Biology and management of Bihar hairy caterpillar, *Spilosoma obliqua* Walker on cowpea, *Vigna unguiculata* (Linnaeus) Walpers and its population dynamics on various pulse crops

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Dedicated

To

My Beloved Family,

Friends

&

Respected Guide

Abstract

BIOLOGY AND MANAGEMENT OF BIHAR HAIRY CATERPILLAR, *Spilosoma obliqua* WALKER ON COWPEA, *Vigna unguiculata* (LINNAEUS) WALPERS AND ITS POPULATION DYNAMICS ON VARIOUS PULSE CROPS

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ABSTRACT

Present investigations were carried out on biology and management of Bihar hairy caterpillar, *Spilosoma obliqua* walker on cowpea and its population dynamics on various pulse crops at Anand Agricultural University, Anand during the year 2013-14.

The female laid eggs in masses on lower surface of the upper as well as middle leaves of cowpea. The eggs were greenish in colour and look like seed of grape with flattened base and measured on an average 0.34 ± 0.04 mm in diameter. The mean incubation period was 3.68 ± 0.63 days with the hatching per cent ranged from 78 to 92. Newly hatched larvae feed gregariously on lower surface of leaves by scraping its surface which resulted into papery leaves. Larvae of third, fourth, fifth instars fed the whole leaves except veins and veinlets.

Larva passed through six instars. The freshly hatched first instar larva was creamy whitish with shining brown head and having brown spots over entire body from which white hair arises which later turn black and transparent abdominal segment. Distinct three pairs of prologs were clearly observed. The larva in second instar slightly increased in size having light yellow colour body with brown markings on thoracic and last abdominal segment. Third instar larva was similar to second instar but the colouration of head and body segments were little darker compared to the second instar. The fourth instar larva was uniformly yellowish in colour as the segments were brown and tuft of brownish white hairs arose from reddish brown verrucae and the head turned dark brownish black. The fifth instar larva was dark yellow with reddish tinge in colour and the heads and thoracic shields were dark brown in colour while the legs were reddish brown. The full-grown sixth instar larva had dark black head with brownish legs and uniformly reddish brown body with brownish black verrucae on which there were whitish hairs.

The average duration of first to sixth instar larvae was 3.12 ± 0.78, 3.44 ± 0.51, 3.56 ± 0.51, 2.56 ± 0.51, 3.72 ± 0.46 and 2.72 ± 0.46 days, respectively. The lengths of first to sixth instar larvae were 4.54 ± 0.82, 7.56 ± 1.11, 9.90 ± 0.40, 18.34 ± 0.80, 22.08 ± 1.91 and 26.29 ± 1.14 mm, respectively whereas its breaths were 0.79 ± 0.22, 1.59 ± 0.11, 2.01 ± 0.16, 2.36 ± 0.28, 3.30 ± 0.56 and 5.10 ± 0.56 mm. The widths of the head capsule of respective instars were 0.61 ± 0.11, 1.09 ± 0.25, 1.68 ± 0.19, 2.06 ± 0.14, 2.84 ± 0.13 and 3.71 ± 0.41 mm, respectively. The prepupal period ranged from 2 to 3 days with an average of 2.60± 0.50 days. The average lengths and widths of the pre-pupae were 24.71 ± 1.58 and 4.06 ± 0.32 mm, respectively. The newly formed pupae were soft and green or pale brown in colour.

The average pupal period of male and female were 9.04 ± 0.73 and 9.36 ± 0.49 days, respectively. Average lengths and breadths of male and female pupae were 21.02 ± 1.90 and 5.54 ± 0.43 mm and 22.19 ± 0.84 and 5.73 ± 0.48 mm, respectively.

The adult moths were straw in colour with orange and brown streaks over the forewings, white streaks along the anterior margin and black spots on each abdominal segment. Average longevity of male and female moths were recorded to be 5.00 ± 0.82 and 7.08 ± 0.81 days, respectively. The average pre-oviposition, ovipostion and post ovipositon periods were 2.40 ± 0.50, 5.16 ± 0.85 and 2.84 ± 0.75 days, respectively with, average fecundity of 976.84 ± 194.58 eggs per female.

Study on seasonal abundance of *S. obliqua* on various pulse crops revealed that the pest was active on various crops from 3rd week of July to 4th week of October. The higher activity on cowpea, green gram, black gram and soybean was found during 1st week of August to 2nd week of October. The pest showed significantly positive correlation with bright sunshine hours and maximum temperature and while significantly negative correlation with evening relative humidity.

The study on bio-efficacy of different insecticides in laboratory revealed that significantly maximum larval mortality (81.70 %) was found in treatment thiodicarb 75 WP. Chlorphyriphos 20 EC and fenvalerate 0.4 % DP were found to be next best insecticides. These insecticides also showed same type of effectiveness in the field experiment. Lowest leaf damage and highest yields were also recorded

in the treatment of thiodicarb 75 WP which was followed by fenvalerate 0.4 % DP, chlorphyriphos 20 EC, methomyl 40 SP, novaluron 10 EC, quinalphos 25 EC and emamectin benzoate 5 SG, respectively.

The data on economics showed that maximum NICBR was obtained in the treatment of chlorpyriphos 20 EC which was followed by fenvalerate 0.4 % DP, thiodicarb 75 WP, quinalphos 25 EC, methomyl 40 SP and novaluron 10 EC.

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AAU
कृण्वन्तो राष्ट्रं कृषि संपन्नम्

CERTIFICATE

This is to certify that the thesis entitled **Biology and management of Bihar hairy caterpillar, *Spilosoma obliqua* Walker on cowpea, *Vigna unguiculata* (Linnaeus) Walpers and its population dynamics on various pulse crops** submitted by **Desai Vimal Haribhai (Reg. No. 04-1852-2012)** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agricultural Entomology** of the Anand Agricultural University, Anand is a record of bonafide research work carried out by him under my guidance and supervision. The thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand
Date: 04/04/**2015**

(C. C. Patel)
Major Guide

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DECLARATION

This is to certify that whole of the research work reported in the thesis in partial fulfillment of the requirement for the award of the degree of **Master of Science** in Agriculture in the subject of **Agricultural Entomology** is the result of investigation done by undersigned under the direct guidance and supervision of **Dr. C. C. Patel, Research scientist, Department of Agricultural Entomology**, **B. A. College of Agriculture, Anand Agricultural University, Anand** and no part of the research work has been submitted for any other degree so far.

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In most of mankind gratitude is merely a secret hope for great favors
Life is not so short but that there is always time enough for courtesy

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Place: Anand

Date: 04/04/2015

(Vimal Desai)

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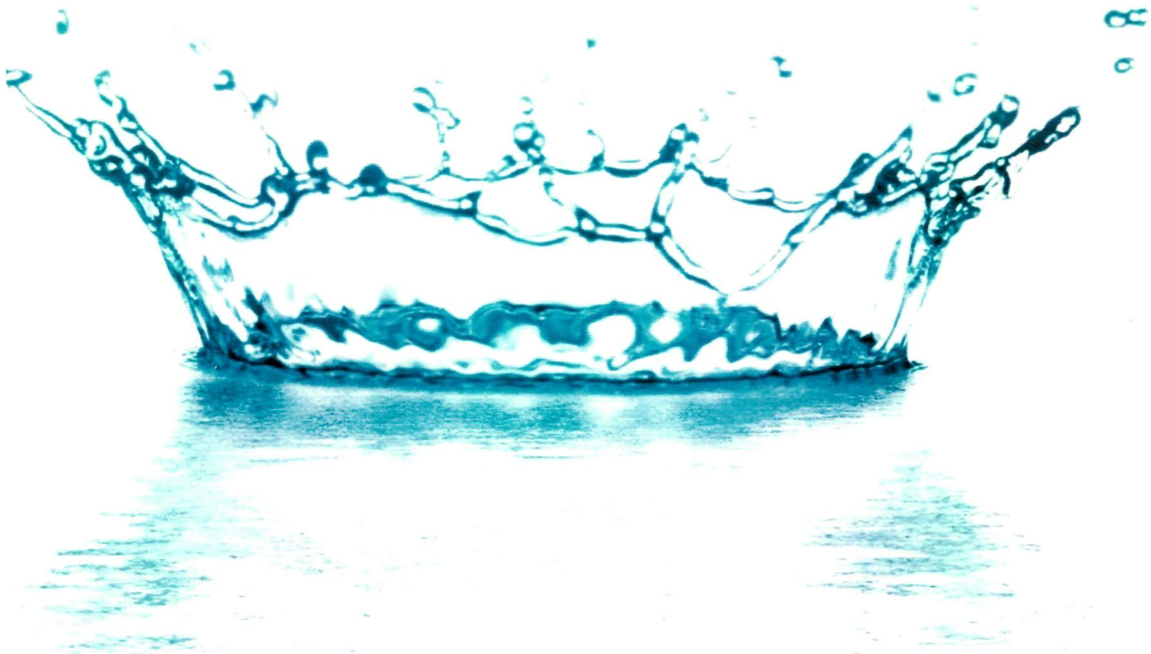
LIST OF ABBREVIATIONS

Anon.	:	Anonymous
@	:	At the rate of
Fig.	:	Figure
^{0}C	:	Degree Celsius
viz.,	:	Namely
%	:	Per cent
et al.	:	*Et allii*; and others
etc.	:	Etcetera
=	:	Equal to
>	:	Greater than
<	:	Less than
ha	:	Hectare
i. e.	:	That is
mg	:	Milligram
g	:	Gram
q/ha	:	quintal per hectare
m	:	Meter
ml	:	Milliliter
mm	:	Millimeter
Cm	:	Centimeter
l	:	Litre
NS	:	Non significant
₹	:	Rupees
SD	:	Standard Deviation
C. V.	:	Coefficient of Variance
C. D.	:	Critical Difference
S. Em. ±	:	Standard Error of mean
a. i.	:	Active Ingredient
SL	:	Soluble Liquid
SC	:	Soluble concentrate
WG	:	Wettable Granules
EC	:	Emulsifiable Concentrate
WP	:	Wettable Powder
DP	:	Dust Powder
DAS	:	Day after spray

Introduction



INTRODUCTION

Pulse crops play an important role in Indian agriculture. Besides being rich in proteins, it enhance the productivity of succeeding crops. The bacteria on roots of plant fix the atmospheric nitrogen through biological nitrogen fixation (BNF) is economically sound and environmentally acceptable. Cowpea, *Vigna unguiculata* (Linnaeus) Walpers [Syn. *Vigna sinensis* (Linnaeus)] is one of the important pulse crops grown in different parts of our country. It constitutes the cheapest source of dietary protein for most of poor people and provides good quality nutritious fodder for cattle. Cowpea belongs to family Fabaceae / Papilionaceae and sub family Fobaidae / Papilionoidae. It is also known as black eyed bean or Southern pea in English while *chola* or *choli, chavli,lobia* in various vernacular languages in India.

Cowpea is considered as most versatile *kharif* pulse crop because it has draught tolerant characters, soil restoring properties and multipurpose uses. It is also considered as vegetable meat due to high amount of proteins. Cowpea grain contains about 60% carbohydrates, 22 to 28% proteins and 1.8% fat. Moreover, it is a rich source of calcium and iron (Sharma, 2000). It is also grown for green manuring to improve soil fertility. It contains 54 kg N/ha in tops and 49 kg N/ha in roots. The nutritious value of cowpea as a fodder crop is high and quite comparable to lucerne.

The area, production and productivity of pulses in India are 25.6 million ha, 14.8 million tonnes and 608 kg/ha, respectively (Swaminathan, 2000). It is mainly grown in the states of Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala, Uttar Pradesh, Haryana, Delhi and Panjab. In Gujarat, cowpea asgreen vegetable is cultivated in about 27,627 ha with an annual production of 2, 89,907 tonnes and average productivity of 10.49 tonnes/ha (Anonymous, 2011). It is cultivated in Anand districtin an area of 1,300ha with annual production of 12,064 MT and productivity of 9.3 MT/ha.

Among the various constraints responsible for low yield of cowpea, insect pests are considered to be one of the most important constraints. The crop is ravaged by many insect pests at different stages of its growth. The avoidable losses in yield due to insect pests have been recorded in the range of 66 to 100 per cent (Pandey *et al.,* 1991). As many as 21 insect pests of different groups have been observed damaging from germination to maturity of the crop.

Among different insect pests recorded damaging the cowpea crop from germination to maturity, important insect species attacking cowpea crop are aphid, *Aphis craccivora* Koch. (Hemiptera: Aphididae), leafhopper, *Empoasca kerri* Pruthi (Hemiptera : Cicadellidae), thrips, *Megaleurothrips distalis* Karny, *Megaleurothrips sjostedi* Trybom and *Megaleurothrips usitatus* Bangnall (Thysanopterà : Thripidae), whitefly, *Bemisia tabaci*, Gennadius (Hemiptera: Aleyrodidae), leafminer, *Acrocercops caerulea* Meyrick

(Lepidoptera: Gracillanidae), spotted pod borer, *Maruca vitrata* (Fabricius), tobacco leaf eating caterpillar *Spodopetera litura* Fabricius (Lepidoptera: Noctuidae), blue butterfly, *Euchrysops cnejus* (Lepidoptera : Lycaenidae) and Bihar hairy caterpillar, *Spilosomaobliqua* Walker (Lepidoptera: Noctuidae). Among these Bihar hairy caterpillar,*S.obliqua*has been damaging the crop severely since last three years.

Bihar hairy caterpillar, *S. obliqua* is sporadic in nature and voracious feeder. As it is feeding on variety of plants,(*viz.*, pulses, oil seeds, cash crops, and many vegetables) it has assumed a status of the "polyphagous pest". It is reported as a severe pest of important crops including sweet potato, potato, cole crops, cowpea, garden pea, beans, raddish, yam, black gram, sesame and mustard (Nair, 1970; Butani and Jotwani, 1984; Gupta, 1990; David, 2001; Mandal *et al.*, 2013 and Biswas *et al.*, 2000).Damage due to *S. obliqua* in sesame crop varied from 80 to 90 per cent in Punjab (Dhaliwal,1997).

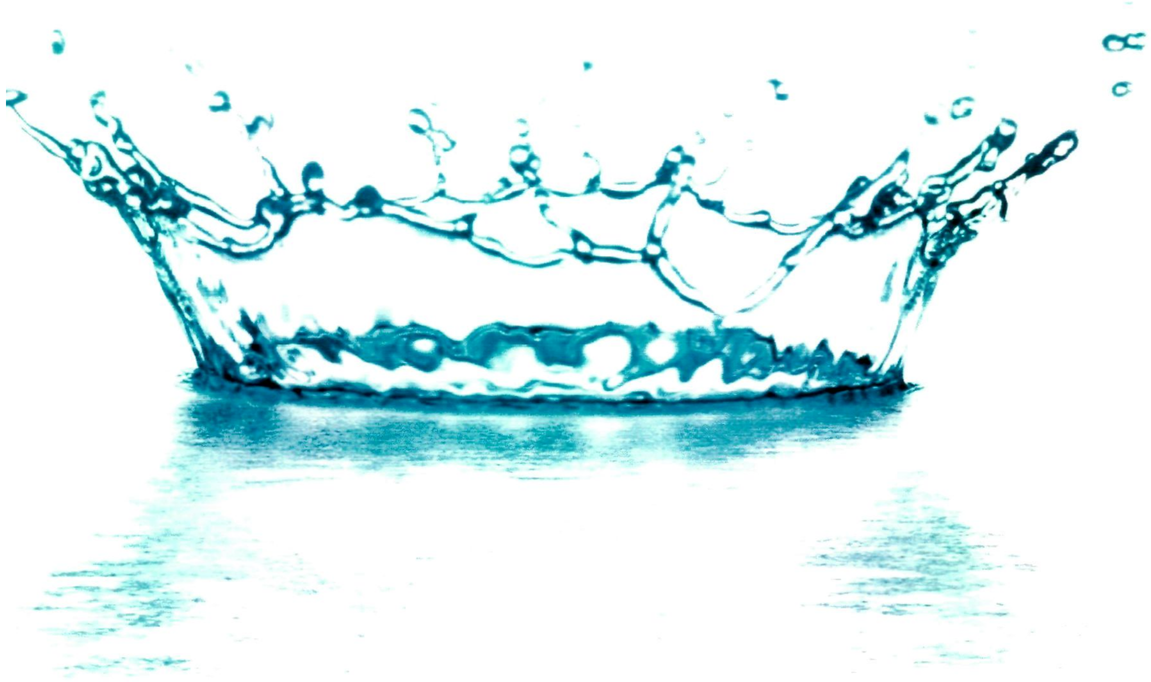
Information regarding biology, population dynamics and chemical control of pests in short duration crops like cowpea is very very useful to the farmers for suppressing the pest population. The basic information on biology of any insect pest is necessary before deciding the strategy to combat the pest. Information on population dynamics is useful for selecting insecticides, as well as proper time and site of application of insecticides.

