chickpea (*Cicer arietinum* L.). The per cent population reduction of gram pod borer *Helicoverpa armigera* on third, seventh and fourteenth days after spraying revealed that all treatments are superior over control. Among the treatments spinosad 45 SC found superior over all the treatments followed by cypermethrin and indoxacarb after first and second sprays, respectively. Highest reduction in larval population (72.12 %) was observed with spinosad 45 SC at 0.5 ml/l. Minimum pod damage of 11.98 % and highest yield of 1745 Kg/ha was registered in spinosad. Highest cost benefit ratio (C:B) was recorded in spinosad (1:2.36) followed by cypermethrin (1:1.94), indoxacarb (1:1.84), chlorpyriphos (1:1.60), profenophos (1:1.34), NSKE (1:1.20) and neem oil (1:0.90).

Ganai *et al.* (2017) evaluated the efficacy of different insecticides namely, novaluron, carbosulfan, imidachloprid, bifentrhin, methyl-o-demeton, chlorpyriphos dust, neem oil, propargite and thiamethoxam against the field populations of pod borer (*Helicoverpa armigera*) infesting marigold (*Tagetes erecta*). Mean population of *Helicoverpa armigera* after two sprays revealed that carbosulfan 0.003 % was effective and superior. The next best were novaluron 0.100 % and bifenthrin 0.050 % which were at par. Propargite 0.800 % and neem oil 0.050 % were found to be least effective against *Helicoverpa armigera*.

Jaba *et al.* (2017) investigated the bioefficacy of biopesticides such as Jatropha oil, NSKE and NPV in various combinations along with control under chickpea-coriander intercropping ecosystem for three seasons against *Helicoverpa armigera* and resulted that the most effective treatment was T_4 (chickpea; Jatropha treated) + coriander (NPV treated) followed by T_9 (chickpea; Jatropha treated alone). The mean grain yield of 1292 kg/ha was recorded for T_4 treatment in chickpea (Jatropha at 5 mL/L) + coriander (NPV at 0.5 mL/L). The maximum coriander yield of 1008 kg/ha was obtained in T_2 treatment *i.e*., chickpea (NSKE treated) + coriander (untreated).

A study was undertaken to determine the bio-efficacy of six insecticides *viz.,* indoxacarb 14.5 SC, flubendiamide 480 SC, novaluron 10 EC, carbosulfan 25 EC, lambda cyhalothrin 5 EC and cypermethrin 25 EC against pod borer, *Helicoverpa armigera* in black gram. Flubendiamide 480 SC was superior in recording lower larval population followed by indoxacarb 14.5 SC. The highest grain yield (928 kg/ha) as well as cost benefit ratio (1:9.57) was obtained from the treatment flubendiamide 480 SC and followed by indoxacarb 14.5 SC. The minimum yield was obtained from the cypermethrin 25 EC (428 kg/ha). Flubendiamide 480 SC at 75 ml/ha proved effective treatment against *Helicoverpa armigera* in black gram (Kumar *et al.,* 2017).

Makwana *et al.* (2017) investigated the efficacy of different bio pesticides against pearl millet ear head worm, *Helicoverpa armigera*. Among the tested treatments, spinosad and indoxacarb were found to be most effective in reducing the larval population of *Helicoverpa armigera* whereas *L. lecanii* and *B. bassiana* proved to be least effective. As far as economics of various insecticides are concerned, the treatments of HaNPV at 500 LE/ha or spinosad at 0.014 % or azadirechtin at 0.000375 % were found as effective and economical as recommended synthetic insecticides and are recommended for eco-friendly management of *Helicoverpa armigera* in pearl millet ecosystem.

Muzammil *et al.* (2017) studied on the field efficacy of new molecules and biorationals against on sunflower defoliator pests. Among the chemical treatments minimum population and percent foliage damage recorded in chlorantraniliprole which was significantly superior in recording the lowest population and percent foliage damage and were found to be significantly superior over profenophos 50 EC treated plot. Among chemical treatments highest net profit was recorded in chlorantraniliprole 18.5 SC and emamectin benzoate 5 SG. The results clearly indicated the superiority of newer insecticides and biorationals in controlling *Spilarctia obliqua* and *Thysanoplusia orichalcea* of sunflower.

Nitharwal *et al.* (2017) conducted an experiment to study the efficacy of newer molecules against gram pod borer, *Helicoverpa armigera* (Hub.) on chickpea (*Cicer arietinum* L.). Among the treatments used, lowest number of gram pod borer was recorded in spinosad (2.85). The next followed treatment was chlorpyriphos (3.40), which was also statistically at par with quinalphos (3.69), cypermethrin (3.95). Remaining treatments are fipronil (4.45) and indoxcarb (4.63) were statistically at par malathion (5.25) was recorded as least effective within the chemical insecticides. Among the treatment studied, the best and most economical treatment was spinosad (1:3.40), followed by chlorpyriphos (1:3.03), quinalphos (1:2.99), cypermethrin (1:2.71), fipronil (1:2.36), indoxacarb (1:2.30), malathion (1:1.81) as compared to control (1:1.46).

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation on ‘Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower’ was carried out during *Kharif* 2017 at main campus of UAHS, Shivamogga (Plate 1) located at 14^0 28' N latitude, 74^0 44’E longitude and 582 m above mean sea level. The materials used and techniques employed for the investigations are presented in this chapter.

3.1 Population dynamics of lepidopteran pests of sunflower

The sunflower hybrid KBSH-53 was grown during *Kharif* 2017 in an area of 150 sq.m with the spacing of 60×30 cm at UAHS, Shivamogga by following the package of practices except the plant protection measures against insect pests.

For the estimation of population dynamics, twenty plants were randomly selected for taking the observations. The incidence of lepidopteran pests were taken at ten days interval from one week after germination till the maturity of the crop. The adult specimens of lepidopteran pests on sunflower were sent to Mr. P. R. Shashank, Scientist, Department of Entomology, Indian Agricultural Research Institute, New Delhi for identification and got identified as *Spodoptera litura*, *Thysanoplusia orichalcea*, *Spilarctia obliqua, Hyposidra* sp. and *Helicoverpa armigera.*

All the lepidopteran pests were counted from twenty randomly selected plants and expressed as number of larvae per plant. Thus obtained population trend of *Spodoptera litura, Thysanoplusia orichalcea, Spilarctia obliqua,* looper *Hyposidra* sp. and *Helicoverpa armigera* were compared with the weather parameters.

Data obtained was correlated with various weather parameters using Statistical Package for the Social Sciences (SPSS) software to find out the influence of weather parameters on the population dynamics of lepidopteran pests.

3.2 Crop loss estimation due to lepidopteran pests of sunflower

An experiment was laid out at UAHS, Shivamogga. A sunflower hybrid KBSH-53 was grown in a plot size of 2×3 m during *Kharif* 2017 with 5 treatments and 4 replications (Plate 8).

Treatment details:

T_1 - Chemical control

T_2 - Caging method

T_3 - Mechanical method

T_4 - Chemical + mechanical method

T_5 – Untreated control

All the above treatments were applied from the germination (July 29) till the harvest of the crop. In first treatment indoxacarb 14.5 SC (0.5 ml/lit) was sprayed at 15 days interval using knapsack sprayer for the management of lepidopteran pests. In second treatment entire plants were covered with the nets to completely exclude the entry of lepidopteran pests. Hand pollination was done in this treatment during flowering as plants were covered with nets, so pollinators like honey bees could not aid in the pollination and in other treatments pollinators assisted in the pollination (Plate 7). In the third treatment larvae on each and every plant were removed mechanically with hands daily and in fourth treatment both chemical (indoxacarb 14.5 SC at 0.5 ml/lit) and mechanical (hand picking) methods were followed to keep away the lepidopteran pests damaging the crop. But in untreated check crop was allowed for the natural infestation by all lepidopteran pests.

The larval count of all lepidopteran pests was taken in each treatment at ten days interval till crop was harvested on ten randomly selected plants and mean larval population/plant was worked out.

At harvest, grain yield in all treatments was recorded as kg/plot and later converted to q/ha. The data collected on mean larval population and yield was subjected to appropriate statistical analysis done by analysis of variance (ANOVA), Duncan multiple range test using software, Web Agri Stat Package (WASP-2) and per cent yield loss due to lepidopteran pests was worked out by using the formula

$$\text{Per cent yield loss} = \frac{\text{Yield in caging method - Yield in other treatments}}{\text{Yield in caging method}} \times 100$$

3.3 Management of lepidopteran pests of sunflower

The field experiment was carried out at main campus of UAHS, Shivamogga (14^0 $28^{'}$ N latitude, 74^0 44'E longitude and 582 m above mean sea level on sunflower).

Plate 1. General view of experimental plot

Plate 8. General view of crop loss estimation experimental plot

Plate 7. Pollinators noticed in sunflower field during flowering

.3.1 Details of management experiment

Plot size: 2 X 3 m

Season: *Kharif* 2017

Design: RCBD

Treatments: 9

Replications: 3

Variety: KBSH-53

The pre-treatment observation on defoliators like *Thysanoplusia orichalcea, Spodoptera litura* and *Spilarctia obliqua* was taken on ten randomly selected plants a day before treatment. First spraying was taken 45 days after sowing and spraying was done the next day as per the treatment details (Table 1) using knapsack sprayer. Post treatment count on defoliator larvae was taken 1, 7 and 14 days after first spraying (DAS). Second spraying was taken 15 days after first spraying.