It also gives an important set of data for deciding integrated pest management strategies. Population dynamics of *S. obliqua*has been studied by Thakur and Kaistha (1994). Chemical insecticides are only alternative that works as frontline defense sources to combat the problem of any insect pest in any crop. New insecticides with different mode of actions available in the market are needed to evaluate for their efficacy against this new pest, *S. obliqua*.

Since last three years, the cowpea crop is severely affected by Bihar hairy caterpillar regularly during *kharif* season (July to September) but no research work has been done on this new pest particularly in cowpea crop. Therefore, to fill up the lacunae and to generate the data, present investigations were carried out with following objectives:

1) To study the biology of *S. obliqua* on cowpea
2) To study the population dynamics of *S. obliqua* on various pulse crops
3) To study the bio-efficacy of different synthetic insecticides against *S. obliqua* on cowpea

Review of Literature



II. REVIEW OF LITERATURE

Cowpea is an important pulse crop cultivated more profitably in Gujarat state. Area under this crop is increasing year by year due to high demand and its remunerative price. Among different factors responsible for lower production of cowpea, insect pests are one of the important factors. Of these, Bihar hairy caterpillar, *Spilosoma obliqua* Walker is a serious pest causing considerable damage to the crop. It is polyphagous in habit, feeds on various hosts and causing appreciable yield losses.

From available source of literature, it is revealed that the work pertaining to biology and bio-efficacy of insecticides against Bihar hairy caterpillar infesting cowpea and its population dynamics on various pulse crops is meager. Hence, an attempt was made to review the available literature for different species of hairy caterpillar on cowpea as well as on the other host crops having direct or indirect relation with different aspects of present investigations and are presented here under different headings.

2.1 Biology and morphometry of Bihar hairy caterpillar, *S. obliqua*

The literature on the biology and morphometry of *S. obliqua* are scanty and therefore, the research work done on other species of hairy caterpillar is also reviewed and presented hereunder.

2.1.1 Egg:

Female of Gujarat hairy caterpillar, *Amsacta moorei* Butler can lay hundreds of eggs in its life. According to Dhamdhere (1988), one female of *A. moorei* laid 600-700 eggs and the incubation was found to be 4-5 days while as per the report of Singh *et al.* (1989) the pest could lay 2,300 eggs/female.

Singh and Singh (1990) studied biology of *A. moorei* on soybean in Madhya Pradesh and found that a single female laid 445-1407 eggs on lower surface of the leaves and the incubation period was 4.4 ± 0.82 days. It was also found that the diameter of egg was 0.73 ± 0.13 mm and the eggs were spherical and creamy in colour and changed to ash colour before hatching.

Ahlawat *et al.* (1993) studied the biology of *A. moorei* on cotton and found that about 92 per cent of eggs were laid within the first 3 days after the start of egg laying. They also observed that the female laid 90-805 eggs (average 435.6 eggs) during its life time.

Singh and Singh (1995) studied the biology of Bihar hairy caterpillar, *S. obliqua* on sunflower. The data revealed that female moth laid 1089 eggs in March while 1849 eggs in November and the incubation period was found to be 3-12 days with 83.5 to 99.33 per cent hatchability. They also recorded egg diameter of 0.57 mm. The incubation period was found to be 5.60 days on groundnut (Nath and Singh, 1996).

Ganiger and Sannaveerappanavar (2007) studied the field biology of red hairy caterpillar, *A. albistriga* on groundnut in Karnataka and reported that the egg laying capacity of single female was 262 to 1103 eggs (average 589.70 eggs) with incubation period of 3.2 days.

Debaraj and Singh (2010) studied the seasonal biology of Bihar hairy caterpillar, *S. obliqua* on castor at RSRS, Mendipathar in Meghalaya and recorded incubation period of 6.5 to 10.5 days. It was also found that the incubation period was shortest in October-November while longest in December-January.

2.1.2 Larvae:

Nayar *et al.* (1983) reported that the larval period of *A. moorei* was 40-50 days. Kishore (1987) studied the biology of *A. moorei* and found total larval period of 21- 23 days.

Singh and Singh (1990) reported that first, second, third and fourth instars of *A. moorei* lasted for 7.20 ± 0.78, 5.30 ± 0.48, 4.50 ± 0.51 and 4.95 ± 0.99 days respectively with total larval period of 21.95 ± 2.76 days. It was also found that the body length and width of first, second, third and fourth instar larvae were 2.21 ± 0.09 and 0.38 ± 0.04, 12.40 ± 1.65 and 0.78 ± 0.07, 23.5 ± 1.15 and 1.68 ± 0.25, 38.10 ± 3.09 and 3.20 ± 0.25 mm respectively. As per the findings of Alhawat *et al.* (1993) total larval period of *A. moorei* on cotton lasted for 18.4 days.

Singh and Singh (1995) studied the biology of Bihar hairy caterpillar, *S. obliqua* on sunflower and reported total larval period of 17.50 days. The larval period was found to be 24.72 days in case of Bihar hairy caterpillar, *S. obliqua* on groundnut in Nath and Singh, (1996).

Ganiger and Sannaveerappanavar (2007) studied the field biology of *A. albistriga* in Karnataka and reported that larval period was 32-45 days.

Debaraj and Singh (2010) who found that larval period and total life cycle of *S. obliqua* on castor was 24 to 48 and 39.6 to 70 days, respectively.

2.1.3 Pupa:

Singh and Singh (1990) studied biology of *A. moorei* on soybean and found that the full grown larvae entered the prepupal period which was lasted for 1.50 ± 0.45 days and pupal period was found to be 10.8 ± 1.64 days and also found that the pupa of *A. moorei* with cocoon measured 29.9 ± 5.50 mm in length, 16.3 ± 3.0 mm in width while, without cocoon 18.0 ± 2.0 mm in length, 7.0 ± 1.9 mm in width. According to Alhawat *et al.* (1993) pre-pupal and pupal period of *A. moorei* lasted for 1.8 and 6.8 days.

Singh and Singh (1995) studied the biology of Bihar hairy caterpillar, *S. obliqua* on sunflower and reported that pupal period was 10.25 days. The prepupal and pupal period of the pest were found to be 1.76 and 11.46 days on groundnut in Nath and Singh, (1996)

Ganiger and Sannaveerappanavar (2007) studied the field biology of *A. albistriga* in Karnataka and noted that pupal period was found to be 15-26 days.

2.1.4 Adult:

Singh and Singh (1990) found that preoviposition, oviposition and post-oviposition periods of *A. moorei* were 3.3 ± 1.59, 5.90 ± 1.22 and 2.50 ± 0.45 days, respectively and also found that the sex ratio of males to females was 1: 1.6. Alhawat *et al.* (1993) studied biology of *A. moorei* on cotton and found that average pre-oviposition, oviposition and post-oviposition periods were 1.60, 2.5 and 2.0 days, respectively.

Singh and Singh (1995) studied the biology of Bihar hairy caterpillar, *S. obliqua* on sunflower and found that average pre-oviposition, oviposition and post-oviposition periods were 2.14, 2.44 and 1.75 days, respectively and also reported average generation period of 37.50 days. The total life cycle was found to be of 53.06 days on groundnut (Nath and Singh, 1996)

Ganiger and Sannaveerappanavar (2007) studied the field biology of *A. albistriga* in Karnataka and found that adult male, adult female, oviposition and post oviposition periods were 6.75, 5.35, 2.55 and 1.55 days, respectively. Further, they observed the fecundity of the pest and found that it was in the range of 262-1103 (mean of 589.70) eggs /7.6 egg masses.

The biology of Bihar hairy caterpillar, *Spilarctia obliqua* Walker infesting castor was studied in different seasons at Mendipathar in Meghalaya. The biological parameters like larval and pupal periods, total life cycle, fecundity, hatchability, incubation period and adult longevity were recorded during four seasons, *viz.* March-April, June-July, October-November and December-January.

Results revealed that shortest incubation period of 6.5-10.5 days was found in October-November and longest in December-January. There was no any effect of season on the hatchability of the eggs. The larval period was found to be 24 (June-July) to 44 days (December-January). Similarly, the total life cycle (egg to adult) was completed in 39.6 days in June - July and it was prolonged up to 70 days during December-January (Debaraj and Singh, 2010).

2.2 Population dynamics of Bihar hairy caterpillar, *S. obliqua*

Influence of various abiotic factors on the incidence of *S. obliqua* on different cultivated crops has been studied by some workers and tried to find out correlation among them. Among the various abiotic factors, temperature, humidity, sunshine and rainfall are the most prominent components which appear to have profound effect on the development, population, multiplication and survival of insects. No any research work on population dynamics of *S. obliqua* infesting various pulse crops is found in available literature. Hence, an attempt was made to review the research work done by earlier workers on the impact of meteorological factors on population fluctuation of *S. obliqua* and other hairy caterpillars attacking different field crops and presented hereunder.

Kulshrestha and Diwakar (1987) reported that the incidence of *A. moorei* was found on sunnhemp, castor, maize, cotton and soybean in Gujarat. Adult emergence coincided with the seedling stage in *kharif* crops during the last week of June. Hatching and development of larvae occurred in July. Larvae reached to later instar within 2-3 weeks and completely defoliated the crop. Sunnhemp was the most preferred crop. Intermittent showers in July and sandy soil conditions favoured rapid development of the pest, while heavy and continuous rainfall was unfavourable for its development.

Udai *et al.* (1989) carried out a survey in Uttar Pradesh and reported that larvae of *A. moorei* were found infesting to *Eclipta alba* and *Euphorbia hirta* which were found on bunds of fields. Thakur and Kaistha (1994) observed that *S. obliqua* appeared in the sesame crop from the second week of August to third week September at vegetative to pod maturity stage and the peak infestation (3 larvae/ plant) occurred during last week of August in Himachal Pradesh.

Study conducted by Saini and Ram (2000) on *A. moorei* indicated that about three-fourth moth population of a generation emerged during the same year while the remaining one-fourth remained in soil up to monsoon of next year.

2.2.1 Correlation with weather parameters:

Saini and Ram (2000) studied emergence of *A. moorei* in relation to weather parameters and concluded that after hot summer, emergence of moths started during August when temperature decreased to 29°C and relative humidity increased to 80% and as temperature started increasing (above 31°C) and relative humidity decreasing (below 58%), there was no subsequent moth emergence during August, 1993.

Reddy *et al.* (2004) studied influence of environmental factors on *A. albustriga* larvae and revealed that the rainfall intensity was a limiting factor for moth emergence. So Temperature and relative humidity were the two factors complementing the effect of rainfall on moth emergence. Temperature around 30 °C and 70% RH were congenial for the emergence of moths which activated prior by soaking rain.

2.3 Bio-efficacy of different insecticides against Bihar hairy caterpillar, *S. obliqua* on cowpea in laboratory and field trial

Synthetic insecticides are widely used in most developing countries to control insect pests of food crops. These are the soul alternative to get immediate control against pest. In the light of present studies, the available literature on efficacy of different insecticides used for the control of *S. obliqua* on cowpea have been reviewed here under.

2.3.1 Laboratory trial

Verma *et al.* (1973) studied different insecticides against *A. moorei* on cotton crop at Hissar, Haryana under laboratory as well as in field conditions. They found that trichlorphon, monocrotophos, chlorfenvinphos and methyl-parathion gave effective control of the pest.

Tandi *et al.* (1993) carried out an experiment to test the efficacy of some insecticides against *A. moorei* under laboratory as well as in the guar field in Rajasthan. They found that all treatments were effective as they gave 100 per cent mortality of first instar larvae after

12 h of feeding and after 24 h feeding by 2nd and 3rd instar larvae. Among the different insecticides, chlorpyrifos was found the most effective treatment against 4th and 5th instar larvae of *A. moorei.*

Saini (1995) evaluated the toxicity of different insecticides (endosulfan, monocrotophos, chlorpyrifos, quinalphos, triazophos, alphamethrin, cypermethrin and deltamethrin) against 6th instar larvae of *A. moorei* in the laboratory. Quinalphos 0.05 %, monocrotophos 0.05% and triazophos 0.06% exhibited good contact and oral toxicity, while chlorpyrifos 0.05% had good contact toxicity but poor oral toxicity.

Field and laboratory experiments were carried out in Punjab to determine the effectiveness of endosulfan, carbaryl, fenitrothion, monocrotophos, quinalphos, phosalone and phenthoate against fourth- and fifth-instar larvae of *A. moorei* on cotton. The order of effectiveness of the compounds was monocrotophos > phenthoate > quinalphos > endosulfan > fenitrothion > carbaryl > phosalone (Verma, 1980).

Nair *et al.* (2007) evaluated various insecticides against *S. obliqua* under laboratory conditions and found that efficacy of insecticides tested was in descending order of toxicity as: emamectin benzoate 5 SG (0.00005), cypermethrin 10 AF (0.00013), indoxacarb 14.5 SC (0.00053), endosulfan 35 EC (0.00323), fenvalerate 20 EC (0.00340) and fenpropathrin 30 EC (0.00513).

2.3.2 Field trial

Jat and Sharma (1989) determined the effectiveness of several insecticides against 3rd and 5th instar larvae of *A. moorei* on cowpea in Rajasthan. Against 3rd instar larvae, cypermethrin 0.02 per cent was the most effective compound, giving 95 per cent mortality after 72 h of application followed by 0.2 per cent carbaryl (90 % mortality) and 0.03 per cent monocrotophos (80 % mortality). Cypermethrin and carbaryl were also the most effective against 5th instar larvae by registering 70 and 65 per cent mortality.

As per the report of Verma (1980), all the tested insecticides were found highly effectiveness against *A. moorei* infesting pearl millet and the order of effectiveness of the insecticides was: parathion (Methyl parathion), dichlorvos (DDVP), quinalphos > fenitrothion > parathion-methyl (methyl parathion).

Field studies were conducted in Haryana to compare the effectiveness of 5 synthetic pyrethroids and 2 organophosphorus insecticides against the arctiid *A. moorei* on cotton. The organophosphorus insecticides monocrotophos 0.04 per cent and quinalphos 0.05 per cent caused 100 per cent mortality of 6th instar larvae after 24 h of the treatment. Fluvalinate, cypermethrin, fenvalerate and flucythrinate, all at 0.008 per cent, and deltamethrin at 0.002 per cent, registered 14.7, 28.2, 39.6, 41.7 and 44.4 % mortality, respectively after 24 h of application, and 62.7, 79.8, 87.5, 80.8 and 79.6% after 72 h of application (Khurana and Verma, 1987).

As per the report of Veda and Shaw (1992), 1.5 per cent quinalphos dust at 25 kg/ha was very effective but was expensive in comparison to fenvalerate (Sumicidin and Fenval) at 0.01 per cent, which were the next most effective treatments among different insecticides tested for the control of *A. moorei* on deshi maize in Madhya Pradesh.

Kadapatti *et al.* (1996) evaluated 10 insecticidal formulations against *S. obliqua* in field conditions on sunflower and concluded that fenvalerate spray (0.01 %), dust (0.04 %) and dichlorovos (0.076 %) spray proved to be better against larvae till 5 days after spray. They also found that second instar larvae were more susceptible to insecticides than fourth instar larvae.

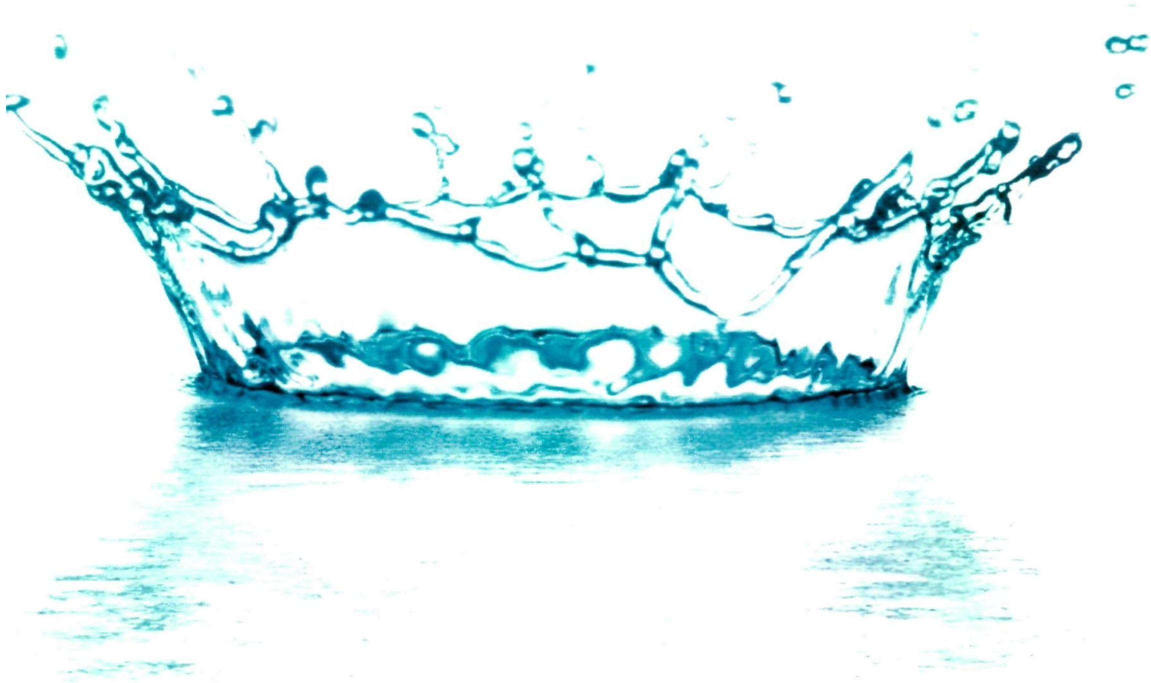
Manjula (2003) tested the efficacy of quinalphos and methyl parathion against second and third instar of the red hairy caterpillar, *A. albistriga* on groundnut in Andhra Pradesh and found 95.45 and 85.75 per cent larval mortality in the treatment of quinalphos 0.05 per cent and methyl parathion at 25 kg/ha.

Manjula (2004) tested the efficacy of some commonly used insecticides by mixing in baits against later instar larvae of red hairy caterpillar, *A. albistriga* in Andhra Pradesh. The insecticides used were monocrotophos, chlorpyrifos, quinalphos, methomyl, thiodicarb and carbaryl. Chlorpyrifos was found to be superior by registering highest larval mortality.

Ganiger and Sannaveerappanavar (2007) evaluated different dust and liquid formulations of insecticides against red hairy caterpillar, *A. albistriga* in Karnataka. In case of dust formulation, fenvalerate 0.4 D was found the most effective insecticide followed by malathion 5 D and methyl parathion 2 D (all @ 25 kg /ha); while among the liquid sprays; fenvalerate 20 EC (150 g a.i/ha), quinalphos 25 EC (375 g a.i/ha) and monocrotophos 36 SL (360 g a.i/ha) were found effective followed by methomyl 40 SP, dipel 8 L (*B. thuringiensis*) and carbaryl 50 WP insecticides.

Mandal *et al.* (2013) evaluated insecticidal formulations against *S. obliqua* in field conditions in blackgram and concluded that the order of efficacy in respect to per cent larval reduction was trizophos (90.64%) > *e*-cyhalothrin (83.71) > indoxacarb (78.76%) > endosulfan (69.53%) > imidacloprid (62.31%) > thiamethoxam (57.40%).

Material and Methods



III. MATERIALS AND METHODS

Present investigations on biology and management of Bihar hairy caterpillar, *Spilosoma obliqua* Walker on cowpea, *Vigna unguiculata* (Linnaeus) Walpers and its population dynamics on various pulse crops were carried out at farm of department of entomology, B. A. college of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif,* 2013-14. The materials used and methodology adopted during these studies are describe here in this chapter.

3.1 Biology of *S. obliqua*

In order to study the Biology of *S. obliqua* on cowpea, an experiment was conducted at department of entomology, B. A. College of Agriculture, AAU, Anand during *kharif* season of the year 2013-14.

3.1.1 Rearing techniques

The larvae of *S. obliqua* were collected from the unsprayed cowpea crop grown at Agronomy Farm, B.A. college of Agriculture, AAU, Anand. The collected larvae were brought to the laboratory and reared in round rearing cage containing moist soil. The larvae were fed fresh and tender leaves of cowpea variety AVCP-1(Anand Vegetable Cowpea-1). The leaves were changed every day morning to provide fresh food and maintain sanitation. After pupation of larvae in the soil, the pupae were collected and put in petridis. The male and female pupae after determining the sex were kept in separate acrylic cages (30 × 30 × 30 cm) for emergence of adult. Male and female adults emerged out from pupae were collected with the help of plastic tube and again released in separate acrylic rearing cage for egg laying. The potted AVCP-1 cowpea variety plants were placed inside the cage for egg laying. Absorbent pieces of cotton dipped in 5 per cent honey solution were kept in cage as food for the adults. The leaves with freshly laid eggs were examined under stereoscopic microscope and the eggs were used to study the biology of the pest.

3.1.2 Eggs

In order to determine the hatching per cent and incubation period, the eggs laid on leaves of cowpea were counted and put in glass petridish (10 cm diameter). The petridishes containing eggs were kept in laboratory for hatching. The egg duration and number of eggs hatched were counted.

3.1.3 Larvae

With a view to determine number of instars, instar duration and total larval duration, fifty newly hatched larvae of *S. obliqua* were transferred individually with the help of fine camel hair brush in plastic tube (5.0 × 3.8 cm) having fresh and tender leaves of cowpea. The plastic tubes were covered individually with plastic lid having aeration holes. The individual plastic tube having *S. obliqua* larvae were observed daily. The food was changed every day in the morning. In order to determine the larval instars, the individual larva was observed daily for the exuviae as well as head capsule. The moulting was confirmed by the presence of casted off head capsule. Observations on number of instars, instar duration and total larval period were recorded. When the larvae were about to pupate, sieved

A. Rearing cage for egg laying

B. Individual rearing of larvae

Plate 1. Rearing technique of *S. obliqua*

moist soil was provided at the bottom of the galvanized cages to facilitate the pupation.

To know the pre-pupal period, observations were taken every day in the morning during the larval development. Full grown larvae stopped feeding, became sluggish and turned darken before entering into the pupal stage. These characteristics were used to record the initiation of the pre-pupal stage. The period from the larva stopped the feeding to entered into the soil for pupation was considered as pre-pupal period. Pupal period was considered from the date of entry inside the soil to the date of emergence of imago. The pupae were collected three days after pupation from soil.

3.1.4 Adult

The male and female adults emerged from the pupae were enclosed in acrylic cage (30 × 30 × 30 cm) for mating. Cowpea plant was kept inside the acrylic cage for resting and oviposition. To avoid starvation, absorbent cotton dipped in 5 per cent honey solution was provided inside the cage. The absorbent cotton was changed every day in morning.

With a view to determine fecundity, the eggs laid by the females were collected daily in morning and counted. The total number of eggs laid during the life span of female moth was considered as it's fecundity. The Observations on duration of various life stages i.e. egg, larva, pre-pupa, pupa and adult were recorded and their measurements were noted through Magnus-Pro software.

3.2 Population dynamics of *S. obliqua* on various pulse crops

To know the population fluctuation of *S. obliqua* attacking various pulse crops, an experiment was carried out during *kharif* season of 2013 at Farm of Department of Entomology, BACA, AAU, Anand.

3.2.1 Details of agronomical practices

(a) Location	: Farm of Department of Entomology, BACA, AAU, Anand
(b) Season year	: *Kharif*, 2013
(c) Date of sowing	: 10/07/2013
(d) Variety	: Cowpea, Anand Vegetable Cowpea-1 Pulse crops (soybean, green gram, black gram,)
(e) Plot size	: 25x 25 m^2
(f) Method of sowing	: Dibbling
(g) fertilizers	: 20:40:0 NPK Kg/ha

3.2.2 Methods of recording observations

The cowpea cultivar AVCP-1 (Anand Vegetable Cowpea-1) was grown in an area of 625 m^2 (25 m × 25 m) as well as micro plots 100 m^2 (10 m x 10 m) of Soybean, Green gram and Black gram were also grown in the first fortnight of July at a distance of 45 cm between two rows and 15 cm within the rows. For recording observations, five plants randomly selected and tagged were observed for egg masses and number of larvae present on three branches of each randomly selected plant. Damage of *S. obliqua* was recorded by observing damaged and healthy leaves and at weekly interval. The whole experimental plot was kept free from insecticidal application. The meteorological data recorded at Agricultural Meteorological Observatory, AAU, Anand were used to determine correlation of insect pest population with weather parameters.

3.2.3 Correlation study

In order to find out the specific impact of different weather parameters on population fluctuation of *S. obliqua* on various pulse crops, the data on number of larvae present on three branches of selected plant in experiment plot were correlated with the different meteorological parameters [Sunshine hours, temperature, relative humidity, vapour pressure deficit and wind velocity]. Correlation was worked out by standard statistical procedure (Steel and Torrie, 1980) in the Department of Agricultural Statistics, B. A. College of Agriculture, Anand Agricultural University, Anand.

3.3 Evaluation of insecticides against *S. obliqua* on cowpea in laboratory

In order to determine the relative bio-efficacy of insecticides against *S. obliqua* on cowpea, a laboratory experiment was carried out with following details:

3.3.1 Experimental details:

a.	Location	:	Department of Entomology, B. A. College of Agriculture AAU, Anand
b.	Season and Year	:	*Kharif*, 2013

c.	Crop and Variety	:	Cowpea, Anand Vegetable Cowpea-1
d.	Design	:	Completely Randomized Design (CRD)
e.	Treatments	:	9 + 1
f.	Replications	:	3

Table. 1: Details of treatments

Sr. No.	Name of insecticides	Trade Name	Conc. (%)	ml or g / 10 litre of water	Source
T_1	Chlorphyriphos 20 EC	Dursban	0.04	20 ml	Dow Agro Science (India) Pvt. Ltd., Mumbai
T_2	Thiodicarb 75 WP	Larvin	0.015	20 g	Bayer CropScience Ltd., Mumbai
T_3	Quinalphos 25 EC	Ekalux	0.005	20 ml	Syngenta (India) Pvt. Ltd. Mumbai
T_4	Emamectin benzoate 5 SG	Proclaim	0.0025	5 g	Syngenta India Ltd., Mumbai
T_5	Phenthoate 50 EC	Phendal	0.1	20 ml	Coromandal Agrico. Pvt. Ltd. Ankleshwar
T_6	Spinosad 45 SC	Spintor	0.0135	3 ml	Bayer CropScience Ltd., Mumbai
T_7	Fenvalerate 0.4% DP	Devifen 0.4 DP	-	25 kg/ha	Devidayal Agrochemicals Mumbai
T_8	Novaluron10 EC	Remon	0.01	10 ml	Rallis India Ltd., Bangalore
T_9	Methomyl 40 SP	Lannet	0.08	20 ml	EI Dupont India Ltd., Gurgaon
T_{10}	Control (Water spray)	-	-	-	-

3.3.2 Methods of recording observations

For the purpose of testing the bioefficacy of insecticides against *S. obliqua,* plants were sprayed directly with each decided concentration of commercially available formulation of test insecticides (as per treatment details) with the help of knapsack sprayer in the field. After 12 hours of spraying, treated cowpea leaves were collected from the sprayed plots and placed individually in plastic bowls (11 cm diameter and 5 cm height).

For the evaluation of insecticides laboratory reared third instar larvae of *S. obliqua* were used. Ten larvae of *S. obliqua* were carefully placed on cowpea leaves and whole set was covered and were kept at room temperature in the laboratory. Untreated control was kept as one treatment. The treatments were replicated thrice. The observations on mortality of larvae were recorded at 1, 2, 3 and 7 days after treatment.

3.3.3 Statistical analysis of data

Observations on larval mortality were recorded at 1, 2, 3 and 7 days after treatment and per cent mortality were calculated using Abbott's formula. (Abbott's 1925).

$$P = \frac{P1 - C}{100 - C} \times 100$$

Where,

P = Corrected per cent mortality

P1= Observed per cent mortality in treatment

C = Per cent mortality in control

The zero and hundred per cent values were removed by using the formula 1/4 x 100 and 1-1/4n x 100, respectively (Bartiett, 1947) where n= number of larvae per treatment

Plate 2. General view of experimental site

3.4 Field trial

Evaluation of insecticides against *S. obliqua* on cowpea.

3.4.1 Experimental details:

a.	Location	:	Farm of department of Entomology, BACA, AAU, Anand
b.	Season and Year	:	*Kharif*, 2013
c.	Crop and Variety	:	Cowpea, Anand Vegetable Cowpea-1
d.	Design	:	Randomized Block Design
e.	Plot size	:	Gross: 3.15 m × 3 m Net: 2.25 m × 2.4 m
f.	Spacing	:	45 × 15 cm
g.	Seed rate	:	20 kg/ha
h.	Fertilizer	:	20:40:0 NPK Kg/ha
i.	Treatments	:	9 + 1
j.	Replications	:	3

3.4.2 Details of Treatments

As per laboratory trial.

3.4.3 Methodology:

In order to study the effectiveness of different insecticides (Table 1) against *S. obliqua*, an experiment was carried out at farm of Department of entomology, B.A. College of Agriculture, AAU, Anand in randomized block design with three replications. Cowpea cultivar

AVCP-1 (Anand Vegetable Cowpea-1) was grown by keeping spacing of 45 cm between two rows and 15 cm within the rows in a gross and net plot area of 3.15 × 3 m and 2.25 × 2.4 m, respectively during first fortnight of July, 2013.

Spray of respective insecticides was applied on appearance larvae of Bihar hairy caterpillar by using manually operated knapsack sprayer with duromist nozzle. Spray application was made to the extent of slight run off stage.

For recording the observations, five plants were selected randomly from each plot. The observations of *S. obliqua* were recorded as per the methodology described under 3.2.2. The observations were recorded before spray and 3, 5, 7 and 10 days after spray. Data, thus obtained were subjected to the appropriate transformations and statistically analyzed for interpretation.

3.4.4 Observations recorded

1) Number of larvae of *S. obliqua* on five plants.
2) Total and *S. obliqua* infested plants in each net plot.
3) Green pod yield.

3.5 Yield, avoidable losses and economics

3.5.1 Yield

Pickings were made when green pods were ready for vegetable purpose. Treatment wise yield of green pods was recorded to judge the efficacy of the treatments during every picking. The yield obtained per plot was converted into quintal per hectare.

3.5.2 Avoidable losses

On the basis of cowpea green pod yield harvested from various treatments, the avoidable loss due to *S. obliqua* incidence was calculated by applying formula of Poul (1976) which is as under.

$$\text{Avoidable loss in yield (\%)} = \frac{\text{Yield in treatment which gave the highest yield} - \text{Yield in any other treatment}}{\text{Yield in treatment which gave the highest yield}} \times 100$$

3.5.3 Economics and cost benefit ratio

Efforts have been made to work out cost benefit ratio (ICBR) from the experimental data to calculate economics of the different insecticidal treatments. For the purpose, total cost of plant protection for each treatment was worked out on the basis of insecticidal formulation used and labour charges for their application. Net gain in yield over control was calculated by deducting the yield of control from yield of each treatment. Realization was worked out by multiplying the prevailing market price of cowpea green vegetable pod and net gain over control. ICBR for each treatment was calculated by dividing realization with total cost of plant protection. Finally, net ICBR for each treatment was calculated by deducting one rupee from ICBR.

Results and Discussion

IV. RESULTS AND DISCUSSION

The present investigations were carried out on biology and management of Bihar hairy caterpillar, *Spilosoma obliqua* Walker on cowpea, *Vigna unguiculata* (Linnaeus) Walpers and its population dynamics on various pulse crops presented here in this chapter. The results are also discussed in light of the research carried out elsewhere which has a direct or indirect relation with the present investigations.

4.1 Biology of Bihar hairy caterpillar, *S. obliqua*

The biology of *S. obliqua* on cowpea was carried out at Department of entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during July to October, 2013. The research was carried out at the temperature of 25.20 to 33.40 with an average of 28.80 ± 1.32 ˚C and relative humidity of 64.75 to 71.40 with an average of 66.91 ± 12.97 per cent in laboratory condition.