For the head borer, the pre-treatment larval count was taken a day before treatment on ten randomly selected plants in each treatment and mean larval population was worked out per plant. Spraying was done the next day as per the treatment details given in the table 1 using knapsack sprayer. Post treatment count was recorded 1, 7 and 14 DAS. Second spraying was taken 15 days after first spraying. The grain yield was taken at harvest in all the treatments as kg/plot and later worked out as q/ ha. The data collected was subjected to appropriate statistical analysis done by analysis of variance (ANOVA) using software, Web Agri Stat Package (WASP-2). Finally the B: C ratio was worked out for all the insecticides used for evaluation.

Economic analysis

Based on the yield data, the gross returns and net returns were calculated for each treatment. The benefit cost ratio was determined by calculating the yield, cost of plant protection and total cost of production in each treatment. The gross returns were worked out by taking the selling price of sunflower as Rs.1800/q. The net returns of different treatments were worked out by deducting total cost of production from gross returns. Finally the B: C ratio was worked out by dividing gross returns and total cost of production in each treatment

Cost of cultivation

Treatment wise cost of cultivation was worked out. The prevailing cost of input materials, insecticides and labour cost were considered for computing the cost of cultivation which was expressed in Rs/ha.

Gross return

The price of sunflower seeds prevailing in the market at the time of harvest was used for the calculation of gross return (Rs/ha).

Gross return = Marketable yield x Market price

Net return

Net return (Rs/ha) was calculated by subtracting the cost of cultivation (Rs /ha) from the gross return (Rs/ha).

Net return = Gross return – Cost of cultivation

Benefit cost ratio

Benefit cost ratio was calculated by using the formula:

$$\text{BC ratio} = \frac{\text{Gross returns (Rs/ha)}}{\text{Total cost of production(Rs/ha)}}$$

Table 1. List of insecticides used against lepidopteran pests of sunflower

Tr. No.	Insecticide	Dose (ml/l)	Trade name
T_1	Profenophos 50 EC	2.00	Carina
T_2	Quinalphos 25 EC	2.00	Ekalux
T_3	Flubendiamide 480 SC	0.25	Fame
T_4	Chlorantraniliprole 18.5 SC	0.20	Coragen
T_5	Spinosad 45 SC	0.15	Tracer
T_6	Lufenuron 5.4 EC	2.00	Match
T_7	Indoxacarb 14.5 SC	0.50	Kento
T_8	Chlorpyriphos 20 EC	2.00	Hilban
T_9	Untreated Control	-	-

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Results of the present investigation 'Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower' are presented here.

4.1 Population dynamics of lepidopteran pests of sunflower

Study on the population dynamics of lepidopteran pests of sunflower was carried out during *Kharif* 2017 at UAHS, Shivamogga.

Data recorded in the table 2 indicated that incidence of *Spodoptera litura* commenced from August 15th onwards (Plate 2). Maximum larval population (0.85 larva/plant) was observed on August 25 (rainfall of 49.20 mm, maximum and minimum temperature of 29.08 and 21.86 ˚C, morning and evening relative humidity of 88.50 and 80.20 per cent, sunshine hours of 50.30 were recorded). This clearly shows that its incidence was more during vegetative stage of the crop. Occurance of *S. litura* started to decline after September 4 (0.75 larva/plant) onwards.

Activity of *Thysanoplusia orichalcea* (Plate 3) started from August 15th and reached peak *i.e.,* 2.10 larvae/plant during August 25. Incidence was more during vegetative stage of the crop and it was found to be decreased after September 4 (1.30 larvae/plant) onwards.

Bihar hairy caterpillar, *Spilarctia obliqua* incidence started during August 25th onwards and maximum larval population (2.70 larvae/plant) recorded during October 4 (RF 112.20 mm, max. temperature 30.08 ˚C, min. temperature 21.60˚C, morning RH 89.80 %, evening RH 83.30 % and sunshine hours 34.10) and later on found to be decreased. Also its incidence was absent (zero larva/plant from August 5th to August 15th) during early stage of the crop (Plate 4).

Helicoverpa armigera incidence and population build up started from September 4 onwards. Incidence was peak during flowering stage (Plate 6) *i.e.,* during September 24 (1.50 larvae/plant) (RF of 38.80 mm, max. temperature 29.28 ˚C, min. temperature 20.96˚C, morning RH 86.30 %, evening RH 77.20 % and sunshine hours of 54.00 were recorded). This pest appeared till the harvest of the crop.

Incidence of *Hyposidra* sp. was observed (Plate 5) from August 15th to October 4th. After October 14th its population count was found to be nill (zero larva/plant).

4.1.1 Correlation of lepidopteran pests of sunflower with weather parameters

Form the table 3 it is evident that average number of *Spodoptera litura* larvae/plant showed negative correlation with maximum temperature (r = -0.416) and sunshine hours (r = -0.206). It showed positive correlation with remaining weather

Table 2. Mean larval population of lepidopteran pests of sunflower during different dates of observation

Dates of observation	Mean number of *S. litura* larva/ plant	Mean number of *T. orichalcea* larvae/plant	Mean number of *S. obliqua* larvae/plant	Mean number of *H. armigera* larvae/plant	Mean number of *Hyposidra* sp. larva/plant
Aug-05	0.00	0.00	0.00	0.00	0.00
Aug-15	0.45	1.95	0.00	0.00	0.30
Aug-25	0.85	2.10	0.95	0.00	0.50
Sep-04	0.75	1.30	1.35	0.75	0.60
Sep-14	0.50	0.95	2.00	0.60	0.20
Sep-24	0.40	0.60	1.90	1.50	0.15
Oct-04	0.35	0.40	2.70	0.55	0.10
Oct-14	0.25	0.25	1.90	1.25	0.00
Oct-24	0.10	0.10	1.65	1.05	0.00

Crop growth stages: Vegetative stage-Seedling stage (10-12 days after sowing), Reproductive stage-Bud initiation (30-35 DAS), Flowering (50-55 DAS), Seed development (70-90 DAS).

Plate 2. Larva of *Spodoptera litura*

Plate 3. *Thysanoplusia orichalcea* larva

Plate 4. *Spilarctia obliqua* larva

Plate 5. Larva of *Hyposidra* sp.

Plate 6. *Helicoverpa armigera* larvae feeding on sunflower head

Table 3. Correlataion coefficient of lepidopteran pests of sunflower with abiotic factors

Variables	Meteorological parameters					
	Temp. Max.(^{0}C)	Temp. Min.(^{0}C)	RH-1 (%)	RH-2 (%)	Rainfall (mm)	Sunshine hours
S. litura **larvae**	-0.416	0.375	0.284	0.544	0.332	-0.206
T. orichalcea **larvae**	-0.443	0.314	0.291	0.310	0.106	-0.344
S. obliqua **larvae**	0.334	-0.057	0.332	0.345	0.502	-0.085
H. armigera **larvae**	0.269	-0.362	0.040	-0.022	-0.176	0.239
Hyposidra **sp. larvae**	-0.521	0.289	0.222	0.396	0.164	-0.190

N = 9, * Significant at P = 0.05; Table r value at P = 0.05 is 0.666

parameters such as rainfall (r = 0.332), minimum temperature (r = 0.375), morning and evening relative humidity (r = 0.284 and r = 0.544 respectively).

Average larval population of *Thysanoplusia orichalcea* were having non-significant negative correlation with maximum temperature (r = -0.443) and sunshine hours (r = -0.344). Whereas with other weather parameters like rainfall (r = 0.106), minimum temperature (r = 0.314), morning and evening relative humidity (r = 0.291 and r = 0.310 respectively) it was having positive correlation similar to *Spodoptera litura*.

Mean larval population of hairy caterpillar, *Spilarctia obliqua* per plant was found to be having positive correlation with rainfall (r = 0.502), maximum temperature (r = 0.334), morning and evening relative humidity (r = 0.332 and r = 0.345 respectively) whereas, it had non-significant negative correlation with minimum temperature (r = -0.057) and sunshine hours (r = -0.085).

Average larval population of capitulum borer, *Helicoverpa armigera* per plant was observed to be having non-significant positive correlation with maximum temperature (r = 0.269), morning relative humidity (r = 0.040) and sunshine hours (r = 0.239). It showed negative correlation with other weather parameters like rainfall (r = -0.176), minimum temperature (r = -0.362) and evening relative humidity (r = -0.022).

Mean larval population of *Hyposidra* sp. showed positive correlation with rainfall (r = 0.164), minimum temperature (r = 0.289), morning and evening relative humidity (r = 0.222 and r = 0.396 respectively). It was found to be having negative correlation with maximum temperature (r = -0.521) and sunshine hours (r = -0.190).

4.2 Crop loss estimation due to lepidopteran pests of sunflower

Data from the table 4 clearly indicates that on August 5th, mean number of larvae in all the five treatments was zero. Overall mean larval population taken at ten days interval from August 5th to October 24th indicates that caging method was highly effective which recorded zero larval population followed by chemical + mechanical method (0.58 larva/plant), chemical method (0.71 larva/plant) and mechanical method (1.07 larvae/plant). Untreated control recorded the highest larval population of 2.01 larvae/plant.

Table 4 shows that crop protected through chemical, caging, mechanical, chemical + mechanical methods yielded more compared to the crop left unprotected. Among these treatments, caging method recorded the yield of 24.83 q/ha with zero larval population. The next best treatment was chemical + mechanical method which recorded the yield of 21.83 q/ha with mean larval population of 0.58 larva/plant. It

Table 4. Estimation of crop loss in sunflower due to lepidopteran pests during *Kharif* 2017

Sl.no	Treatment	Average number of larvae/ plant	Yield (kg/plot)	Yield (q/ha)	Per cent yield loss over caging method (%)
1	Chemical method	0.71 (1.30)^{b}	1.25	20.83^{ab}	16.11
2	Caging method	0.00 (1.00)^{c}	1.49	24.83^{a}	0.00
3	Mechanical method	1.07 (1.54)^{b}	1.02	17.00^{b}	31.54
4	Chemical + mechanical method	0.58 (1.27)^{b}	1.31	21.83^{ab}	12.11
5	Untreated Control	2.01 (1.73)^{a}	0.59	9.83^{c}	60.43
	SEm±	0.07	-	2.90	-
	CD (P=0.05)	0.22	-	8.81	-
	CV%	11.44	-	6.92	-

Figures in parentheses are square root transformed values transformed values
Means followed by same letters do not differ significantly by DMRT (P=0.05)

was followed by chemical method which recorded the yield of 20.83 q/ha with mean larval population of 0.71 larva/plant. Mechanical method recorded the mean larval population of 1.07 larvae/plant and yield of 17.00 q/ha. The highest mean larval population of 2.01 larvae/plant and lowest yield of 9.83 q/ha was recorded in untreated control. Yield loss of 12.11 per cent was recorded in chemical + mechanical method over caging method and it was followed by chemical method (16.11 %), mechanical method (31.54 %). Untreated control recorded the yield loss of 60.43 per cent.

4.3 Management of lepidopteran pests of sunflower

4.3.1 Efficacy of different insecticides against Spodoptera litura of sunflower

Results of efficacy of different insecticides against *S. litura* after first and second spray are mentioned in the table 5 and 6 respectively.

4.3.1.1 Efficacy of insecticides against S. litura after first spray

Pre-treatment larval count varied from 0.70 to 0.90 larva/plant one day before spraying. Data in the table shows that one day after spraying profenophos 50 EC was found to be highly effective with the minimum larval count of 0.23 larva/plant and it was noticed to be on par with quinalphos 25 EC with larval count of 0.27 larva/plant. They were followed by flubendiamide 480 SC and chlorantraniliprole 18.5 SC (0.30 and 0.33 larva/plant respectively). Next best treatments were spinosad 45 SC, indoxacarb 14.5 SC and chlorpyriphos 20 EC in which spinosad and indoxacarb were found to be on par with one another (0.43 and 0.47 larva/plant). Lufenuron with larval count of 0.53 larva/plant was noticed to be less effective.

Data recorded on seven days after spraying depicts that all treatments effectively reduced larval population over untreated control. Among these treatments flubendiamide 480 SC was highly effective in reducing the larval population to 0.03 larva/plant which was on par with chlorantraniliprole 18.5 SC recorded the larval count of 0.07 larva/plant. These two treatments were followed by spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. With the maximum larval population of 0.37 larva/plant lufenuron 5.4 EC was found to be least effective.

It is evident from the data that on 14 days after spraying flubendiamide 480 SC was highly effective in reducing the larval population to 0.33 larvae/plant and emerged as best treatment. It was very closely followed by chlorantraniliprole 18.5 SC with the larval population to 0.37 larva/plant. The next best treatments were spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, chlorpyriphos 20 EC and

Table 5. Efficacy of different insecticides against *Spodoptera litura* of sunflower during *Kharif* 2017 (first spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	0.70 (1.09)	0.23 $(0.85)^{c}$	0.17 $(0.82)^{bc}$	0.63 $(1.06)^{bcd}$	0.34	64.92
2	Quinalphos 25 EC	2.00	0.73 (1.11)	0.27 $(0.87)^{bc}$	0.20 $(0.84)^{bc}$	0.67 $(1.08)^{bc}$	0.38	61.05
3	Flubendiamide 480 SC	0.25	0.80 (1.14)	0.30 $(0.89)^{bc}$	0.03 $(0.73)^{c}$	0.33 $(0.91)^{d}$	0.22	77.45
4	Chlorantraniliprole 18.5 SC	0.20	0.83 (1.15)	0.33 $(0.91)^{bc}$	0.07 $(0.76)^{c}$	0.37 $(0.93)^{cd}$	0.26	73.69
5	Spinosad 45 SC	0.15	0.87 (1.17)	0.43 $(0.96)^{bc}$	0.10 $(0.77)^{bc}$	0.40 $(0.95)^{bcd}$	0.31	68.11
6	Lufenuron 5.4 EC	2.00	0.83 (1.15)	0.53 $(1.01)^{b}$	0.37 $(0.93)^{b}$	0.70 $(1.09)^{b}$	0.53	45.44
7	Indoxacarb 14.5 SC	0.50	0.77 (1.12)	0.47 $(0.98)^{bc}$	0.13 $(0.80)^{bc}$	0.43 $(0.96)^{bcd}$	0.34	64.92
8	Chlorpyriphos 20 EC	2.00	0.87 (1.17)	0.50 $(1.00)^{bc}$	0.23 $(0.85)^{bc}$	0.63 $(1.06)^{bcd}$	0.45	53.76
9	Untreated Control	-	0.90 (1.18)	0.90 $(1.18)^{a}$	0.93 $(1.18)^{a}$	1.13 $(1.26)^{a}$	0.97	-
	SEm±	-	NS	0.06	0.05	0.05	-	-
	CD (P=0.05)	-	NS	0.19	0.16	0.16	-	-
	CV%	-	-	8.69	11.01	8.48	-	-

Figures in parentheses are $\sqrt{x} + 0.5$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

quinalphos 25 EC. Maximum larval count of 0.70 larva/plant was recorded in T_6 *i.e.,* lufenuron and it was proved to be less effective.

It is evident from the data that overall mean of larval population on 1, 7 and 14 days after spraying reveals that flubendiamide 480 SC and chlorantraniliprole 18.5 SC emerged as best treatments by recording the larval count of 0.22 and 0.26 larva/plant. Whereas, highest mean larval population of 0.53 larva/plant was recorded in lufenuron 5.4 EC and it was proved to be less effective.

Per cent reduction over untreated control

With maximum reduction over control *i.e.,* 77.45 per cent flubendiamide 480 SC stood as superior treatment and it was reported to be closely followed by chlorantraniliprole 18.5 SC (73.69 % reduction over control).Whereas lufenuron 5.4 EC with 45.44 per cent reduction of larval population over control noticed to be least effective.

4.3.1.2 Efficacy of insecticides against S. litura after second spray

Data from the table 6 reveals that pre-treatment larval count ranged from 0.33 to 1.13 larvae/plant. On one day after spraying profenophos 50 EC reduced larval population to 0.17 larva/plant and found to be superior. It was closely followed by quinalphos 25 EC and chlorantraniliprole 18.5 SC with larval count of 0.20 larva/plant. Among all these treatments maximum larval population was recorded in lufenuron 5.4 EC (0.53 larva/plant).

Data recorded on seven days after spraying indicates that chlorantraniliprole 18.5 SC was highly effective in which lowest number of larval population was recorded *i.e.,* 0.03 larva/plant. It was found to be on par with flubendiamide 480 SC and spinosad 45 SC. The next best treatments were indoxacarb 14.5 SC, quinalphos 25 EC, profenophos 50 EC and chlorpyriphos 20 EC. The Highest larval population of 0.27 larva/plant was recorded in lufenuron 5.4 EC treatment and it was noticed to be less effective. In untreated control larval population of 1.20 larvae/plant was reported.

On 14 days after spraying flubendiamide 480 SC was highly effective with the larval count of 0.13 larva/plant which was on par with chlorantraniliprole 18.5 SC in which larval population was found to be 0.17 larva/plant. Lufenuron 5.4 EC recorded larval population of 0.60 larva/plant and proved to be less effective treatment. In control larval population was increased to 1.30 larvae/plant.

Data on overall mean of larval population from 1, 7 and 14 days after spraying reveals that all treatments used significantly reduced the larval population over the untreated control. However among these treatments chlorantraniliprole 18.5 SC and

Table 6. Efficacy of different insecticides against *Spodoptera litura* of sunflower during *Kharif* 2017 (second spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	0.63 (1.06)^{bcd}	0.17 (0.82)^{d}	0.13 (0.79)^{bc}	0.47 (0.98)^{b}	0.26	78.25
2	Quinalphos 25 EC	2.00	0.67 (1.08)^{bc}	0.20 (0.83)^{cd}	0.10 (0.78)^{bc}	0.50 (1.00)^{b}	0.27	77.50
3	Flubendiamide 480 SC	0.25	0.33 (0.91)^{d}	0.23 (0.85)^{cd}	0.07 (0.75)^{c}	0.13 (0.80)^{c}	0.14	87.85
4	Chlorantraniliprole 18.5 SC	0.20	0.37 (0.93)^{cd}	0.20 (0.84)^{cd}	0.03 (0.73)^{c}	0.17 (0.82)^{c}	0.13	88.79
5	Spinosad 45 SC	0.15	0.40 (0.95)^{bcd}	0.27 (0.87)^{bcd}	0.07 (0.75)^{c}	0.27 (0.88)^{bc}	0.20	82.86
6	Lufenuron 5.4 EC	2.00	0.70 (1.09)^{b}	0.53 (1.00)^{b}	0.27 (0.88)^{b}	0.60 (1.04)^{b}	0.47	60.55
7	Indoxacarb 14.5 SC	0.50	0.43 (0.96)^{bcd}	0.30 (0.89)^{bcd}	0.10 (0.77)^{bc}	0.30 (0.89)^{bc}	0.23	80.32
8	Chlorpyriphos 20 EC	2.00	0.63 (1.06)^{bcd}	0.43 (0.96)^{bc}	0.20 (0.83)^{bc}	0.53 (1.01)^{b}	0.39	67.33
9	Untreated Control	-	1.13 (1.26)^{a}	1.00 (1.22)^{a}	1.20 (1.31)^{a}	1.30 (1.33)^{a}	1.18	-
	SEm±	-	0.05	0.04	0.04	0.05	-	-
	CD (P=0.05)	-	0.16	0.13	0.13	0.16	-	-
	CV%	-	8.48	8.70	7.94	9.72	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

flubendiamide 480 SC with larval population of 0.13 and 0.14 larvae/plant respectively stood as the best treatments than others and with 0.47 larva/plant lufenuron 5.4 EC was found to be least effective treatment.