4.1.1 Egg

4.1.1.1 Oviposition site of *S. obliqua*

The oviposition site was recorded by observing different parts of the cowpea plant on which eggs were laid. The results showed that the female moths laid the eggs in masses on lower surface of the upper as well as middle leaves. Further, different spots of field were observed and found that many egg masses were laid by single female on single plant. Similar egg laying pattern of *A. albistriga* was observed by different research workers (Singh and Singh, 1990; Ganiger and

Sannaveerappanavar, 2007). Thus, the present findings are in close conformity with the results of earlier research workers but no information is available on the site of oviposition of *S. obliqua* in the literature and hence the present results could not be discussed and compared with research done by other scientists in the context to *S. obliqua*.

4.1.1.2 Colour, shape and size of *S. obliqua* eggs

Colour, shape and size of the eggs laid by *S. obliqua*, were recorded by observing eggs under the stereoscopic binocular microscope. The observations on these characters revealed that the eggs of *S. obliqua* were greenish in colour when it was freshly laid thereafter, it turned to creamish and became dark brownish prior to hatching. The eggs were laid in masses which look like seed of grape from upper side. The eggs are round on upper surface and flattened at base. Further, the diameter of eggs was found to be 0.29 to 0.40 mm with an average of 0.34 ± 0.04 mm (Table 3). No information is available on the colour, size and shape of the eggs of *S. obliqua* in the literatures and hence the present results could not be discussed and compared with research done by other scientists.

4.1.1.3 Incubation period of *S. obliqua* eggs

The observations on incubation period of *S. obliqua* were started immediately after the egg laying and continued up to hatching. The incubation period was varied from 3 to 5 days with an average of 3.68 ± 0.63 days (Table 2). Results of the present investigation on incubation period of *S. obliqua* were in close agreement with the results of the earlier workers as they recorded the incubation period of eggs in the range of 3-12 days (Singh and Singh, 1995); 5.60 days (Nath and Singh, 1996) and 6.5 to 10.5 days (Debaraj and Singh, 2010).

4.1.1.4 Hatching percentage of *S. obliqua* eggs

Observations on hatching percentage of *S. obliqua* eggs were recorded by putting five sets each of fifty eggs. The hatching percentages (Table 2) were found to be of 78 to 92 with an average of 85.60 ± 4.80. The results are in conformity with the report of Singh and Singh (1995) who observed 83.5 to 99.33 percent hatchability for the eggs of *S. obliqua*.

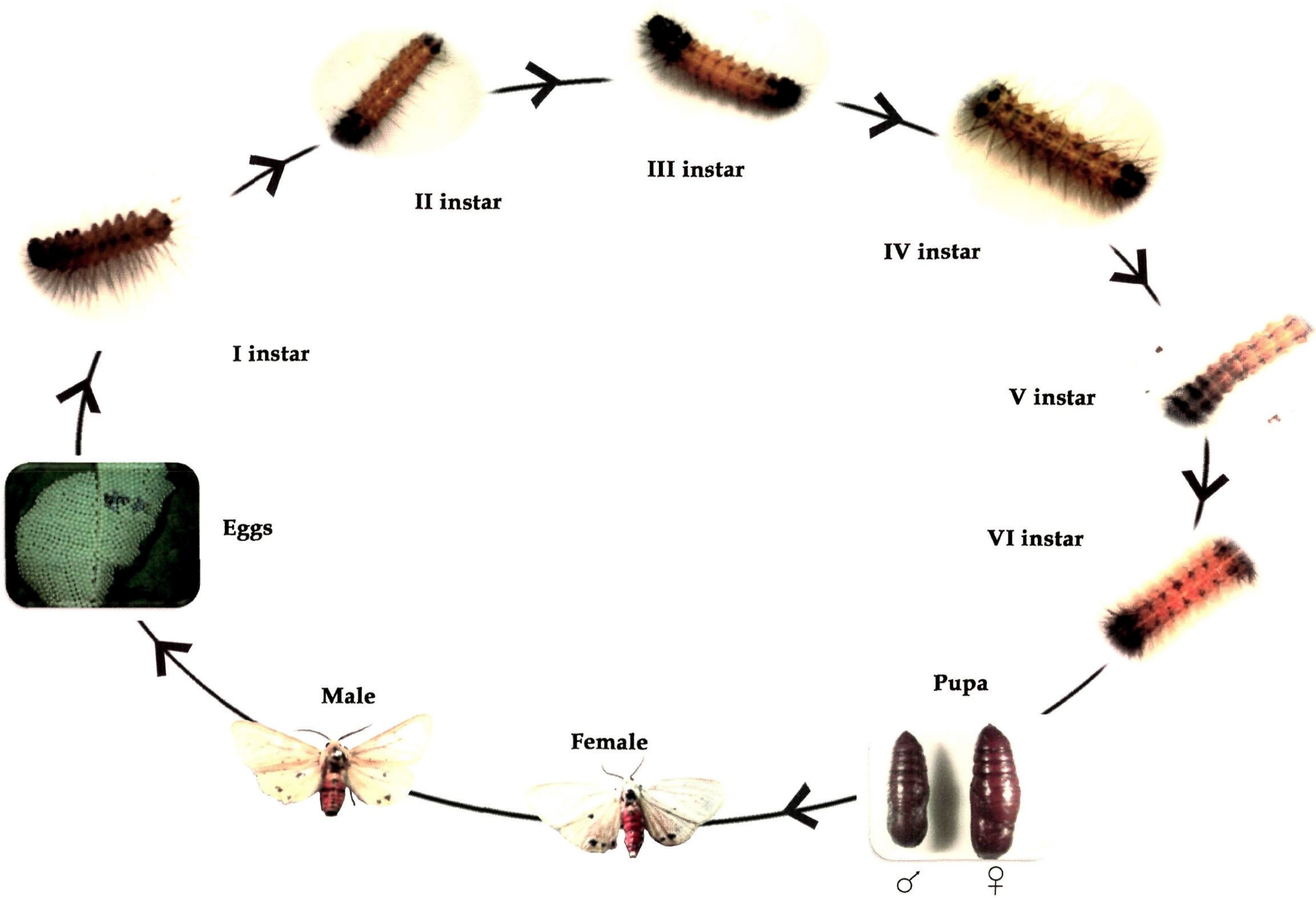


Plate 3. Different stages of *S. obliqua*

Table 2: Duration of different life stages of *S. oblique*

Sr. No.	Life stage	Periods (days)		
		Min.	Max.	Mean ± SD
1	**Egg**	3	5	3.68±0.63
	Hatching (%)	78	92	85.60±4.80
2	**Larva**			
	I instar	2	4	3.12±0.78
	II instar	3	4	3.44±0.51
	III instar	3	4	3.56±0.51
	IV instar	2	3	2.56±0.51
	V instar	3	4	3.72±o.46
	VI instar	2	3	2.72±0.46
	Total	15	22	19.12±1.54
3	**Pre-pupa**	2	3	2.60±0.50
4	**Pupa**			
	Male	8	10	9.04±0.73
	Female	9	10	9.36±0.49
5	**Adult**			
	Pre-oviposition	2	4	2.40±0.50
	Oviposition	4	6	5.16±0.85
	Post-oviposition	2	4	2.84±0.75
	Longevity			
	Male	4	6	5.00±0.82
	Female	6	8	7.08±0.81
	Fecundity	760	1420	976.84±194.58
	Sex ratio (Male : Female)			
	Laboratory	1:1.6	1:4.2	1:3.02
6	**Total life span: Egg to adult death**			
	Male	33	40	36.57 ± 2.29
	Female	42	47	43.30 ± 3.94

Table 3: Measurements of different life stages of *S. oblique*

Sr. No.	Life stage	Particulars	Measurement (mm)		
			Min.	Max.	Mean + SD
1	**Egg**	Diameter	0.29	0.40	0.34±0.04
2	**Larva**				
	I instar	Length	3.51	5.70	4.54±0.82
		Breadth	0.55	1.06	0.79±0.22
		Head capsule	0.46	0.74	0.61±0.11
	II instar	Length	6.30	8.99	7.56±1.11
		Breadth	1.45	1.74	1.59±0.11
		Head capsule	0.77	1.42	1.09±0.25
	III instar	Length	9.49	10.42	9.90±0.40
		Breadth	1.84	2.20	2.01±0.16
		Head capsule	1.51	1.98	1.68±0.19
	IV instar	Length	17.21	19.05	18.34±0.80
		Breadth	2.10	3.00	2.36±0.28
		Head capsule	1.88	2.21	2.06±0.14
	V instar	Length	19.13	23.93	22.08±1.91
		Breadth	2.80	3.60	3.30±0.56
		Head capsule	2.67	3.01	2.84±0.13
	VI instar	Length	24.75	28.25	26.29±1.14
		Breadth	4.20	5.92	5.10±0.56
		Head capsule	3.12	4.21	3.71±0.41
3	**Pre-pupa**	Length	21.5	26.80	24.71+1.58
		Breadth	3.50	4.50	4.06 + 0.32
4	**Pupa**				
	Male	Length	19.20	22.40	21.02±1.90
		Breadth	4.9	6.20	5.54±0.43
	Female	Length	21.00	23.40	22.19±0.84
		Breadth	4.95	6.50	5.73±0.48
5	**Adult**				
	Antennae	Length	6.74	11.26	9.09±1.47
	Leg				
	Fore legs	Length	6.87	10.23	8.59±1.26
	Middle legs	Length	5.88	8.22	7.01±0.78
	Hind legs	Length	9.84	12.53	11.12±0.76
	Wing				
	Fore wing	Length	16.32	20.80	18.53±1.31
		Breadth	6.0	9.44	7.91±1.08
	Hind wing	Length	9.83	13.47	11.82±1.13
		Breadth	6.33	8.84	7.57±0.71
	Male	Length	19.10	22.40	20.33±0.95
		Breadth	3.42	5.66	4.60±0.62
	Female	Length	20.44	24.82	22.52±1.49
		Breadth	3.75	5.25	4.58±0.52

4.1.2 Larva

4.1.2.1 Nature of damage and behaviour of *S. obliqua* larvae

The observation on nature of damage due to Bihar hairy caterpillar, S. obliqua on cowpea were made visually in laboratory as well as in field conditions and it was found that the newly hatched larvae of *S. obliqua* feed gregariously on lower surface of leaves by scraping its surface which resulted in to papery leaves. Larvae (*viz.,* Third, fourth, fifth) fed the whole leaves except veins and veinlets. It was also found that the larvae stoped feeding for few hours before moulting. No information is available in literature on the feeding behavior of *S. obliqua* on cowpea.

4.1.2.2 Larval instars

The observations were made on duration and morphometry of (length, width as well as width of head capsule) different instars of *S. obliqua* with the help of stereoscopic binocular microscope. It was found that the larvae passed through sixth instars on cowpea leaves under the laboratory condition. The results on larval periods as well as morphometrics are presented hereunder.

4.1.2.3 First instar

The newly hatched larva was creamy whitish with shining brown head and having brown spots over entire body from which white hair arises which later turn black. The integument was transparent, abdominal segments were distinct with three pairs of prologs. Larvae turned pale yellow colour within a few hours after hatching. The data (Table 2) on first instar larvae of *S. obliqua* revealed that the duration of first instar was found to be 2 to 4 days with an average of 3.12 ± 0.78 days. Further, it was also found that the length and breadth of first instar larvae 3.51 to 5.70 mm with an average of 4.54 ± 0.82 mm and 0.55 to 1.06 mm with an average of 0.79 ± 0.22 mm, respectively. The head capsule widths varied from 0.46 to 0.74 with an average of 0.61 ± 0.11 mm (Table 3).

4.1.2.4 Second instar

The larva in second instar slightly increased in size having light yellow colour body with brown markings on thoracic and last abdominal segment, more hairs on the body compared to first instar and thoracic legs were black with brown abdominal legs. The duration of second instar was varied from 3 to 4 days with an average of 3.44 ± 0.51 days. Further, it was found that the lengths and breadths of second instar larvae were from 6.30 to 8.99 mm with an average of 7.56 ± 1.11 mm and 1.45 to 1.74 mm with an average of 1.59±0.11 mm, respectively while the head capsule widths were varied from 0.77 to 1.74 mm with an average of 1.09 ± 0.25 mm (Table 3).

4.1.2.5 Third instar

Third instar larvae were similar to second instar but the colouration of head and body segments were little darker compared to the second instar. The third instar larvae were more active than the first and second instar larvae. The duration of third instar were found to be from 3 to 4 days with an average of 3.56 ± 0.51 days. Further, it was also found that the lengths and breadths of third instar larvae were varied from 9.49 to 10.42 mm with an average of 9.90 ± 0.40 mm and 1.84 to 2.20 mm with an average of 2.01 ± 0.16 mm, respectively while the head capsule widths ranged from 1.51 to 1.98 mm with an average of 1.68 ± 0.19 mm (Table 3).

4.1.2.6 Fourth instar

The larva in fourth instar were uniformly yellowish in colour as the segments were brown and tuft of brownish white hairs arose from reddish brown verrucae and when the larvae approached late fourth instar stage, the head turned dark brownish black. The data (Table 2) on fourth instar larvae revealed that the duration of fourth instar larvae was from 2 to 3 days with an average of 2.56 ± 0.51 days. Further, it was also found that the lengths and breadths of fourth instar larvae were found from 17.21 to 19.05 mm with an average of 18.34 ± 0.80 mm and 2.10 to 3.00 mm with an average of 2.36 ± 0.28 mm, respectively while the head capsule width was varied from 1.88 to 2.21 mm with an average of 2.06 ± 0.14 mm (Table 3).

4.1.2.7 Fifth instar

The fifth instar larvae were dark yellow with reddish tinge in colour and the heads and thoracic shields were dark brown in colour while the legs were found to be reddish brown. Spiracles were inconspicuous and visible only under magnification as circular patches. The data (Table 2) on fifth instar larvae of *S. obliqua* revealed that the duration was varied from 3 to 4 days with an average of 3.72 ± 0.46 days. Further, it was also found that the lengths and breadths of fifth instar larvae were varied from 19.13 to 23.93 mm with an average of 22.08 ± 1.91 mm and 2.80 to 3.60 mm with an average of 3.30 ± 0.56

mm, respectively while the head capsule width was varied from 2.67 to 3.01mm with an average of 2.84 ± 0.13 mm (Table 3).

4.1.2.8 Sixth instar

The fully grown sixth instar larva had dark black head with brownish legs and uniformly reddish brown body with brownish black verrucae on which there were whitish hairs. The data (Table 2) on sixth instar larvae revealed that the duration was varied from 2 to 3 days with an average of 2.72 ± 0.46 days. Further, it was also found that the lengths and breadths of sixth instar larva were varied from 24.75 to 28.25 mm with an average of 26.29 ± 1.14 mm and 4.20 to 5.92 mm with an average of 5.10 ± 0.56 mm, respectively while the head capsule width was varied from 3.12 to 4.21mm with an average of 3.71 ± 0.41mm (Table 3).

4.1.2.9 Total larval duration

The total larval period (Table 2) of *S. obliqua* was ranged from 15 to 22 days with an average of 19.12 ± 1.54 days. Earlier workers also reported larval period of 17.22 days (Singh and Singh, 1995), 24.72 days (Nath and Singh, 1996) and 24 days (Debaraj and Singh, 2010).

4.1.3 Pre-pupal

The observations on pre-pupal stage of *S. obliqua* showed that the seventh instar larva stoped feeding for few hours. The duration of pre-pupal stage was varied from 2 to 3 days with an average of 2.60 ± 0.50 days (Table 2). The data of present investigation are in close conformity with the reports of Nath and Singh (1996), who reported the pre-pupal period of 1.76 days. Further, the lengths and widths of the pre-pupae were also measured and results revealed that the lengths were found from 21.5 to 26.8 mm with an average of 24.71 $\pm$ 1.58 mm, while the width ranged from 3.5 to 4.5 mm with an average of 4.06 $\pm$ 0.32 mm (Table 3). No information is available on measurement of pre-pupa in the literature and hence the present findings could not be discussed.

4.1.4 Pupae

4.1.4.1 Site of pupation, colour and shape

The observation on site of pupation, colour and shape were visually recorded in laboratory as well as in field conditions and it was revealed that the larvae of *S. obliqua* pupated in the moist soil kept in galvanized cage, but in field condition it was pupated in soil at a depth of 10.3 to 15 cm. The pupae were found in earthen cocoons. The newly formed pupae were soft and green or pale brown in colour. Later on, the pupa turned brownish in colour. The pupa which has to develop into male moth has a slit representing the genital opening in the posterior part of 9^{th} abdominal segment while in the case of female it was on the eight abdominal segments. The anal apture in both sexes was located on the tenth abdominal segment. No information is available in case of site of pupation, colour and shape of *S. obliqua* pupae in the literature and hence the present findings are not discussed with the reports of earlier workers.