Per cent reduction over untreated control

With maximum reduction of larval population to 88.79 per cent over control chlorantraniliprole 18.5 SC was noticed to be highly effective and very closely followed by flubendiamide 480 SC with 87.85 per cent reduction of larval population over control. These two insecticides were followed by spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. Lufenuron 5.4 EC with 60.04 per cent reduction over control noticed to be least effective than other treatments. Order of efficacy was chlorantraniliprole 18.5 SC > flubendiamide 480 SC > spinosad 45 SC > indoxacarb 14.5 SC > profenophos 50 EC > quinalphos 25 EC > chlorpyriphos 20 EC > Lufenuron 5.4 EC.

4.3.2 Efficacy of different insecticides against semilooper, Thysanoplusia orichalcea of sunflower

4.3.2.1 Efficacy of insecticides against T. orichalcea after first spray

Data from the table 7 indicates that all the treatments were significantly different and superior from the control in reducing the larval population of semilooper, *Thysanoplusia orichalcea.* The pre-treatment count of larvae ranged from 2.10 to 2.97 larvae/plant and the treatment differences were non-significant. Spraying was taken the next day after pre-treatment count was taken. Data recorded on one day after spraying shows that profenophos 50 EC was found to be superior of all the treatments with the minimum larval population of 1.00 larva/plant. Quinalphos 25 EC was found to be on par with profenophos 50 EC where the larval population was 1.01 per plant. After these two insecticides chlorantraniliprole 18.5 SC and flubendiamide 480 SC were found to be effective in reducing the larval population to 1.30 and 1.33 larvae/plant respectively. Next insecticides in the order of efficacy were spinosad 45 SC, indoxacarb 14.5 SC and chlorpyriphos 20 EC. Lufenuron 5.4 EC was found to be least effective with larval population of 2.10 larvae/plant. In untreated control larval population was found to be 2.97 larvae/plant, which was same as pre-count.

On seven days after spraying, the treatment chlorantraniliprole 18.5 SC was found to be highly effective with minimum larval population density *i.e.,* 0.80 larva/plant which was followed by flubendiamide 480 SC. The next best insecticides were quinalphos 25 EC and profenophos 50 EC which were on par with each other, they were followed by spinosad 45 SC and indoxacarb 14.5 SC. In lufenuron maximum larval population of 1.97 larvae/plant was recorded. In control larval population was raised to 3.07 larvae/plant.

Table 7. Efficacy of different insecticides against semilooper, *Thysanoplusia orichalcea* of sunflower during *Kharif* 2017 (first spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	2.33 (1.66)	1.00 $(1.22)^{d}$	0.97 $(1.21)^{cd}$	2.03 $(1.58)^{b}$	1.33	58.06
2	Quinalphos 25 EC	2.00	2.20 (1.64)	1.01 $(1.23)^{d}$	0.97 $(1.21)^{cd}$	2.00 $(1.58)^{b}$	1.33	58.20
3	Flubendiamide 480 SC	0.25	2.10 (1.61)	1.33 $(1.35)^{cd}$	0.83 $(1.15)^{d}$	1.10 $(1.25)^{c}$	1.09	65.82
4	Chlorantraniliprole 18.5 SC	0.20	2.27 (1.66)	1.30 $(1.34)^{cd}$	0.80 $(1.13)^{d}$	1.07 $(1.25)^{c}$	1.06	66.79
5	Spinosad 45 SC	0.15	2.13 (1.60)	1.50 $(1.41)^{bcd}$	1.00 $(1.22)^{cd}$	1.27 $(1.32)^{bc}$	1.26	60.43
6	Lufenuron 5.4 EC	2.00	2.33 (1.68)	2.10 $(1.60)^{b}$	1.97 $(1.57)^{b}$	2.07 $(1.60)^{b}$	2.05	35.58
7	Indoxacarb 14.5 SC	0.50	2.17 (1.63)	1.60 $(1.45)^{bc}$	1.01 $(1.23)^{cd}$	1.37 $(1.36)^{bc}$	1.33	58.23
8	Chlorpyriphos 20 EC	2.00	2.27 (1.66)	1.97 $(1.57)^{b}$	1.63 $(1.45)^{bc}$	1.97 $(1.57)^{b}$	1.86	41.56
9	Untreated Control	-	2.97 (1.86)	2.97 $(1.86)^{a}$	3.07 $(1.88)^{a}$	3.50 $(2.00)^{a}$	3.18	-
	SEm±	-	NS	0.07	0.09	0.10	-	-
	CD (P=0.05)	-	NS	0.22	0.28	0.31	-	-
	CV%	-	-	8.39	11.25	11.72	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

The data recorded on 14 days after spraying indicated that chlorantraniliprole 18.5 SC was superior and promising insecticide with minimum larval population of 1.07 larvae/plant which was closely followed by flubendiamide 480 SC with 1.10 larvae/plant. The next best treatments were found to be spinosad 45 SC and indoxacarb 14.5 SC which were followed by chlorpyriphos 20 EC, quinalphos 25 EC and profenophos 50 EC. Maximum larval population was recorded in lufenuron 5.4 EC (2.07 larvae/plant) and it was proved to be least effective.

Data from the table 7 clearly indicates that all the treatments effectively reduced larval population over control. Among these treatments, chlorantraniliprole 18.5 SC was noticed to be highly effective with the minimum overall mean larval count of 1.06 larvae/plant and it was closely followed by flubendiamide 480 SC with the larval population of 1.09 larvae/plant. The next best treatment was spinosad 45 SC (0.26 larvae/plant) and it was followed by indoxacarb 14.5 SC and quinalphos 25 EC, profenophos 50 EC and chlorpyriphos 20 EC stand next to above insecticides. T_6 *i.e.*, lufenuron 5.4 EC found to be least effective (2.05 larvae/plant). Mean number of larvae in untreated control was 3.18 larvae/plant.

Per cent reduction over untreated control

With 66.79 per cent reduction over control chlorantraniliprole 18.5 SC was found to be highly effective. It was followed by flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC, quinalphos 25 EC, profenophos 50 EC and chlorpyriphos 20 EC. With 35.58 per cent reduction of larval population over control lufenuron 5.4 EC was noticed to be least effective.

4.3.2.2 Efficacy of insecticides against T. orichalcea after second spray

Larval count which was taken on 14 days after spraying was considered as pre-count for the second spray as in the table 8 and the spraying was carried out the very next day. Data from the table shows that all the treatments which were used here successfully reduced the larval population over control. It also indicates that on one day after spraying, profenophos 50 EC successfully reduced the larval population to the minimum *i.e.*, 0.90 larva/plant and found to be more effective. It was closely followed by quinalphos 25 EC with larval count of 0.93 larva/plant. After these two treatments other best treatments were found to be chlorantraniliprole 18.5 SC, flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC and chlorpyriphos 20 EC. Lufenuron 5.4 EC with maximum larval count 1.93 larvae/plant was observed to be less effective than other insecticides.