4.1.4.2 Pupal period

The duration of male pupae were varied from 8 to 10 days with an average of 9.04 $\pm$ 0.73 days, while duration of female pupae was found to be 9 to 10 days with an average of 9.36 $\pm$ 0.49 days, (Table 2). The present findings are in close conformity with the report of Singh and Singh (1995) and Nath and Singh (1996) in which they reported pupal period of 10.25 and 11.46 days, repsectively.

4.1.4.3 Morphometric of pupae

The observations on size of pupae were recorded with the help of binocular microscope in laboratory. The results revealed that the lengths of male pupae were found in the range of 19.20 to 22.40 mm with an average of 21.02 $\pm$ 1.90 mm while the lengths of female pupae varied from 21.0 to 23.4 mm with an average of 22.19 $\pm$ 0.84 mm, which was found to be slightly more than the male pupa. In case of widths of the male pupae, it was found in the range of 4.9 to 6.20 mm with an average of 5.54 $\pm$ 0.43 mm. Similarly, it was 4.95 to 6.50 mm with an average of 5.73 $\pm$ 0.48 mm in case of female pupae which was slightly more than male pupae (Table 3). No information is available on morphometric of *S. obliqua* pupae in the literature and hence the present findings are not discussed with the reports of earlier workers.

4.1.5 Adult

4.1.5.1 Colour and appearance

The observations were made on colour and appearance of the *S. obliqua* adults. It was found that the moths were straw in colour with orange and brown streaks over the forewings and white streak along the anterior margin. The hind wings were found yellowish in colour with black markings. However, variations were observed in respect to number of black markings and their distribution on the wings. Black spots on each abdominal segment were also observed. No information is available on colour and appearance of *S. obliqua* adults in the literature and hence the present findings could not be compared and discussed with the reports of earlier workers.

4.1.5.2 Size

The observations were made on size of the *S. obliqua* adults and it was found that the lengths of male moths were ranged from 19.10 to 22.40 mm with an average of 20.33 $\pm$ 0.95 mm (Table 3) while the lengths of the female moths were ranged from 20.44 to 24.82 mm with an average of 22.52 $\pm$ 1.49 mm. Further, the lengths of the antennae and legs of adult were also measured and results revealed that the lengths of antennae were found to be 6.74 to 11.26 mm with an average of 9.09 $\pm$ 1.47 mm, while the lengths of fore legs, middle legs and hind legs were ranged from 6.87 to 10.23 mm, 5.88 to 8.22 and 9.84 to 12.53 mm with an average of 8.59 $\pm$ 1.26, 7.01 $\pm$ 0.78 and 11.12 $\pm$ 0.76 mm, respectively. No information is available on size of *S. obliqua* adults in the literature and hence the present findings are not discussed with the reports of earlier workers.

4.1.5.3 Pre-oviposition, oviposition and post oviposition periods

The observations were made on pre-oviposition, oviposition and post oviposition periods of *S. obliqua* in laboratory and found that the pre-oviposition period varied from 2 to 4 days with an average of 2.40 ± 0.50 days (Table 2) while oviposition period was ranged from 4 to 6 days with an average of 5.16 ± 0.85 days (Table 2). The female moths lived for 2 to 4 days after completion of egg laying. The post-oviposition period was found to be 2 to 4 day with an average of 2.84 ± 0.75 days (Table 2). According to Singh and Singh, 1995 and Nath and Singh, 1996, pre-oviposition, oviposition and post oviposition periods were 2.14 to 2.40; 2.44 to 2.88 and 1.75 to 4.00 days, respectively. The present findings are in close conformity with the report of Singh and Singh, 1995 and Nath and Singh, 1996.

4.1.5.4 Longevity and fecundity

The data on longevity of female moths were found in the range of 6 to 8 days with an average of 7.08 ± 0.81 days, while in case of male moths it was found to be of 4 to 6 days with an average of 5.00 ± 0.82 days (Table 2). No information is available on longevity of *S. obliqua* adults in the literature and hence the present findings are not discussed with the reports of earlier workers.

The fecundity was varied from 760 to 1420 eggs with an average of 976.84 ± 194.58 eggs (Table 2) which is in the conformity with the report of Singh and Singh (1995) who reported that the *S. obliqua* laid 1849 eggs /female while Debaraj and Singh (2010) reported that the fecundity was 987 eggs /female.

4.1.6 Sex ratio

The data on sex ratio was found in range of 1:1.6 (male: female) to 1:4.2 with an average of 1:3.02. The data revealed that the female births were more than the male births.

4.1.7 Total life span

The total life span was found to be of 33 to 40 days with an average of 36.57 $\pm$ 2.29 days in case of male, while it was ranged from 42 to 47 days with an average of 43.30 $\pm$ 3.94 days in case of female. The present findings are in close conformity with the report of Singh and Singh, 1995; Nath and Singh, 1994 and Debaraj and Singh, 2010 as they reported that the total life span was found to be 37.50; 53.06 and 39.60 days, respectively.

4.2 Population dynamics of Bihar hairy caterpillar, S. *obliqua* on various pulse crops

To know the effect of different abiotic factors on the incidence of *S. obliqua* on cowpea (AVCP-1) as well as various pulse crops, an experiment was carried out at farm of department of entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during the *kharif*, 2013.

4.2.1.1 Cowpea

The data (Table 4 and figure 1) on population count showed that the pest started egg laying (0.2 egg mass/plant) on cowpea crop from 29th standard meteorological week (3rd week of July) and it was continued till 40th standard meteorological week (1st week of October). Maximum egg masses (1.26 egg masses/plant) were laid in the 35th standard meteorological week (5th week of August). The gregarious larval population (first to third instars) was first found on crop (23.2 larvae/ plant) in the 29th standard meteorological week (3rd week of July) and the population was found till 39th standard meteorological week (4th week of September). The number of gregarious larva were steadily increased from 29th standard meteorological week and reached to peak level (68.13 larvae/plant) in the 35th standard meteorological week (5th week of August). Thereafter, the gregarious larval population was slowly decreased up to 39th standard meteorological week (4th week of September) and disappeared from the crop from 40th standard meteorological week (1st week of October). The larval activity (fourth to seventh instars) was started (5.33 larvae/3

Table 4: Seasonal abundance of *S. obliqua* and its damage on cowpea

Month/ Week		SMW	WAS	No. of egg masses /plant	No. of gregrous larvae/plant	No. of larvae/ 3 branches	Leaf damage (%)
July	II	**28**	3	0.00	0.00	0.00	0.00
	III	**29**	4	0.20	23.2	0.00	8.45
	IV	**30**	5	0.46	35.26	5.33	13.20
Aug.	I	**31**	6	0.53	45.2	7.60	17.72
	II	**32**	7	0.66	40.43	10.73	22.12
	III	**33**	8	0.93	56.90	9.11	25.42
	IV	**34**	9	1.02	59.66	10.15	27.15
	V	**35**	10	1.26	68.13	12.17	30.45
Sept	I	**36**	11	0.73	45.2	8.04	28.62
	II	**37**	12	1.00	35.70	3.06	25.15
	III	**38**	13	0.8	36.76	3.66	22.52
	IV	**39**	14	0.46	26.13	0.00	18.55
Oct.	I	**40**	15	0.26	0.00	0.00	15.05
	II	**41**	16	0.00	0.00	0.00	12.72

SMW: Standard Meteorological Week **WAS:** Week after sowing

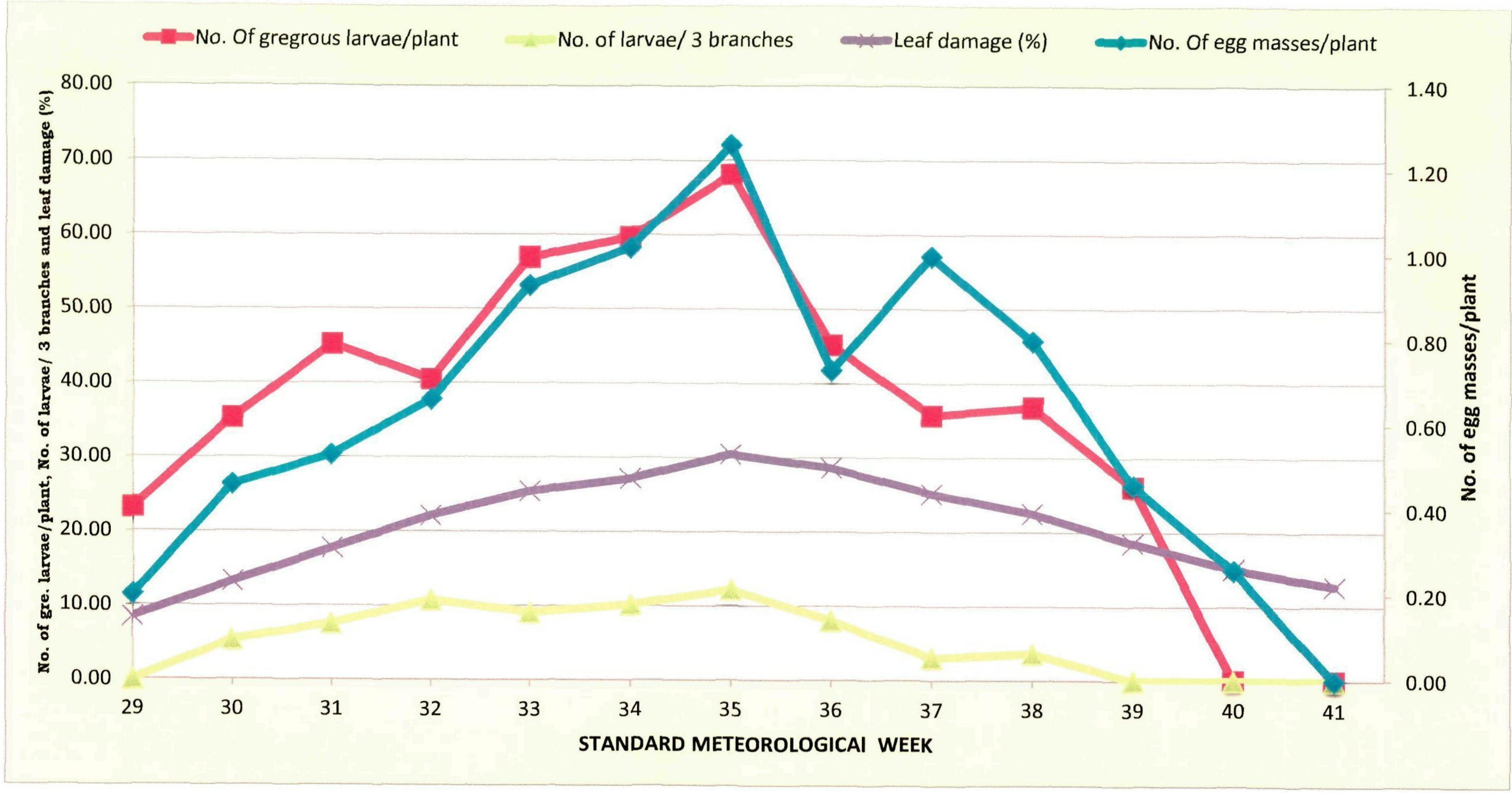


Fig. 1: Seasonal abundance of *S. obliqua* on cowpea

branches) from 30th standard meteorological week (4th week of July) and it was continued till 38th standard meteorological week (3rd week of September) with peak (12.17 larvae/ plant) in the 35th standard meteorological week (5th week of August). Thereafter, the activity was slowly decreased up to 38th standard meteorological week (3rd week of September). The activity of bigger size larvae was not found from 39th standard meteorological week (4th week of September) in the crop.

The population of larvae was also reflected on leaf damage. The damaged leaves were found from 29th standard meteorological week (3rd week of July) to 41th standard meteorological week (2nd week of October). As larval population increased, the damage was also increased in cowpea. The leaf damage was found to be 8.45 per cent on first appearance of the pest. The maximum damage (30.45%) was found in the 35th standard meteorological week (5th week of August). After the 35th standard meteorological week, the leaf damage gradually decreased up to 41th standard meteorological week (2nd week of October). The higher damage (22.12 to 30.45 %) was noticed during 2nd week of August (32th standard meteorological week) to 3rd week of September (38th standard meteorological week).

The above results clearly indicated that the pest started it's activity on cowpea from 3rd week of July (29th standard meteorological week) and continued till 1st week of October (40th standard meteorological week) which was also reflected on damage on crop. The higher activity and damage was found during 2nd week of August to 3rd week of September (38th standard meteorological week).

4.2.1.2 Green gram

The data (Table 5 and figure 2) on population count showed that the pest started egg laying (0.46 egg mass/ plant) on green gram crop from 29th standard meteorological week (3rd week of July) and it was continued till 40th standard meteorological week (1st week of October). Maximum egg masses (1.56 egg masses/ plant) were laid in the 34th standard meteorological week (4th week of August). The gregarious larval population was first found (24.40 larvae/ plant) from 29th standard meteorological week (3rd week of July) and the population was present on crop till 40th standard meteorological week (1th week of October). The number of gregarious larva were steadily increased from 29th standard meteorological week and reached to peak level (72.35 larvae/ plant) in the 36th standard meteorological week (1st week of September). Thereafter, the larval population was slowly decreased up to 40th standard meteorological week (1st week of October) and disappeared from the crop from 41th standard meteorological week (2nd week of October). The bigger larval population was first found (6.45 larvae/3 branches) from 30th standard meteorological week (4th week of July) and it was continued till 40th standard meteorological week (1st week of October) with peak level (14.55 larvae/ plant) in the 36th standard meteorological week (1st week of September). Thereafter, the activity was slowly decreased up to 40th standard meteorological week (1st week of October). The activity of bigger size larvae was not found from 41th standard meteorological week (2nd week of October) in the crop.

Table 5: Seasonal abundance of *S. obliqua* and its damage on green gram

Month/ Week		SMW	WAS	No. of egg masses /plant	No. of gregrous larvae/plant	No. of larvae/ 3 leaves	Leaf damage (%)
July	II	**28**	3	0.00	0.00	0.00	0.00
	III	**29**	4	0.46	24.40	0.00	10.90
	IV	**30**	5	0.66	25.78	6.45	14.30
Aug.	I	**31**	6	0.80	28.60	7.80	18.46
	II	**32**	7	0.95	33.65	8.90	21.64
	III	**33**	8	1.06	38.70	10.30	24.57
	IV	**34**	9	1.08	42.10	12.04	27.82
	V	**35**	10	1.56	64.16	12.05	28.39
Sept	I	**36**	11	1.00	72.35	14.55	30.57
	II	**37**	12	0.95	62.86	10.32	26.65
	III	**38**	13	0.46	57.56	8.66	22.39
	IV	**39**	14	0.40	46.80	7.70	18.47
Oct.	I	**40**	15	0.24	30.12	5.46	15.35
	II	**41**	16	0.00	0.00	0.00	12.78

SMW: Standard Meteorological Week **WAS:** Week after sowing

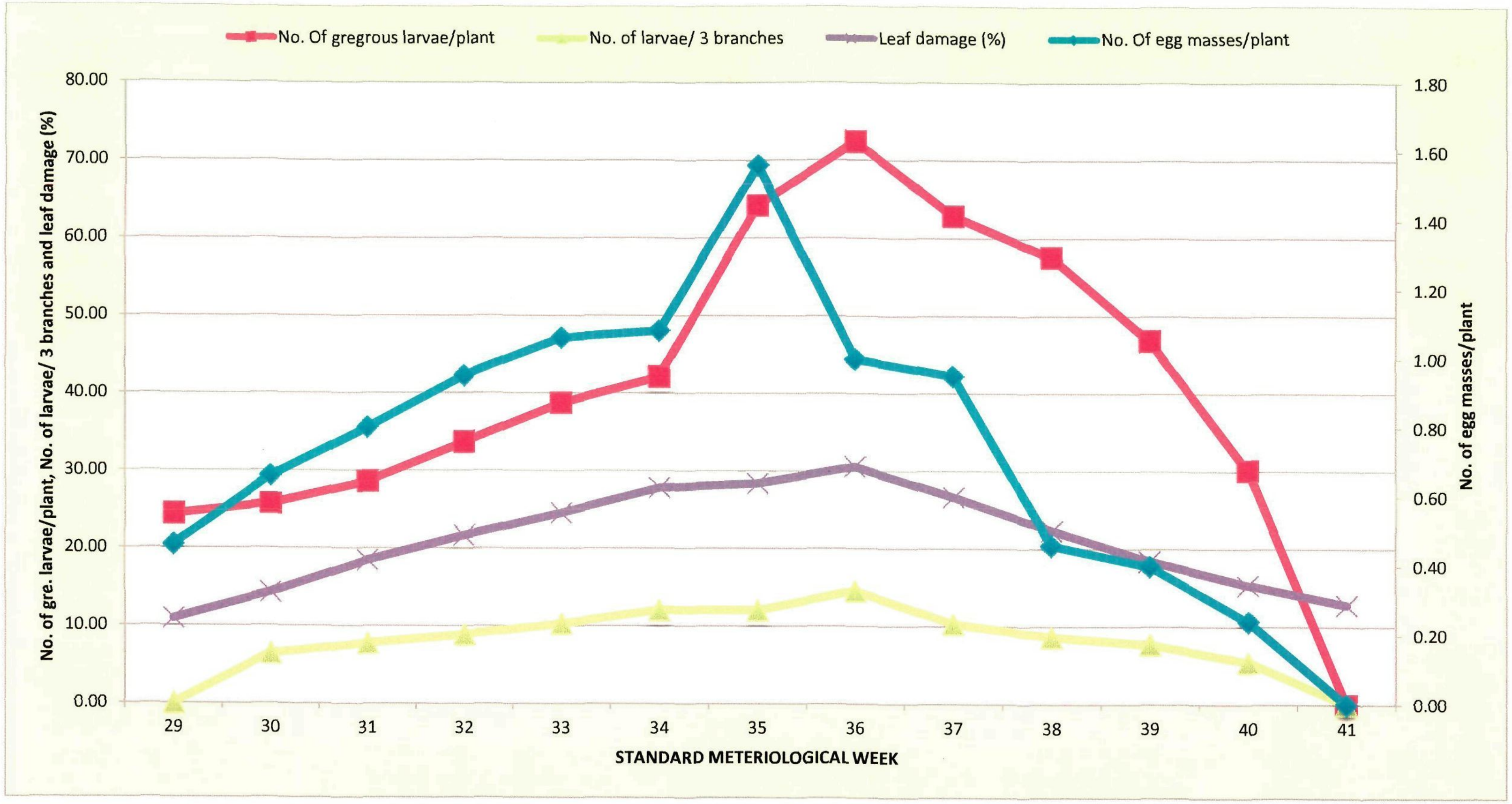


Fig. 2: Seasonal abundance of *S. obliqua* on green gram

The leaf damage was dependent on larval population. The damaged leaves were found from 29th standard meteorological week (3rd week of July) to 41th standard meteorological week (2nd week of October). As larval population increased, the damage was also increased in green gram crops. The damage was found to be 10.90 per cent on appearance of the pest. The maximum damage (30.57 %) was found in the 36th standard meteorological week (1st week of September). After 36th standard meteorological week, the leaf damage gradually decreased up to 41th standard meteorological week (2nd week of October). The higher damage (21.64 to 30.57 %) was noticed during 2nd week of August (32th standard meteorological week) to 3rd week of September (38th standard meteorological week).

The above results clearly indicated that the pest started its activity on green gram from 3rd week of July (29th standard meteorological week) and continued till 1st week of October (41th standard meteorological week) which was also reflected on damage on crop. The higher activity and damage was found during 2nd week of August to 3rd week of September (38th standard meteorological week).

4.2.1.3 Black gram

The data (Table 6 and figure 3) on population count showed that the pest started egg laying (0.56 egg mass/plant) on black gram crop from 29th standard meteorological week (3rd week of July) and it was continued till 40th standard meteorological week (1st week of October). Maximum egg masses (1.40 egg masses/plant) were laid in the 34th standard meteorological week (4th week of August).

Table 6: Seasonal abundance of *S. obliqua* and its damage on black gram

Month/ Week		SMW	WAS	No. of egg masses /plant	No. of gregrous larvae/plant	No. of larvae/ 3 branches	Leaf damage (%)
July	II	**28**	3	0.00	0.00	0.00	0.00
	III	**29**	4	0.56	26.00	0.00	7.42
	IV	**30**	5	0.68	32.90	3.88	10.15
Aug.	I	**31**	6	0.76	36.60	5.40	14.45
	II	**32**	7	0.86	42.55	8.11	18.35
	III	**33**	8	1.06	48.86	10.45	21.10
	IV	**34**	9	1.14	52.36	13.36	24.32
	V	**35**	10	1.40	58.32	15.08	27.52
Sept	I	**36**	11	1.05	68.12	17.46	29.75
	II	**37**	12	0.94	52.40	16.80	25.15
	III	**38**	13	0.52	46.74	10.36	23.62
	IV	**39**	14	0.46	34.76	7.66	20.15
Oct.	I	**40**	15	0.40	0.00	3.65	18.75
	II	**41**	16	0.00	0.00	0.00	15.15

SMW : Standard Meteorological Week **WAS :** Week after sowing

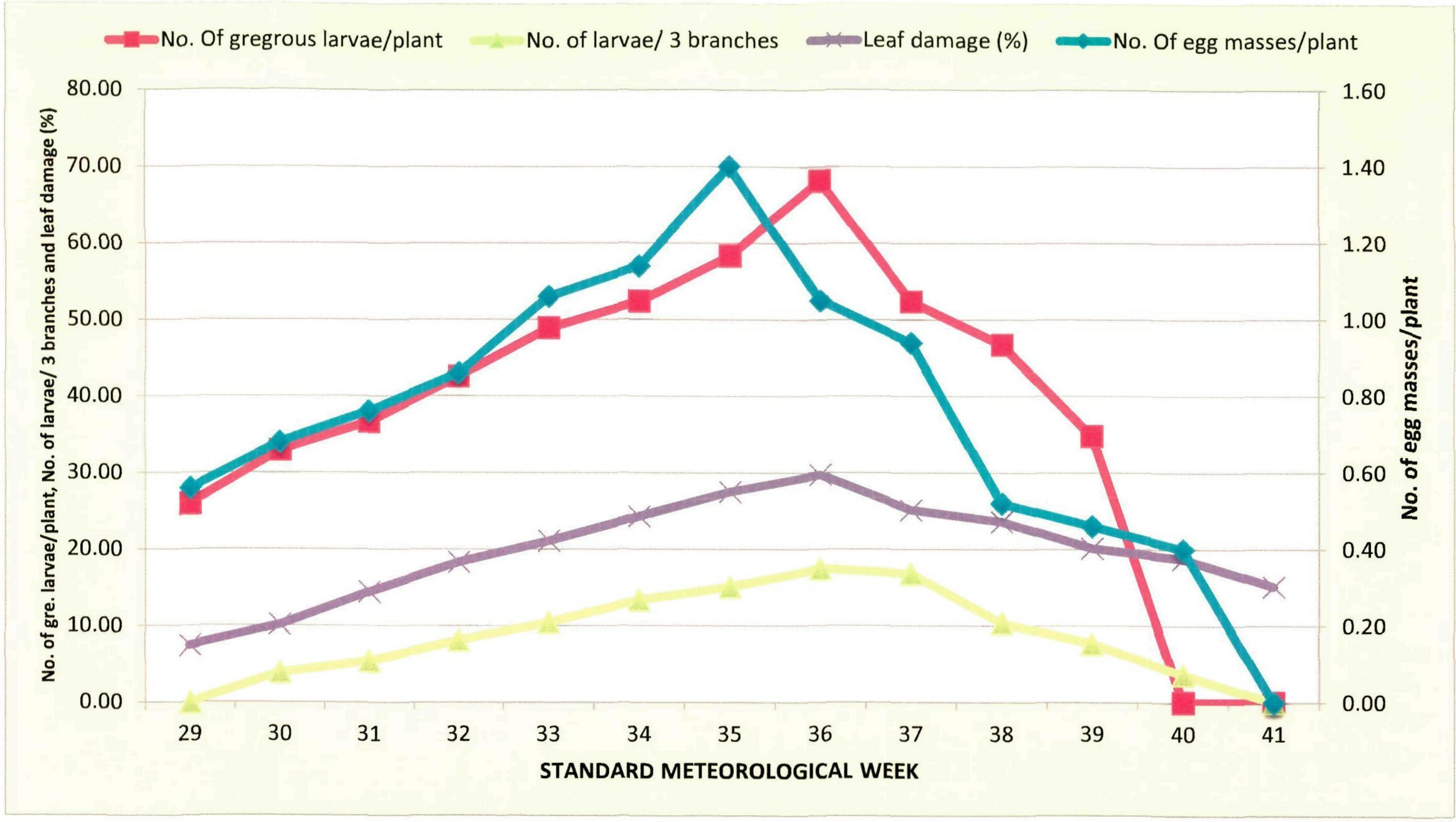


Fig. 3: Seasonal abundance of *S. obliqua* on black gram

The gregarious larval population started on crop (26.00 larvae/ plant) in the 29th standard meteorological week (3rd week of July) and the population was found till 39th standard meteorological week (4th week of September). The number of gregarious larva were steadily increased from 29th standard meteorological week and reached to peak level (68.12 larvae/plant) in the 36th standard meteorological week (1st week of September). Thereafter, the gregarious larval population was slowly decreased up to 39th standard meteorological week (4th week of September) and disappeared from the crop from 40th standard meteorological week (1st week of October). The bigger larval population was first found (3.88 larvae/3 branches) from 30th standard meteorological week (4th week of July) and it was continued till 40th standard meteorological week (1st week of October) with peak level (17.46 larvae/plant) in the 36th standard meteorological week (1st week of September). Thereafter the activity was slowly decreased up to 40th standard meteorological week (1st week of October). The activity of bigger size larvae was not found from 41th standard meteorological week (2nd week of October) in the crop.

The population of larvae was also reflected on leaf damage. The damaged leaves were found from 29th standard meteorological week (3rd week of July) to 41th standard meteorological week (2nd week of October). As larval population increased, the damage was also increased in black gram. The leaf damage was found to be 7.42 per cent on first appearance of the pest (3rd week of July). The maximum damage (29.75 %) was found in the 36th standard meteorological week

(1st week of September). After 36th standard meteorological week, the leaf damage gradually decreased up to 41th standard meteorological week (2nd week of October). The higher damage (21.10 to 29.75 %) was noticed during 3rd week of August (33th standard meteorological week) to 3rd week of September (38th standard meteorological week).

The above results clearly indicated that the pest started its activity on black gram from 3rd week of July (29th standard meteorological week) and continued till 1st week of October (40th standard meteorological week) which was also reflected on damage on the crop. The higher activity and damage was found during 3rd week of August to 3rd week of September (38th standard meteorological week).

4.2.1.4 Soybean

The data (Table 9 and figure 6) on population count showed that the pest started egg laying (0.55 egg mass/plant) on soybean crop from 32th standard meteorological week (2nd week of August) and it was continued till 42th standard meteorological week (3rd week of October). Maximum egg masses (1.65 egg masses/plant) were laid in the 37th standard meteorological week (2nd week of September). The gregarious larval population first found on crop (25.98 larvae/ plant) in the 33th standard meteorological week (3rd week of August) and the population found till 43th standard meteorological week (4th week of October). The number of gregarious larva were steadily increased from 33th standard meteorological week and reached to peak level (78.42 larvae/plant) in the 38th standard meteorological week (3rd week of September).

Table 7: Seasonal abundance of *S. obliqua* and its damage on soybean

Month/ Week		SMW	WAS	No. of egg masses /plant	No. of gregrous larvae/plant	No. of larvae/ 3 branches	Leaf damage (%)
Aug.	I	**31**	3	0.00	0.00	0.00	0.00
	II	**32**	4	0.55	0.00	0.00	0.00
	III	**33**	5	0.76	25.98	5.64	10.72
	IV	**34**	6	0.86	44.46	7.78	12.07
	V	**35**	7	1.24	56.88	9.53	15.21
Sept	I	**36**	8	1.26	70.90	13.45	21.05
	II	**37**	9	1.65	76.65	15.70	24.20
	III	**38**	10	1.13	78.42	17.64	30.45
	IV	**39**	11	1.06	60.56	15.82	27.32
Oct.	I	**40**	12	0.74	53.75	14.28	26.07
	II	**41**	13	0.58	48.14	12.58	22.72
	III	**42**	14	0.34	37.76	10.90	20.33
	IV	**43**	15	0.00	24.33	7.64	18.12
Nov.	I	**44**	16	0.00	0.00	0.00	15.05

SMW: Standard Meteorological Week **WAS:** Week after sowing

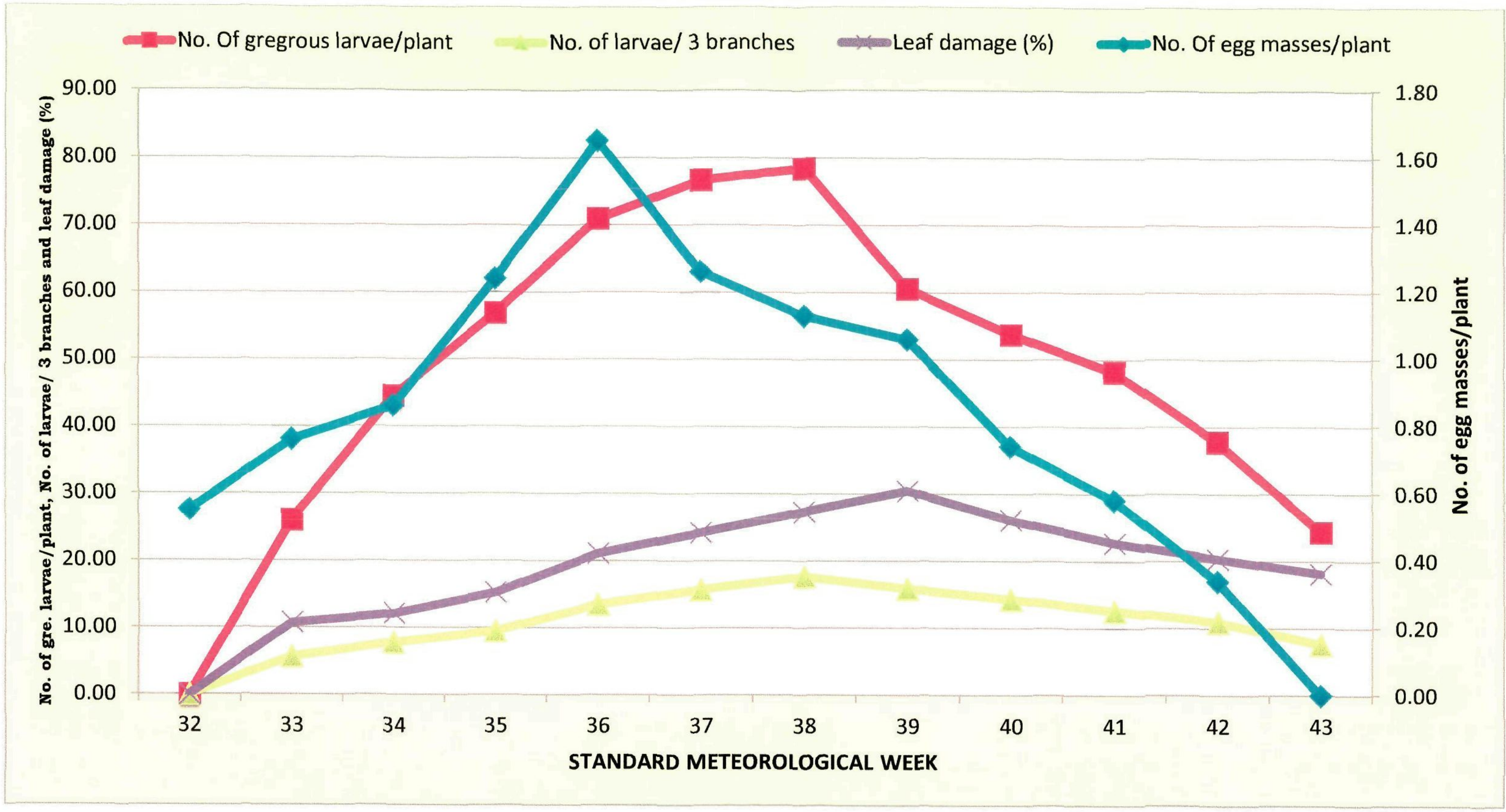


Fig. 4: Seasonal abundance of *S. obliqua* on soybean

Thereafter, the gregarious larval population was slowly decreased up to 43th standard meteorological week (4th week of October) and disappeared from the crop from 44th standard meteorological week (1st week of November). The larval activity first found (5.64 larvae/3 branches) from 33th standard meteorological week (3rd week of August) and it was continued till 43th standard meteorological week (4th week of October) with peak level (17.64 larvae/plant) in the 38th standard meteorological week (3rd week of September). Thereafter, the activity was slowly decreased up to 43th standard meteorological week (4th week of October). The activity of bigger size larvae was not found from 44th standard meteorological week (1st week of November) in the crop.