On seven days after spraying effectiveness of all insecticides was high. All these significantly reduced the larval population over control. Among all these treatments chlorantraniliprole 18.5 SC was more effective in reducing the larval count to 0.37

Table 8. Efficacy of different insecticides against semilooper, *Thysanoplusia orichalcea* of sunflower during *Kharif* 2017 (second spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	2.03 $(1.58)^{b}$	0.90 $(1.18)^{c}$	0.83 $(1.15)^{cd}$	1.57 $(1.43)^{bc}$	1.10	69.39
2	Quinalphos 25 EC	2.00	2.00 $(1.58)^{b}$	0.93 $(1.19)^{c}$	0.87 $(1.17)^{cd}$	1.60 $(1.45)^{bc}$	1.13	68.49
3	Flubendiamide 480 SC	0.25	1.10 $(1.25)^{c}$	1.03 $(1.24)^{c}$	0.40 $(0.95)^{d}$	0.60 $(1.04)^{d}$	0.68	81.12
4	Chlorantraniliprole 18.5 SC	0.20	1.07 $(1.25)^{c}$	1.00 $(1.22)^{c}$	0.37 $(0.93)^{d}$	0.57 $(1.01)^{d}$	0.65	82.02
5	Spinosad 45 SC	0.15	1.27 $(1.32)^{bc}$	1.17 $(1.28)^{bc}$	0.57 $(1.02)^{cd}$	0.97 $(1.21)^{cd}$	0.90	74.88
6	Lufenuron 5.4 EC	2.00	2.07 $(1.60)^{b}$	1.93 $(1.55)^{b}$	1.60 $(1.44)^{b}$	2.00 $(1.58)^{b}$	1.84	48.75
7	Indoxacarb 14.5 SC	0.50	1.37 $(1.36)^{bc}$	1.20 $(1.29)^{bc}$	0.60 $(1.04)^{cd}$	1.00 $(1.21)^{cd}$	0.93	74.02
8	Chlorpyriphos 20 EC	2.00	1.97 $(1.57)^{b}$	1.53 $(1.41)^{bc}$	1.03 $(1.23)^{bc}$	1.67 $(1.47)^{b}$	1.41	60.70
9	Untreated Control	-	3.50 $(2.00)^{a}$	3.50 $(1.99)^{a}$	3.60 $(2.02)^{a}$	3.70 $(2.05)^{a}$	3.60	-
	SEm±	-	0.10	0.09	0.08	0.08	-	-
	CD (P=0.05)	-	0.31	0.28	0.25	0.25	-	-
	CV%	-	11.72	11.58	11.89	10.61	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

larva/plant. Next best treatment was flubendiamide 480 SC with the larval population of 0.40 larva/plant. Other insecticeds in the order of efficacy were spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. Lufenuron 5.4 EC with the larval count of 1.60 larvae/plant was found to be less effective in reducing the larval population than other insecticides. In untreated control larval count on seven days after spraying increased to 3.60 from 3.50 larvae/plant.

Data from the table 8 shows that on 14 days after spraying all treatments significantly reduced the larval population over control. Chlorantraniliprole 18.5 SC and flubendiamide 480 SC were noticed to be on par with each other with minimum larval count of 0.57 and 0.60 larva/plant respectively. These two treatments were followed by spinosad 45 SC and indoxacarb 14.5 SC which were noticed to be on par with one another. Next best treatments were profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. With the maximum larval population of 2.00 larvae/plant lufenuron 5.4 EC was less effective compared to other insecticides. In control 3.70 larvae/plant on 14 days after spraying.

Data on over all mean of larval count shows that chlorantraniliprole 18.5 SC with larval population of 0.65 larva/plant and flubendiamide 480 SC 0.68 larvae/plant were found to be highly effective. The order of efficacy of insecticides was chlorantraniliprole 18.5 SC > flubendiamide 480 SC > spinosad 45 SC > indoxacarb 14.5 SC > profenophos 50 EC > quinalphos 25 EC > chlorpyriphos 20 EC > lufenuron 5.4 EC. All the treatments significantly reduced larval population over control.

Per cent reduction over control

The best treatment was chlorantraniliprole 18.5 SC with 82.02 per cent reduction of larval population over control was noticed to be followed by flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. Lufenuron 5.4 EC with reduction of larval population to 48.75 per cent over control was found to be least effective.

4.3.3 Efficacy of different insecticides against Bihar hairy caterpillar, Spilarctia obliqua of sunflower

Table 9 and 10 clearly depict the results of efficacy of different insecticides against *Spilarctia obliqua* after first and second spray respectively.

4.3.3.1 Efficacy of insecticides against S. obliqua after first spray

Data recorded from the table 9 reveals that pre-treatment larval count of *Spilarctia obliqua* ranged from 2.53 larvae/plant to 2.93 larvae/plant and there was no

Table 9. Efficacy of different insecticides against Bihar hairy caterpillar, *Spilarctia obliqua* of sunflower during *Kharif* 2017 (first spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	2.70 (1.79)	1.30 $(1.34)^{cd}$	0.77 $(1.13)^{bc}$	1.97 $(1.57)^{bc}$	1.35	50.02
2	Quinalphos 25 EC	2.00	2.73 (1.80)	1.27 $(1.33)^{d}$	0.80 $(1.13)^{bc}$	2.00 $(1.58)^{bc}$	1.36	49.77
3	Flubendiamide 480 SC	0.25	2.80 (1.81)	1.50 $(1.41)^{bcd}$	0.40 $(0.94)^{c}$	1.40 $(1.37)^{c}$	1.10	59.20
4	Chlorantraniliprole 18.5 SC	0.20	2.93 (1.85)	1.47 $(1.40)^{bcd}$	0.37 $(0.92)^{c}$	1.37 $(1.36)^{c}$	1.07	60.31
5	Spinosad 45 SC	0.15	2.77 (1.81)	1.67 $(1.47)^{bcd}$	0.53 $(1.01)^{bc}$	1.60 $(1.44)^{bc}$	1.27	53.07
6	Lufenuron 5.4 EC	2.00	2.87 (1.84)	1.90 $(1.54)^{b}$	1.00 $(1.22)^{b}$	2.07 $(1.60)^{b}$	1.66	38.66
7	Indoxacarb 14.5 SC	0.50	2.57 (1.75)	1.70 $(1.48)^{bcd}$	0.57 $(1.02)^{bc}$	1.63 $(1.46)^{bc}$	1.30	51.87
8	Chlorpyriphos 20 EC	2.00	2.70 (1.79)	1.80 $(1.51)^{bc}$	0.77 $(1.12)^{bc}$	2.00 $(1.58)^{bc}$	1.52	43.56
9	Untreated Control	-	2.53 (1.74)	2.53 $(1.74)^{a}$	2.70 $(1.78)^{a}$	2.87 $(1.82)^{a}$	2.70	-
	SEm±	-	NS	0.06	0.07	0.07	-	-
	CD (P=0.05)	-	NS	0.19	0.22	0.22	-	-
	CV%	-	-	7.40	11.42	8.34	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

Table 10. Efficacy of different insecticides against Bihar hairy caterpillar, *Spilarctia obliqua* of sunflower during *Kharif* 2017 (second spray

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	1.97 $(1.57)^{bc}$	0.60 $(1.04)^{f}$	0.50 $(1.00)^{c}$	1.57 $(1.43)^{bcd}$	0.89	70.21
2	Quinalphos 25 EC	2.00	2.00 $(1.58)^{bc}$	0.63 $(1.06)^{ef}$	0.53 $(1.01)^{bc}$	1.60 $(1.45)^{bcd}$	0.92	69.13
3	Flubendiamide 480 SC	0.25	1.40 $(1.37)^{c}$	0.87 $(1.16)^{cdef}$	0.23 $(0.85)^{c}$	0.57 $(1.03)^{e}$	0.56	81.36
4	Chlorantraniliprole 18.5 SC	0.20	1.37 $(1.36)^{c}$	0.83 $(1.15)^{def}$	0.20 $(0.84)^{c}$	0.53 $(1.00)^{e}$	0.52	82.55
5	Spinosad 45 SC	0.15	1.60 $(1.44)^{bc}$	1.10 $(1.27)^{cde}$	0.33 $(0.91)^{c}$	0.97 $(1.19)^{de}$	0.80	73.15
6	Lufenuron 5.4 EC	2.00	2.07 $(1.60)^{b}$	1.80 $(1.52)^{b}$	0.97 $(1.21)^{b}$	2.00 $(1.58)^{b}$	1.59	46.64
7	Indoxacarb 14.5 SC	0.50	1.63 $(1.46)^{bc}$	1.13 $(1.27)^{cd}$	0.37 $(0.93)^{c}$	1.00 $(1.21)^{cde}$	0.83	72.04
8	Chlorpyriphos 20 EC	2.00	2.00 $(1.58)^{bc}$	1.40 $(1.37)^{bc}$	0.50 $(0.99)^{c}$	1.67 $(1.47)^{bc}$	1.19	60.10
9	Untreated Control	-	2.87 $(1.82)^{a}$	2.87 $(1.82)^{a}$	2.97 $(1.86)^{a}$	3.10 $(1.89)^{a}$	2.98	-
	SEm±	-	0.07	0.07	0.07	0.09	-	-
	CD (P=0.05)	-	0.22	0.22	0.22	0.28	-	-
	CV%	-	8.34	9.74	11.34	11.91	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

significant difference among the treatments. On one day after spraying quinalphos 25 EC with minimum larval count of 1.27 larvae/plant was highly effective and it was closely followed by profenophos 50 EC. After these two treatments, other insecticides in the order of superiority were chlorantraniliprole 18.5 SC, flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC and chlorpyriphos 20 EC. Maximum larval count was recorded in lufenuron 5.4 EC *i.e.,* 1.90 larvae/plant and it was noticed to be least effective treatment.

From the data recorded on seven days after spraying it is evident that chlorantraniliprole 18.5 SC stood as an effective treatment in which larval count of 0.37 larva/plant was registered. It was followed by flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC, chlorpyriphos 20 EC, profenophos 50 EC and quinalphos 25 EC. T_6 *i.e.,* lufenuron 5.4 EC registered maximum number of larval population of 1.00 larva/plant. In control larval population was found to be increased to 2.70 larvae/plant.

On 14 days after spraying, lowest number of larval count 1.37 larvae/plant was registered in the chlorantraniliprole 18.5 SC treatment which was closely followed by flubendiamide 480 SC with 1.40 larvae/plant. Spinosad 45 SC and indoxacarb 14.5 SC with larval population of 1.60 and 1.63 larvae/plant respectively found to be on par with one another also emerged as next best treatments. Lufenuron 5.4 EC was noticed to be least effective with maximum larval population of 2.07 larvae/plant. In control larval population of 2.87 larvae/plant was recorded.