The leaf damage was dependent on larval population. The damaged leaves were found from 33th standard meteorological week (3rd week of August) to 44th standard meteorological week (1st week of November). As larval population increased, the damage was also increased in soybean. The leaf damage was found to be 10.72 per cent on appearance of the pest. The maximum damage (30.45%) was found in the 38th standard meteorological week (3rd week of September). After 38th standard meteorological week, the leaf damage gradually decreased up to 44th standard meteorological week (1st week of November). The higher damage (21.05 to 30.45 %) was noticed during 1st week of September (36th standard meteorological week) to 2nd week of October (41th standard meteorological week).

The above results indicated that the pest started its activity on soybean from 3rd week of August (33th standard meteorological week) and continued till 4th week of October (43th standard

Cowpea

Green gram

Black gram

Soybean

Plate 4. Damage caused by *S. obliqua* in various pulse crops

meteorological week) which was also reflected on damage on crop. The higher activity and damage was found during 1st week of September to 2nd week of October (41th standard meteorological week). No information is available on population of *S. obliqua* in the literature and hence the present findings are not discussed with the reports of earlier workers.

4.2.2 Correlation between *S. obliqua* and weather parameter

4.2.2.1 Cowpea

The correlation analysis (Table 11) revealed that evaporation and wind speed were positively correlated but non-significant effect on *S. obliqua* population. While in case of minimum temperature, evening relative humidity and rainfall had negative correlation but non-significant effect on *S. obliqua* population. Whereas, other weather parameters having either positive or negative correlation but non-significant effect on *S. obliqua* population.

4.2.2.2 Green gram

The correlation analysis (Table 12) clearly indicate that bright sunshine hours (r =0.771*) and maximum temperature (r =0.678*) were significantly positively correlated with number of gregarious feeder larvae whereas evening relative humidity (r =-0.844**) had highly significant negative association with number of gregarious feeder larvae. These indicate that the increases in bright sunshine hours and maximum temperature caused increase in number of gregarious feeder larvae while decrease in evening relative humid. Whereas, other weather parameters having either positive or negative correlation but non-significant effect on *S. obliqua* population.

Table 2: Duration of different stages of *S. obliqua*				
Sr. No.	**Life stage**	**Periods (days)**		
		Min.	**Max.**	**Mean ± SD**
1	**Egg**	3	5	3.68±0.63
	Hatching (%)	78	92	85.60±4.80
2	**Larva**			
	I instar	2	4	3.12±0.78
	II instar	3	4	3.44±0.51
	III instar	3	4	3.56±0.51
	IV instar	2	3	2.56±0.51
	V instar	3	4	3.72±o.46
	VI instar	2	3	2.72±0.46
	VII instar	2	3	2.60±0.50
	Total	17	25	21.72±1.67
3	**Pre-pupa**	2	3	2.60±0.50
4	**Pupa**			
	Male	8	10	9.04±0.73
	Female	9	10	9.36±0.49
5	**Adult**			
	Pre-oviposition	2	4	2.40±0.50
	Oviposition	4	6	5.16±0.85
	Post-oviposition	2	4	2.84±0.75
	Longevity			
	Male	4	6	5.00±0.82
	Female	6	8	7.08±0.81
	Fecundity	760	1420	976.84±194.58
	Sex ratio (Male : Female)			
	Laboratory	1:1.6	1:4.2	1:3.02
6	**Total life span: Egg to adult death**			
	Male	33	40	36.57 ± 2.29
	Female	42	47	43.30 ± 3.94

Table 3: Measurements of different stages of *S. obliqua*					
Sr. No.	**Life stage**	**Particulars**	**Measurement (mm)**		
			Min.	**Max.**	**Mean ± SD**
1	**Egg**	Diameter	0.80	1.30	1.08±0.21
2	**Larva**				
	I instar	Length	3.51	5.70	4.54±0.82
		Breadth	0.55	1.06	0.79±0.22
		Head capsule	0.30	0.44	0.38±0.04
	II instar	Length	6.30	8.99	7.56±1.11
		Breadth	1.45	1.74	1.59±0.11
		Head capsule	0.50	0.68	0.59±0.05
	III instar	Length	9.49	10.42	9.90±0.40
		Breadth	1.84	2.20	2.01±0.16
		Head capsule	0.68	0.78	0.73±0.04
	IV instar	Length	17.21	19.05	18.34±0.80
		Breadth	2.10	3.00	2.36±0.28
		Head capsule	1.02	1.38	1.27±0.08
	V instar	Length	19.13	23.93	22.08±1.91
		Breadth	2.80	3.60	3.30±0.56
		Head capsule	1.92	2.15	2.00±0.08
	VI instar	Length	24.75	28.25	26.29±1.14
		Breadth	4.20	5.92	5.10±0.56
		Head capsule	2.22	3.20	2.81±0.28
	VII instar	Length	30.20	36.55	34.96±1.65
		Breadth	6.00	6.90	6.5±0.42
		Head capsule	3.00	3.65	3.27±0.23
3	**Pre-pupa**	Length	21.5	26.80	24.71 ± 1.58
		Breadth	3.50	4.50	4.06 ± 0.32
4	**Pupa**				
	Male	Length	19.20	22.40	21.02±1.90
		Breadth	4.9	6.20	5.54±0.43
	Female	Length	21.00	23.40	22.19±0.84
		Breadth	4.95	6.50	5.73±0.48

5	**Adult**				
	Antennae	Length	6.74	11.26	9.09±1.47
	Leg				
	Fore legs	Length	6.87	10.23	8.59±1.26
	Middle legs	Length	5.88	8.22	7.01±0.78
	Hind legs	Length	9.84	12.53	11.12±0.76
	Wing				
	Fore wing	Length	16.32	20.80	18.53±1.31
		Breadth	6.0	9.44	7.91±1.08
	Hind wing	Length	9.83	13.47	11.82±1.13
		Breadth	6.33	8.84	7.57±0.71
	Male	Length	19.10	22.40	20.33±0.95
		Breadth	3.42	5.66	4.60±0.62
	Female	Length	20.44	24.82	22.52±1.49
		Breadth	3.75	5.25	4.58±0.52

Table 8: Correlation between weather parameters and population of *S. obliqua* in cowpea			
Weather parameters	**Correlation co-efficient (r)**		
	No. of egg masses/plant	**No. of gregarious feeder larvae/plant**	**No. of larvae/ 3 branches**
Bright Sunshine Hours, hrday^{-1}	0.311	-0.078	-0.119
Minimum Temperature, ^{0}C	0.286	0.212	0.010
Maximum Temperature, ^{0}C	0.379	0.00	-0.083
Morning Relative Humidity (%)	-0.523	-0.340	-0.073
Evening Relative Humidity (%)	-0.418	-0.093	-0.040
Wind Speed, kmhr^{-1}	0.554*	0.683*	0.449
Rainfall, mm	-0.149	0.039	-0.125
Evaporation, mm day-1	0.548	0.259	0.142

* Significant at 5 % level (r =± 0.553) ** Significant at 1 % level (r =± 0.684) N = 14

Table 9: Correlation between weather parameters and population of *S. obliqua* in green gram

Weather parameters	Correlation co-efficient (r)		
	No. of egg masses/plant	No. of gregarious feeder larvae/plant	No. of larvae/ 3 branches
Bright Sunshine Hours, $hrday^{-1}$	-0.033	0.544	0.278
Minimum Temperature, ^{0}C	0.188	0.354	0.126
Maximum Temperature, ^{0}C	0.047	0.581*	0.283
Morning Relative Humidity (%)	-0.219	-0.592*	-0.349
Evening Relative Humidity (%)	-0.153	-0.641*	-0.401
Wind Speed, $kmhr^{-1}$	0.519	0.490	0.536
Rainfall, mm	-0.115	-0.058	-0.033
Evaporation, mm day-1	0.202	0.362	0.344

* Significant at 5 % level (r = ± 0.553) ** Significant at 1 % level (r = ± 0.684) N= 14

4.2.2.3 Black gram

The correlation analysis (Table 13) revealed that bright sunshine hours was significantly positively correlated with number of larvae/3 branch (r = 0.643*) indicating that the increase in this factor caused increase in number of larvae. Evening relative humidity had highly significant negative association with number of larvae/3 branch (r = -0.746**). Whereas, other weather parameters had either positive or negative correlation but non-significant effect on egg masses and larval population

4.2.2.4 Soybean

The correlation analysis (Table 16) revealed that morning relative humidity had positive association but non-significant effect on *S. obliqua* population. While in case of evaporation had negative correlation but non-significant effect on *S. obliqua* population. Whereas, other weather parameters were had either positive or negative association but non-significant effect on egg masses and larval population. Similar research work on same crop was not been reported by any of the earlier workers. However, Thakur and Kaistha (1994) observed that *S. obliqua* appeared in the sesame crop from the second week of August to third week September at vegetative to pod maturity stage and the peak infestation (3 larvae/ plant) occurred during last week of August in Himachal Pradesh.

Table 10: Correlation between weather parameters and population of *S. obliqua* in black gram

Weather parameters	Correlation co-efficient (r)		
	No. of egg masses/plant	**No. of gregarious feeder larvae/plant**	**No. of larvae/ 3 branches**
Bright Sunshine Hours, hrday^{-1}	0.068	0.292	0.528
Minimum Temperature, ^{0}C	0.102	0.359	0.156
Maximum Temperature, ^{0}C	0.116	0.375	0.538
Morning Relative Humidity (%)	-0.208	-0.445	-0.473
Evening Relative Humidity (%)	-0.267	-0.443	-0.650*
Wind Speed, kmhr^{-1}	0.465	0.576*	0.389
Rainfall, mm	-0.190	-0.037	-0.158
Evaporation, mm day-1	0.175	0.253	0.342

* Significant at 5 % level (r = ± 0.553) ** Significant at 1 % level (r = ± 0.684) N= 14

Table 11: Correlation between weather parameters and population of *S. obliqua* in soybean			
Weather parameters	**Correlation co-efficient (r)**		
	No. of egg masses/plant	**No. of gregarious feeder larvae/plant**	**No. of larvae/ 3 branches**
Bright Sunshine Hours, $hrday^{-1}$	-0.213	0.106	0.116
Minimum Temperature, ^0C	0.493	0.193	-0.017
Maximum Temperature, ^0C	-0.395	-0.240	-0.041
Morning Relative Humidity (%)	0.249	0.246	0.177
Evening Relative Humidity (%)	0.531	0.263	-0.009
Wind Speed, $kmhr^{-1}$	0.656*	0.347	0.190
Rainfall, mm	0.259	0.072	0.142
Evaporation, mm day-1	-0.299	-0.028	-0.019
* Significant at 5 % level (r =± 0.553) ** Significant at 1 % level (r = ± 0.684) N= 14			

4.3 Bio-efficacy of different insecticides against *S. obliqua* on cowpea in laboratory as well as field conditions

To find out the effective and economic insecticides for the management of *S. obliqua* infesting cowpea, different nine insecticides were evaluated in the laboratory as well as field conditions during *kharif*, 2013. The data obtained from these trials are presented in Table 12 and 13, respectively.

4.3.1 Laboratory trial

Different insecticides were evaluated for their bio-efficacy against *S. obliqua* in laboratory condition. The mortality of *S. obliqua* larvae was recorded and corrected per cent mortality was worked out. Thus, the data obtained are presented in Table 12 and depicted in Fig 5.

After one day of spraying, maximum larval mortality of *S. obliqua* (71.93 %) was recorded in the treatment of thiodicarb 75 WP and it was at par with fenvalerate 0.4 % DP (61.30%) and novaluron 10 EC (57.67 %). However fenvalerate 0.4 % DP and novaluron 10 EC were again at par with methomyl 40 SP, quinalphos 25 EC, chlorphyrifos 20 EC and emamectin benzoate 5 SG showing 54.11, 54.11, 50.70 and 43.82 per cent larval mortality, respectively. Among the tested insecticides, the lowest larval mortality was observed in the treatment of phenthoate 50 EC (32.59 %) and it was at par with spinosad 45 SC (32.75 %).

The maximum larval mortality of *S. oblique* (79.04 %) after two days of spraying was recorded in thiodicarb 75 WP and it was at par with chlorphyrifos 20 EC (71.32 %), methomyl 40 SP (64.30 %), fenvalerate 0.4 % DP (63.88 %) and emamectin benzoate 5 SG (63.04 %). However, previous insecticides except thiodicarb 75 WP were also at par with novaluron 10 EC (60.19 %) and quinalphos 25 EC (57.03 %). Among the evaluated insecticides, significantly the lowest larval mortality was exhibited in spinosad 45 SC (38.33 %) and it was at par with phenthoate 50 EC (34.67 %).

After three days of spraying, the larval mortality was found the maximum (85.50%) in thiodicarb 75 WP and it was at par with chlorphyrifos 20 EC (74.19 %). However, chlorphyrifos 20 EC was also found at par with methomyl 40 SP, fenvalerate 0.4 % DP, emamectin benzoate 5 SG and novaluron 10 EC by registering 71.59, 70.48, 66.62 and 66.62 per cent larval mortality, respectively. Again, methomyl 40 SP, fenvalerate 0.4 % DP, emamectin benzoate 5 SG and novaluron 10 EC were also found at par with Quinalphos 25 EC (59.28 %.) Among the tested insecticides, phenthoate 50 EC (40.65 %) and spinosad 45 SC (40.65 %) recorded significantly lower larval mortality and both were at par with each other.

The larval mortality of *S. oblique* after seven days of application was recorded the maximum (88.61%) in the thiodicarb 75 WP and it was at par with chlorphyrifos 20 EC (80.93 %), fenvalerate 0.4 % DP (80.92 %) and methomyl 40 SP (77.57 %). However, methomyl 40 SP was also found at par with Quinalphos 25 EC (65.25 %), emamectin benzoate 5 SG (65.25 %) and novaluron 10 EC (65.25

Table 12: Bio-efficacy of different insecticides againstS. *obliqua*under laboratory conditions

Treatments	Larval Mortality (%)				Pooled Over Period
	1 DAS	2 DAS	3 DAS	7 DAS	
Chlorphyrifos 20 EC @ 0.04 %	45.40b (50.70)*	57.62ab (71.32)	59.47ab (74.19)	64.11ab (80.93)	56.65ab (69.78)
Thiodicarb 75 WP @ 0.015 %	58.01a (71.93)	62.75a (79.04)	67.62a (85.50)	70.28a (88.61)	64.67a (81.70)
Quinalphos 25 EC @ 0.005 %	57.36a (70.91)	49.04bc (57.03)	50.35b (59.28)	53.88b (65.25)	50.16b (58.96)
Emamectin benzoate 5 SG @ 0.0025 %	41.45bc (43.82)	53.06ab (63.04)	54.71b (66.62)	53.88b (65.25)	50.78b (60.02)
Phenthoate 50 EC @ 0.01 %	34.81c (32.59)	36.07d (34.67)	39.61c (40.65)	42.57c (45.76)	38.27c (38.36)
Spinosad 45 SC @ 0.0135 %	34.91c (32.75)	38.25cd (38.33)	39.61c (40.65)	42.57c (45.76)	38.84c (39.33)
Fenvalerate 0.4% DP	51.53ab (61.30)	53.06ab (63.88)	57.09b (70.48)	61.10ab (76.64)	56.45ab (69.46)
Novaluron 10 EC @ 0.01 %	49.41ab (57.67)	50.88ab (60.19)	54.71b (66.62)	53.88b (65.25)	52.22b (67.46)
Methomyl 40 SP @ 0.08 %	47.36ab (54.11)	53.31ab (64.30)	57.79ab (71.59)	61.73ab (77.57)	55.05b (67.18)
S. Em. ± T	3.16	3.59	2.94	3.29	2.64
P	-	-	-	-	0.73
T X P	-	-	-	-	2.18
C. D. at 5% T	9.39	10.67	8.74	9.79	7.81
P	-	-	-	-	2.06
T X P	-	-	-	-	NS
C. V. %	12.00	12.32	9.53	10.13	10.96