Over all mean of larval population recorded on 1, 7 and 14 days after spraying shows that chlorantraniliprole 18.5 SC emerged as highly effective treatment which registered minimum larval count of 1.07 larvae/plant. Lufenuron 5.4 EC with maximum larval count of 1.66 larvae/plant was noticed to be least effective among rest of the treatments.

Per cent reduction over control

With maximum reduction of larval count over control *i.e.,* 60.31 per cent chlorantraniliprole 18.5 SC stood as a superior treatment whereas, lufenuron with 38.66 per cent reduction over control noticed to be least effective.

4.3.3.2 Efficacy of insecticides against S. obliqua after second spray

Pre-treatment larval count ranged from 1.37 larvae/plant to 2.87 larvae/plant. Data on one day after spraying reveals that all the treatments were significantly superior over untreated control in reducing the larval count. However among these treatments profenophos 50 EC successfully reduced larval population to lowest level *i.e.,* 0.60 larva/plant and it was found to be on par with quinalphos 25 EC (0.63

larva/plant). Chlorantraniliprole 18.5 SC and flubendiamide 480 SC were noticed to be the next best treatments. Lufenuron 5.4 EC recorded 1.80 larvae/plant and found to be was least effective in reducing the larval count compared to other treatments.

On seven days after spraying chlorantraniliprole 18.5 SC emerged as highly effective insecticide with minimum larval count of 0.20 larvae/plant. It was followed by flubendiamide 480 SC, spinosad 45 SC and indoxacarb 14.5 SC. After these treatments profenophos 50 EC and chlorpyriphos 20 EC were found to be effective and both recorded the larval population of 0.50 larva/plant. Quinalphos 25 EC with the larval population of 0.53 larva/plant was found to be on par with profenophos and chlorpyriphos. Lufenuron 5.4 EC which registered highest number of larval population *i.e.,* 0.97 larva/plant was found to be least effective than other treatments in reducing the larval population.

From the data recorded on 14 days after spraying it is evident that lowest larval count of 0.53 larva/plant was noticed in chlorantraniliprole 18.5 SC treatment and it stood as superior of all the treatments. It was followed by flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC and chlorpyriphos 20 EC. Highest number of larval population of 2.00 was reported in lufenuron 5.4 EC and emerged as least effective treatment. In control larval count was increased to 3.10 larvae/plant.

Data on overall mean of larval population from 1, 7 and 14 days after spraying reveals that 0.52 larva/plant was recorded in chlorantraniliprole 18.5 SC and it was noticed to be highly effective. Lufenuron 5.4 EC was found to be least effective (1.59 larvae/plant).

Per cent reduction over control

With maximum reduction of larval population over control *i.e.,* 82.55 per cent chlorantraniliprole 18.5 SC emerged as superior treatment and with 46.64 per cent reduction over control lufenuron 5.4 EC stood as least effective treatment.

4.3.4 Efficacy of different insecticides against capitulum borer, Helicoverpa armigera

Results of efficacy of different insecticides against *Helicoverpa armigera* after first and second spray are in the table 11 and 12 respectively.

4.3.4.1 Efficacy of insecticides against H. armigera after first spray

Pre-treatment larval count of capitulum borer ranged from 0.97 to 1.37 larvae/plant. One day after spraying least larval count of 0.47 larva/plant was reported in quinalphos 25 EC treatment and it was noticed to be more effective in reducing larval population. It was followed by profenophos 50 EC, chlorantraniliprole 18.5 SC,

Table 11. Efficacy of different insecticides against capitulum borer, *Helicoverpa armigera* of sunflower during *Kharif* 2017 (first spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	1.07 (1.25)	0.50 (1.00)[c]	0.33 (0.91)[cd]	0.97 (1.21)[cd]	0.60	59.85
2	Quinalphos 25 EC	2.00	0.97 (1.21)	0.47 (1.98)[c]	0.30 (0.89)[cd]	0.93 (1.19)[cd]	0.57	62.22
3	Flubendiamide 480 SC	0.25	1.10 (1.26)	0.67 (1.08)[bc]	0.13 (0.79)[d]	0.60 (1.04)[d]	0.46	69.04
4	Chlorantraniliprole 18.5 SC	0.20	1.00 (1.23)	0.63 (1.06)[bc]	0.10 (0.77)[d]	0.57 (1.03)[d]	0.43	71.04
5	Spinosad 45 SC	0.15	1.27 (1.33)	0.70 (1.09)[bc]	0.20 (0.83)[cd]	0.67 (1.08)[cd]	0.52	65.04
6	Lufenuron 5.4 EC	2.00	1.13 (1.28)	0.93 (1.20)[b]	0.73 (1.10)[b]	1.10 (1.26)[b]	0.92	38.67
7	Indoxacarb 14.5 SC	0.50	1.17 (1.29)	0.73 (1.11)[bc]	0.23 (0.85)[cd]	0.70 (1.09)[cd]	0.55	63.04
8	Chlorpyriphos 20 EC	2.00	1.03 (1.24)	0.87 (1.17)[b]	0.47 (0.98)[c]	0.97 (1.21)[bc]	0.77	48.67
9	Untreated Control	-	1.37 (1.36)	1.37 (1.36)[a]	1.50 (1.41)[a]	1.63 (1.45)[a]	1.50	-
	SEm±	-	NS	0.05	0.05	0.05	-	-
	CD (P=0.05)	-	NS	0.16	0.16	0.16	-	-
	CV%	-	-	7.83	9.19	8.53	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

Table 12. Efficacy of different insecticides against capitulum borer, *Helicoverpa armigera* of sunflower during *Kharif* 2017 (second spray)

SL. No	Treatment details	Dose (ml /lit)	Mean no. of larvae per plant				Overall mean no. of larvae per plant	Per cent reduction over control
			1DBS	1DAS	7DAS	14DAS		
1	Profenophos 50 EC	2.00	0.97 $(1.21)^{bc}$	0.37 $(0.93)^{cd}$	0.27 $(0.88)^{cd}$	0.83 $(1.15)^{bc}$	0.49	72.59
2	Quinalphos 25 EC	2.00	0.93 $(1.19)^{bcd}$	0.33 $(0.91)^{d}$	0.23 $(0.85)^{cde}$	0.80 $(1.14)^{bc}$	0.45	74.70
3	Flubendiamide 480 SC	0.25	0.60 $(1.04)^{cd}$	0.50 $(0.99)^{cd}$	0.07 $(0.75)^{de}$	0.57 $(1.03)^{bc}$	0.38	78.93
4	Chlorantraniliprole 18.5 SC	0.20	0.57 $(1.03)^{d}$	0.47 $(0.97)^{cd}$	0.03 $(0.73)^{e}$	0.53 $(1.01)^{c}$	0.34	80.92
5	Spinosad 45 SC	0.15	0.70 $(1.09)^{bcd}$	0.60 $(1.05)^{bcd}$	0.13 $(0.79)^{de}$	0.60 $(1.05)^{bc}$	0.44	75.14
6	Lufenuron 5.4 EC	2.00	1.10 $(1.26)^{b}$	0.93 $(1.20)^{b}$	0.77 $(1.13)^{b}$	0.90 $(1.18)^{b}$	0.87	51.40
7	Indoxacarb 14.5 SC	0.50	0.67 $(1.08)^{cd}$	0.57 $(1.03)^{bcd}$	0.10 $(0.77)^{de}$	0.63 $(1.06)^{bc}$	0.43	75.70
8	Chlorpyriphos 20 EC	2.00	0.97 $(1.21)^{bcd}$	0.70 $(1.09)^{bc}$	0.47 $(0.98)^{c}$	0.80 $(1.14)^{bc}$	0.66	63.21
9	Untreated Control	-	1.63 $(1.45)^{a}$	1.63 $(1.45)^{a}$	1.77 $(1.50)^{a}$	1.97 $(1.56)^{a}$	1.79	-
	SEm±	-	0.06	0.06	0.04	0.05	-	-
	CD (P=0.05)	-	0.19	0.19	0.13	0.16	-	-
	CV%	-	8.53	9.50	8.35	8.43	-	-

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBS-Day before spray; DAS-Days after spray;

flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC and chlorpyriphos 20 EC. Lufenuron 5.4 EC treatment recorded highest number of larval population *i.e.,* 0.93 larva/plant and found to be less effective than other treatments.

Data reported on seven days after spraying indicates that chlorantraniliprole 18.5 SC with larval count of 0.10 larva/plant was superior over other treatments and it was closely followed by flubendiamide 480 SC (0.13 larvae/plant). Lufenuron 5.4 EC appeared to be least effective with larval count of 0.73 larva/plant. In untreated control larval count was increased to 1.50 larvae/plant.

On 14 days after spraying lowest larval count was recorded in the treatment chlorantraniliprole 18.5 SC *i.e.,* 0.57 larva/plant. Other best treatments were flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC, quinalphos 25 EC, profenophos 50 EC and chlorpyriphos 20 EC. Lufenuron 5.4 EC was found to be least effective in reducing larval population (1.10 larvae/plant). In control larval count of 1.63 larvae/plant was noticed.

Data on overall mean of larval population reveals that minimum larval count was recorded in treatment chlorantraniliprole 18.5 SC (0.43 larva/plant) and it emerged as the best treatment whereas lufenuron 5.4 EC with 0.92 larva/plant noticed to be less effective treatment. Order of efficacy treatments was chlorantraniliprole 18.5 SC > flubendiamide 480 SC > spinosad 45 SC > indoxacarb 14.5 SC > quinalphos 25 EC > profenophos 50 EC > chlorpyriphos 20 EC > lufenuron 5.4 EC.

Per cent reduction over control

With 71.04 per cent reduction of larval population over untreated control, chlorantraniliprole 18.5 SC was considered to be superior treatment. It was followed by flubendiamide 480 SC (69.04 %) and with 38.67 per cent reduction over control, lufenuron 5.4 EC was found to be least effective treatment.

4.3.4.2 Efficacy of insecticides against H. armigera after second spray

Data from the table 12 clearly shows that all treatments were significantly superior over control in reducing the larval population. Pre-treatment larval count ranged from 0.57 larva/plant to 1.63 larvae/plant. On one day after spraying quinalphos 25 EC successfully reduced larval population to low level *i.e.,* 0.33 larva/plant and found to be highly effective. It was closely followed by profenophos 50 EC. The next best treatments were chlorantraniliprole 18.5 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, spinosad 45 SC and chlorpyriphos 20 EC. Lufenuron 5.4 EC treatment reported maximum number of larval count *i.e.,* 0.93 larva/plant and found to be less effective.

Seven days after spraying chlorantraniliprole 18.5 SC emerged as a superior treatment with larval count of 0.03 larva/plant and it was closely followed by flubendiamide 480 SC. Lufenuron 5.4 EC treatment was noticed to be least effective with maximum larval count of 0.77 larva/plant. In untreated control larval count was noticed to be 1.77 larvae/plant.

Data recorded on 14 days after spraying shows that all treatments significantly superior over control in reducing larval population. Among these insecticides chlorantraniliprole 18.5 SC was highly effective with minimum larval count of 0.53 larva/plant and lufenuron 5.4 EC with 0.90 larva/plant emerged as least effective treatment. Larval population was increased to 1.97 larvae/plant in control.

Overall mean of larval population from 1, 7 and 14 days after spraying depicts that chlorantraniliprole 18.5 SC treatment was the best treatment with lowest larval count (0.34 larva/plant) and lufenuron 5.4 EC (0.87 larva/plant) was least effective treatment in reducing larval population.

Per cent reduction over control

Highest reduction of larval population *i.e.*, 80.92 per cent was observed with chlorantraniliprole 18.5 SC over control and found to be highly effective followed by flubendiamide 480 SC. Next best treatments were noticed to be indoxacarb and spinosad which were on par with each other. Whereas, lufenuron 5.4 EC treatment reported 51.40 per cent reduction over control and considered to be least effective than rest of the treatments.

4.3.5 Yield and cost economics

All the chemical treatments recorded significantly superior seed yield and benefit: cost ratio over untreated control. Among eight different chemical treatments chlorantraniliprole 18.5 SC followed by flubendiamide 480 SC recorded maximum yield of 24.66 q/ha and 24.16 q/ha respectively. Other treatments like spinosad 45 SC, indoxacarb 14.5 SC, profenophos 50 EC, quinalphos 25 EC, chlorpyriphos 20 EC and lufenuron 5.4 EC recorded the yield of 22.33, 21.83, 20.50, 20.16, 20.00 and 16.83 q/ha respectively (Table 13).

Highest benefit cost ratio of 1:3.09 and 1:3.01 were obtained from chlorantraniliprole 18.5 SC and flubendiamide 480 SC which were followed by indoxacarb 14.5 SC (1:2.84), spinosad 45 SC (1:2.82), chlorpyriphos 20 EC (1:2.80), profenophos 50 EC (1:2.79), quinalphos 25 EC (1:2.78) and lufenuron 5.4 EC (1:2.09). Lower yield (12.50 q/ha) and benefit cost ratio (1:1.95) was obtained from untreated control compared to rest of the treatments (Table 13).

Table 13. Cost economics of different insecticides

Sl.no	Treatment	Dosage (ml/lit)	Yield (q/ha)	Cost of production (Rs/ha)	Cost of protection (Rs/ha)	Total cost of production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	C:B ratio
1	Profenophos 50 EC	2.00	20.50^{abc}	11520	1700	13220	36900	23680	1: 2.79
2	Quinalphos 25 EC	2.00	20.16^{bc}	11520	1500	13020	36288	23268	1: 2.78
3	Flubendiamide 480 SC	0.25	24.16^{ab}	11520	2925	14445	43488	29043	1: 3.01
4	Chlorantraniliprole 18.5 SC	0.20	24.66^{a}	11520	2800	14320	44388	30068	1: 3.09
5	Spinosad 45 SC	0.15	22.33^{ab}	11520	2729	14249	40194	25945	1: 2.82
6	Lufenuron 5.4 EC	2.00	16.83^{cd}	11520	2937	14457	30294	15837	1: 2.09
7	Indoxacarb 14.5 SC	0.50	21.83^{ab}	11520	2300	13820	39294	25474	1: 2.84
8	Chlorpyriphos 20 EC	2.00	20.00^{bc}	11520	1300	12820	36000	23180	1: 2.80
9	Untreated Control	-	12.50^{d}	11520	-	11520	22500	10980	1: 1.95

Note: Selling price of sunflower = Rs. 1800/q

Cost of insecticides: 1: Profenophos 50 EC (100 ml)- 90/-, 2: Quinalphos 25 EC (500 ml)- 350/-, 3: Flubendiamide 480 SC (50 ml)- 850/-, 4: Chlorantraniliprole 18.5 SC (10 ml)- 200/-, 5: Spinosad 45 SC (7 ml)- 180/-, 6: Lufenuron 5.4 EC (1 lit)- 2137/-, 7: Indoxacarb 14.5 SC (100 ml)- 600/-, 8: Chlorpyriphos 20 EC (100 ml)- 50/-

Cost of labour: Rs. 200/day, Standard spray volume: 500 lit/ha

DISCUSSION

V DISCUSSION

The results of the experiment entitled 'Population dynamics, crop loss estimation and management of lepidopteran pests of sunflower' are discussed in the following paragraphs

5.1 Population dynamics of lepidopteran pests of sunflower

In the present investigation, *Spodoptera litura*, *Thysanoplusia orichalcea* and *Spilarctia obliqua* were found to be major defoliator pests of sunflower. *Hyposidra* sp. was also noticed to be feeding on the foliage. Whereas, *Helicoverpa armigera* was found to be feeding on sunflower head.

Incidence of *S. litura, T. orichalcea* and *Hyposidra* sp. more during vegetative stage of the crop (August 15). Population of *S. litura* and *T. orichalcea* reached their peak (0.85 and 2.10 larvae/plant respectively) during August 25th, *Hyposidra* sp. reached its peak (0.60 larva/plant) during September 4. Incidence of *Spilarctia obliqua* started during vegetative stage of the crop *i.e.*, August 25th and attained peak during October 4th (2.70 larvae/plant) whereas, incidence of *Helicoverpa armigera* started during reproductive stage of the crop *i.e.*, September 4th onwards and reached its peak (1.05 larvae/plant) during flowering stage of the crop *i.e.*, during September 24th in *Kharif* 2017. This result was more or less similar to the findings of Muzammil (2015) who reported that population of defoliator insect pests like *S. litura, T. orichalcea* and *S. obliqua* was low during seedling stage and increased during vegetative stage and reproductive stage of sunflower crop. Keyhanian (2000) conducted an experiment during spring and reported that *S. litura* was active during 12th March – 29th April, *T. orichalcea* during 5th March – 6th May whereas *H. armigera* was active during 19th March – 10th June *i.e.*, during reproductive phase of sunflower crop. The result of present study clearly shows that as defoliator pests mainly feed on foliage hence their incidence started during vegetative stage of the crop and as *H. armigera* mainly feed on sunflower head their incidence started during reproductive stage of the crop.

In the current study *Spodoptera litura*, *Thysanoplusia orichalcea* and *Hyposidra* sp. showed non-significant negative correlation with maximum temperature and sunshine hours whereas with other parameters like rainfall, minimum temperature, morning and evening relative humidity were found to be having non-significant positive correlation. *Spilarctia obliqua* had non-significant negative correlation with minimum temperature and sunshine hours whereas with remaining weather parameters it was found to be having non-significant positive correlation. *Helicoverpa armigera* was noticed to be having non-significant positive correlation with maximum temperature, morning relative humidity, sunshine hours and negative correlation with rainfall, minimum temperature and evening relative humidity. It was more or less similar to the findings of Basavaraj (2014) in which he reported that *H. armigera* was having negative correlation with all weather parameters and positive correlation with sunshine hours during *Kharif* 2012-13. Results on the correlation of *S. litura* and *T. orichalcea* with weather parameters were in contrary with the results of Keyhanian (2000) as he conducted experiment during *Spring* and reported that *Spodoptera* and *Thysanoplusia* were having positive correlation with maximum temperature and sunshine hours whereas with the rest of weather parameters they were having negative correlation. Results on correlation of *S. obliqua* with weather parameters were almost similar to the findings of Sethi *et al.* (1979) reported that rainfall followed by gradual rise in temperature, under high humidity and longer sunshine provided conducive conditions for population build up of bihar hairy caterpillar in sunflower. Manjunatha (2014) but he reported that *S. obliqua* was having negative correlation with rainfall and maximum temperature in castor.

5.2 Crop loss estimation due lepidopteran pests of sunflower

In the present investigation protected plots *i.e.*, plots incorporated with chemical, caging, chemical+mechanical and mechanical methods recorded higher yield and lowest mean larval population than that of unprotected plot (untreated control) because in untreated control crops were left for the natural infestation by all the lepidopteran pests which resulted in the yield loss of 60.43 per cent whereas in other treatments respective methods were taken from the germination till the harvest of the crop to keep away the lepidopteran pests. The results are in confirmity with Jayewar *et al.*, (2017) who reported that sunflower crop left unprotected recorded significant yield reduction to the extent of 20.29 per cent as compared to crop protected through chemicals and unprotected plot recorded a yield loss of 368 kg/ha. He also reported that mean population of defoliators in protected plot was 0.99 larvae/plant which was significantly less of that 1.90 larvae/plant in unprotected plot. Rajanna (1995) reported that defoliators are injurious to sunflower crop and are economically important. Suja (2003) reported in copwpea during 2000 that the treatment which was incorporated with chlorpyriphos along with mechanical+cultural method recorded less insect pest population and yield of 750 kg/ha whereas, the treatment incorporated with mechanical+cultural method recorded relatively high number insect pest population and recorded the yield of 370 kg/ha and during 2001, chemical method along with mechanical+cultural method recorded the high yield of 785 kg/ha whereas, treatment with mechanical+cultural method recorded the yield of 400 kg/ha. Basavaraju *et al.* (2009) reported that yield data obtained with plant protection against *Spodoptera litura* in potato on an average of 144 q/ha and on an average 132.57 q/ha was obtained without plant protection and per cent yield loss was 7.94 per cent.

5.3 Management of lepidopteran pests of sunflower

In the present study chlorantraniliprole 18.5 SC and flubendiamide 480 SC were highly effective followed by spinosad 45 SC and indoxacarb 14.5 SC in reducing the larval population of *Spodoptera litura, Thysanoplusia orichalcea, Spilarctia obliqua* and *Helicoverpa armigera*.

Superiority of newer insecticides against lepidopteran pests of sunflower in present study is in confirmation Patil *et al.* (2014) who reported that chlorantraniliprole (30 g a.i./ha), methomyl (300 g.ai/ha) and spinosad (75 g a.i./ha) were effective in protecting the soybean crop from the infestation of lepidopteran pests namely, *S. litura* and *Chrysodeixis acuta* and chlorantraniliprole provided consistent protection from defoliators with highest cost benefit ratio (1: 4.02) among the tested insecticides. Also supported by the report of Kumar *et al.* (2017) who found that flubendiamide 480 SC was superior which was followed by indoxacarb 14.5 SC in reducing the black gram pod borer, *H. armigera.* Similar trend was reported by Mishra and Gupta (2017) that flubendiamide 480 SC exhibited its superiority by registering lowest larval population of tobacco caterpillar, *S. litura* and it was followed by indoxacarb 14.5 SC and spinosad 45 SC where chlorpyriphos 20 EC was found to be least effective. Muzammil *et al.* (2017) also reported that chlorantraniliprole 18.5 SC was significantly superior against *S. obliqua* and *T. orichalcea* in recording the lowest larval population and per cent foliage damage over profenophos 50 EC in sunflower and highest cost benefit ratio was recorded in chlorantraniliprole and emamectin benzoate (1: 3.00) followed by flubendiamide (1: 2.92).

Effectiveness of spinosad 45 SC and indoxacarb 14.5 SC in current findings are in agreement with Chandra Shekara *et al.* (2017) who reported that highest reduction of larval population of pod borer, *Helicoverpa armigera* in chick pea was found in spinosad 45 SC (72.12 %) followed by cypermethrin and indoxacarb. It is also supported by Basavaraj (2014) who reported that spinosad was significantly superior against sunflower capitulum borer, *H. armigera* which recorded 100 per cent mortality at 48 HAT and 72 HAT and it was followed by profenophos.

In the present study effectiveness of lufenuron 5.4 EC was found to be least and it is in confirmation with Gadiya *et al.* (2014) who reported that chlorantraniliprole 18.5 SC and spinosad 45 SC showed higher effectiveness whereas, metaflumizone (0.044 %) and lufenuron (0.005 %) were noticed to be poor in checking the incidence of *H. armigera* and *S. litura* infesting ground nut and highest cost benefit ratio 1: 3.3 was observed in chlorantraniliprole (0.006 %) followed by indoxacarb treatment.

From the results of the present investigation it is clear that all the treatments were effective in reducing the larval population of lepidopteran pests of sunflower over untreated control. Especially newer insecticides like chlorantraniliprole 18.5 SC and flubendiamide 480 SC were found to be more promising in managing the lepidopteran pests of sunflower whereas, lufenuron 5.4 EC was found to be least effective due to their different mode of action and efficiency.

Conclusion

- *Spodoptera litura*, *Thysanoplusia orichalcea* and *Spilarctia obliqua* were found to be major defoliator pests of sunflower during *Kharif.*
- Capitulum borer, *Helicoverpa armigera* is also an important pest of sunflower. Its incidence was sever during reproductive stage of the crop and found to be damaging sunflower head.
- Protected plots recorded higher yield and lowest mean larval population than that of unprotected plot (untreated control). Caging method was found to be more effective in avoiding the entry of lepidopteran pests of sunflower which resulted in the higher yield.
- Chlorantraniliprole 18.5 SC and flubendiamide 480 SC were found to be highly effective in managing all the lepidopteran pests of sunflower.

Future line of work

1. Effect of sowing date on the incidence of lepidopteran pests of sunflower during *Kharif* can be worked out
2. Safety evaluation of chemicals against the pollinators should be taken
3. Exploitation of natural enemies against lepidopteran pests of sunflower

SUMMARY

VI SUMMARY

The present investigations were conducted on population dynamics, crop loss estimation and management of lepidopteran pests of sunflower during *Kharif* 2017 on KBSH-53 and the salient features of this experiment are summarized in the subsequent paragraphs.

In the population dynamics effect of weather parameters on the population of *Spodoptera litura, Thysanoplusia orichalcea, Spilarctia obliqua, Hyposidra* sp. and *Helicoverpa armigera* were studied. Results revealed that the incidence of all lepidopteran pests started during vegetative stage of the crop except *H. armigera* whose incidence started during reproductive stage of the crop.

Both *S. litura* and *T. orichalcea* showed negative correlation with maximum temperature and sunshine hours. Whereas they had positive correlation with remaining weather parameters such as rainfall, minimum temperature, morning and evening relative humidity. *S. obliqua* was found to be having positive correlation with rainfall, maximum temperature, morning relative humidity, evening relative humidity and it had non-significant negative correlation with minimum temperature and sunshine hours. *Hyposidra* sp. showed positive correlation with rainfall, minimum temperature, morning and evening relative humidity. It was found to be having negative correlation with maximum temperature and sunshine hours. *H. armigera* was observed to be having non-significant positive correlation with maximum temperature, morning relative humidity, sunshine hours and it showed negative correlation with rainfall, minimum temperature and evening relative humidity.

Study on crop loss estimation revealed that per cent yield loss of 12.11 per cent was recorded in chemical + mechanical method over caging method and it was followed by chemical method (16.11 %), mechanical method (31.54 %). Untreated control recorded the per cent yield loss of 60.43 per cent. Among five treatments caging method recorded the yield of 24.83 q/ha with zero larval population chemical + mechanical method which recorded the yield of 21.83 q/ha with mean larval population of 0.58 larva/plant. It was followed by chemical method which recorded the yield of 20.83 q/ha with mean larval population of 0.71 larva/plant. Whereas mechanical method recorded the mean larval population of 1.07 larvae/plant and yield of 17.00 q/ha. The highest mean larval population (2.01 larvae/plant) and lowest yield (9.83 q/ha) was recorded in untreated control.

Results on efficacy of different insecticides against lepidopteran pests of sunflower clearly indicates that all the treatments were effective in reducing the larval population over untreated control. Among those treatments chlorantraniliprole 18.5 SC and flubendiamide 480 SC recorded the highest C: B ratio of 1: 3.09 and 1: 3.01

respectively, as well as highest yield of 24.66 q/ha and 24.16 q/ha respectively. Chlorantraniliprole and flubendiamide were followed by spinosad 45 SC and indoxacarb 14.5 SC in reducing the larval population of *Spodoptera litura, Thysanoplusia orichalcea, Spilarctia obliqua* and *Helicoverpa armigera*.

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VII REFERENCES

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APPENDIX

VIII APPENDIX

Ten days mean meteorological data for rainfall, maximum temperature, minimum temperature, relative humidity and sunshine hours from August to October 2017 at meteorological observatory, Main Agricultural Research Station CoA, UAHS, Shivamogga

Dates of observation	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sunshine hours
		Maximum	Minimum	RH-1	RH-2	
Aug-05	29.00	30.06	21.82	85.20	73.60	55.80
Aug-15	31.80	29.92	21.70	90.20	76.50	37.40
Aug-25	49.20	29.08	21.86	88.50	80.20	50.30
Sep-04	47.00	29.66	21.88	89.70	80.40	46.30
Sep-14	93.20	32.06	22.76	90.00	75.70	55.00
Sep-24	38.80	29.28	20.96	86.30	77.20	54.00
Oct-04	112.20	30.08	21.60	89.80	83.30	34.10
Oct-14	22.80	31.46	22.14	89.10	81.10	47.50
Oct-24	4.20	31.16	20.02	90.60	68.60	54.10