* Figures in parenthesis are retransformed values and those outside are *arcsine* transformed values.
Treatment means with the letter(s) in common are not significant by DNMRT at 5 % level of significance

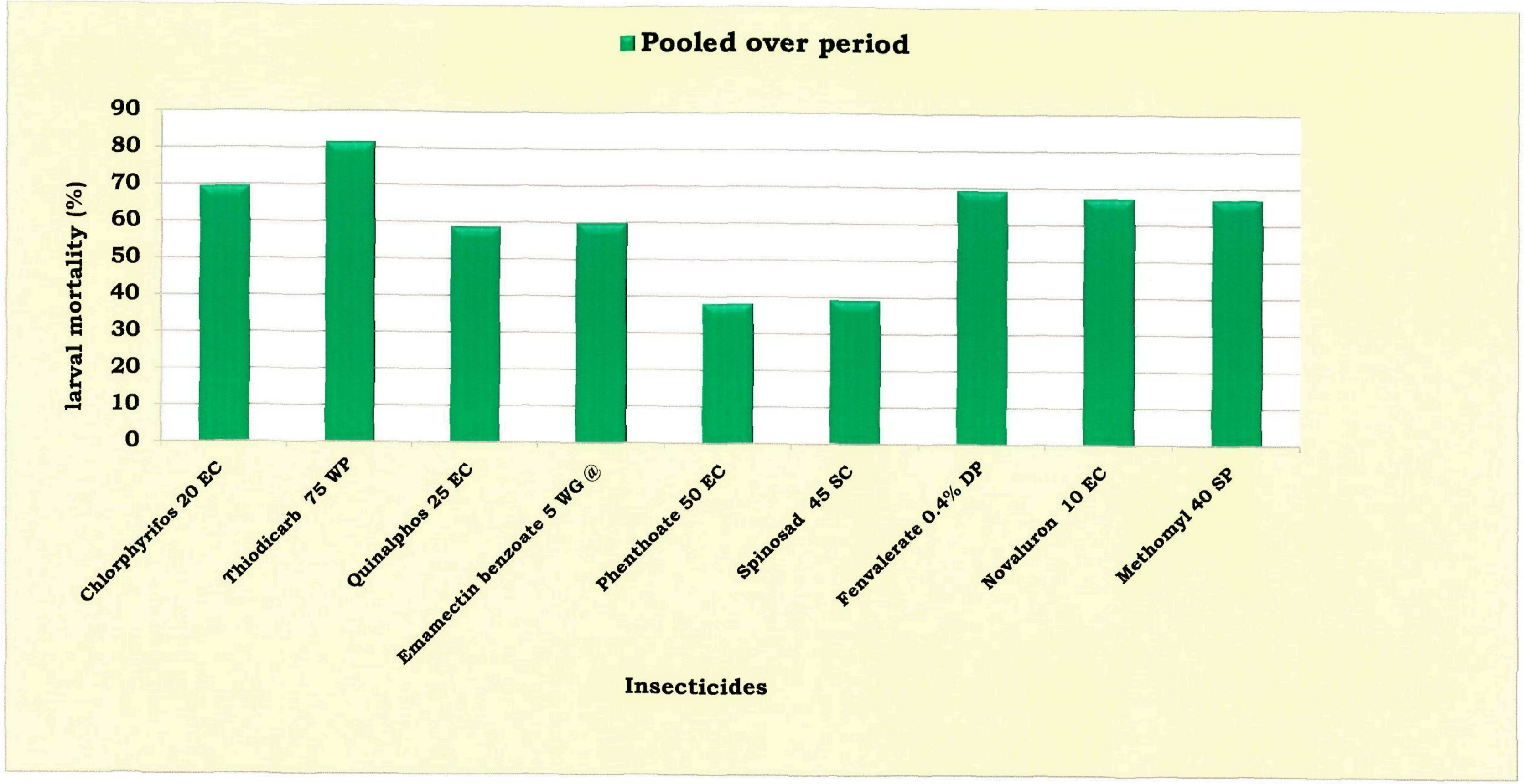


Fig. 5: Bioefficacy of different insecticides against *S. obliqua* in laboratory condition

%). Significantly the lowest (45.76 %) larval mortality was found in treatment phenthoate and spinosad 45 SC.

The pooled data on (Table 12, fig.5) percent larval mortality revealed that there were significant differences among the different insecticides. The chronological order of insecticides based on per cent mortality of *S. obliqua* larvae was: thiodicarb 75 WP (81.70 %) > chlorphyrifos 20 EC (69.78 %) > fenvalerate 0.4 % DP (69.46 %) > novaluron 10 EC (67.46 %) > methomyl 40 SP (67.18 %) > emamectin benzoate 5 SG (60.02 %) > quinalphos 25 EC (58.96 %) > spinosad 45 SC (39.33 %) > phenthoate 50 EC (38.36 %). Among the different tested insecticides, the maximum larval mortality (81.70 %) was found in treatment thiodicarb 75 WP and it was significantly superior to rest of the treatments. Insecticides chlorphyrifos 20 EC, fenvalerate 0.4 % DP, novaluron 10 EC and methomyl 40 SP were at par with each other and recorded larval mortality in the range between 67.00 to 70.00 per cent. Moreover, methomyl 40 SP was also at par with emamectin benzoate 5 SG (60.02 %) and quinalphos 25 EC (58.96 %). Among the tested insecticides under laboratory condition, the lowest (38.36 %) mortality of *S. obliqua* larva was found in phenthoate 50 EC and it was at par with spinosad 45 SC (39.33 %).

Due to lack of references in literature on efficacy of insecticides under laboratory conditions against *S. obliqua*, the present findings could not be compared and discussed with earlier reports. Hence, literature was reviewed to collect the reference on other species of hairy caterpillar and compared with the present findings. Saini (1995) reported that quinalphos 0.05 per cent and chlorpyriphos 0.05 per cent were effective against larvae of *A. moorei.* Tandi *et al.* (1993) found chlorpyriphos 0.02 per cent as most effective against *A. moorei* on guar. Shrinivasan and Haldar (2004) reported that spinosad 45 SC was more effective in controlling *A. albistriga* compared to thiodicarb.

4.3.2 Field trial

(A) Larval population

Different insecticides were evaluated for their comparative bio-efficacy against *S. obliqua* on cowpea by conducting on experiment at farm of Department of entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during *kharif,* 2013. The data obtained are presented in Table 13 and figure 6.

There was no significant difference in larval population among different treatments before spray. All the insecticidal treatments significantly reduced the larval population as compared to control during experimentation.

The observations recorded after three days of insecticidal application showed significantly lowest (1.38 larvae/plant) larval population of *S. obliqua* in plots treated with thiodicarb 75 WP. Insecticide chlorpyriphos 20 EC (2.21 larvae/plant) and fenvalerate 0.4 % DP (2.01 larvae/plant) were next best effective insecticides and both were at par with each other.

Table 13: Bioefficacy of different insecticides against *S. obliqua* infesting cowpea

Treatments	No. of larvae/plant (days after spray)					
	Before	3	5	7	10	Pooled over period
Chlorphyrifos 20 EC @ 0.04 %	5.56 (30.41)	2.21*b (4.38)	2.03bc (3.62)	1.65bc (2.22)	1.26bc (1.09)	1.80bc (2.74)
Thiodicarb 75 WP @ 0.015 %	6.09 (36.59)	1.38a (1.40)	1.09a (0.69)	0.92f (0.35)	0.62a (0.12)	1.00a (0.50)
Quinalphos 25 EC @ 0.005 %	6.15 (37.32)	3.48de (11.61)	2.92de (8.03)	2.71ef (6.84)	1.67cde (2.29)	2.70e (6.79)
Emamectin benzoate 5 SG @ 0.0025 %	6.18 (37.69)	3.66ef (12.90)	3.11e (9.17)	2.94fg (8.14)	1.85de (2.92)	2.90e (7.91)
Phenthoate 50 EC @ 0.01 %	6.13 (37.08)	4.42g (19.04)	4.00f (15.50)	3.60h (12.46)	1.94e (3.26)	3.49f (11.68)
Spinosad 45 SC @ 0.0135 %	5.94 (34.78)	4.24fg (17.48)	3.77f (13.71)	3.36gh (10.79)	1.98e (3.42)	3.34f (10.66)
Fenvalerate 0.4% DP	6.06 (36.22)	2.04b (3.66)	1.63b (2.16)	1.51b (1.78)	0.91ab (0.33)	1.51b (1.78)
Novaluron 10 EC @ 0.01 %	6.07 (36.34)	2.89cd (7.85)	2.43cd (5.40)	2.31de (4.84)	1.54cde (1.87)	2.30d (4.79)
Methomyl 40 SP @ 0.08 %	6.10 (36.71)	2.61bc (6.31)	2.34c (4.98)	2.07cd (3.78)	1.50cd (1.75)	2.13cd (4.03)
Control (water spray)	6.23 (38.31)	5.20h (26.54)	4.75g (22.06)	4.55i (20.20)	3.33f (10.59)	4.45f (19.30)
S. Em. ± T	0.55	0.19	0.16	0.17	0.13	0.10
P	-	-	-	-	-	0.05
T×P	-	-	-	-	-	0.15
C.D. at 5 % T	NS	0.57	0.48	0.50	0.38	0.32
P	-	-	-	-	-	0.13
T×P	-	-	-	-	-	0.41
C.V. (%)	**15.77**	**10.30**	**9.86**	**11.45**	**13.27**	**9.90**

*** Figures outside the parenthesis are $\sqrt{X+0.5}$ transformed values, those inside are retransformed values**
Treatment means with the letter(s) in common are not significant by DNMRT at 5 % level of significance

However, methomyl 40 SP (2.61 larvae/plant) was also at par with novaluron 10 EC (2.89 larvae/plant). Quinalphos 25 EC and emamectin benzoate 5 SG treated plots were found 3.48 and 3.66 larvae per plant, respectively. Among the evaluated insecticides, the plots treated with spinosad 45 SC and phenthoate 50 EC recorded highest (4.24 and 4.42 larvae/plant, respectively) larval population of *S. obliqua* as compared to the other insecticidal treatments.

After five days of spraying, thiodicarb 75 WP treated plots registered significantly lowest larval population (1.09 larvae/ plant) of the *S. obliqua*. Fenvalerate 0.4 % DP and chlorpyriphos 20 EC were found equally effective in reducing larval population by registering 1.63 and 2.03 larvae per plant, respectively. However, chlorpyriphos 20 EC was also at par with methomyl 40 SP (2.34 larvae/plant) and novaluron 10 EC (2.43 larvae/plant). Quinalphos 25 EC (2.92 larvae/plant) and emamectin benzoate 5 SG (3.12 larvae/plant) were also found at par with each other. Spinosad 45 SC and phenthoate 50 EC treated plots recorded higher larval population (3.78 and 4.01/plant, respectively) and were found less effective (Table 13).

After seven days of spraying, all the insecticides treatments were significantly superior to control in checking the larval population (Table 19). Among different insecticides tested thiodicarb 75 WP was found significantly superior to rest of the insecticides and registered lowest larval population (0.92 larvae/ plant). Rest of the insecticides viz, fenvalerate 0.4 % DP (1.52 larvae/ plant), chlorpyriphos 20 EC (1.66 larvae/plant), methomyl 40 SP (2.07 larvae/plant), novaluron 10

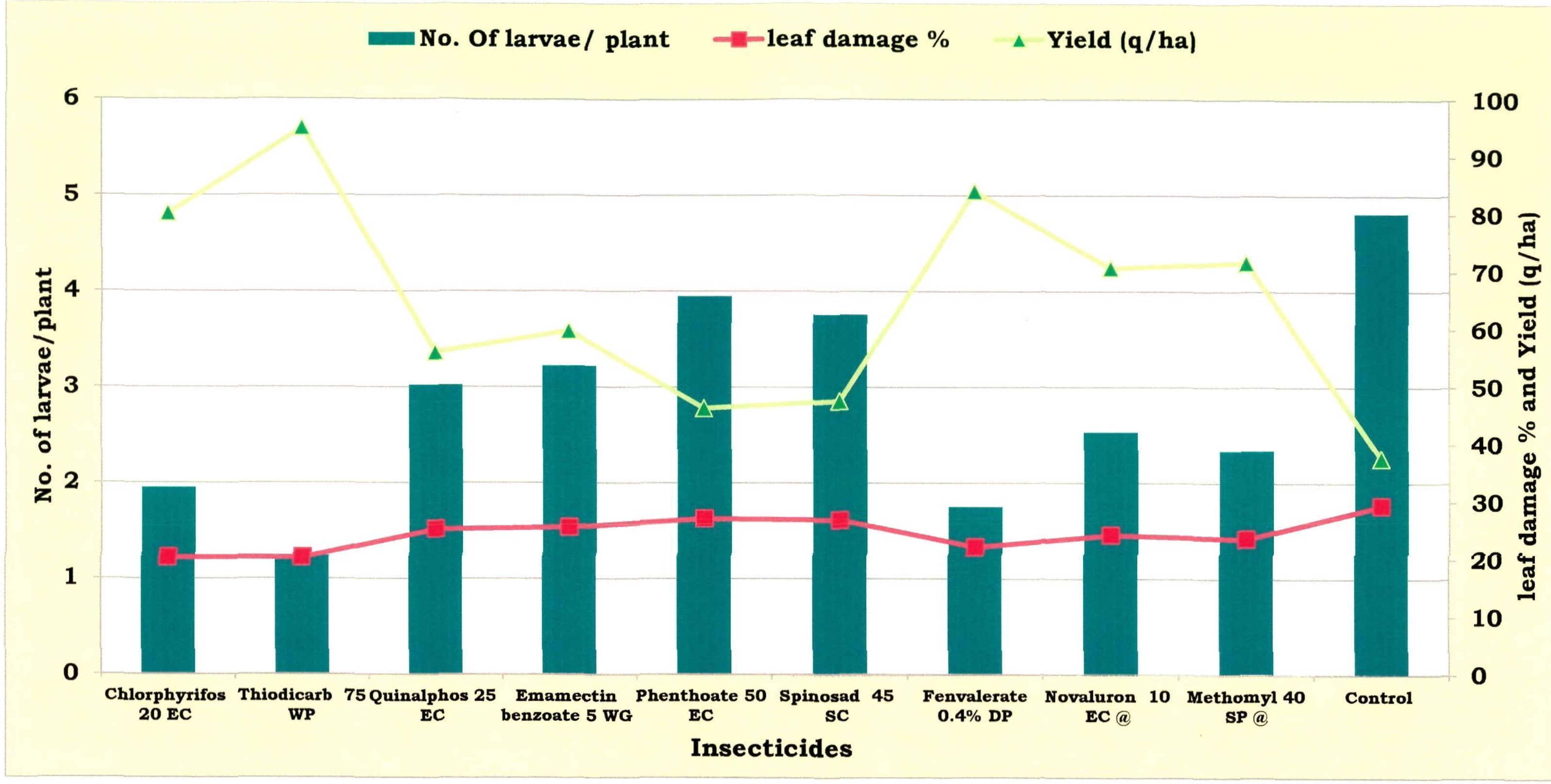


Fig. 6: Efficacy of different insecticides on *S. obliqua* and yield of cowpea (pooled over period)

EC (2.31 larvae/plant), quinalphos 25 EC (2.71 larvae/plant), emamectin benzoate 5 SG (2.94 larvae/plant), spinosad 45 SC (3.36 larvae/plant) and phenthoate 50 EC (3.60 larvae/plant) were found more or less equally effective.

After ten days of spraying, significantly lowest (0.62 larvae/plant) larval population of *S. obliqua* was recorded in the plot treated with thiodicarb 75 WP (Table 19). Fenvalerate 0.4 % DP (0.91 larvae/plant) and chlorpyriphos 20 EC (1.26 larvae/plant) were found next best treatment and they were found at par with each other. Insecticides methomyl 40 SP (1.50 larvae/plant) and novaluron 10 EC (1.55 larvae/plant) as well as quinalphos 25 EC (1.67 larvae/plant) and emamectin benzoate 5 SG (1.86 larvae/plant) were found at par with each other. Among the tested insecticides, significantly the highest (1.94 larvae/plant) larval population was recorded in the plot treated with phenthoate 50 EC and it was at par with Spinosad 54 SC (1.98 larvae/plant). Both were found less effective in reducing larval population.

Pooled over periods

The data of Pooled over period (Table 13 and figure 6) recorded that thiodicarb 75 WP was found to be significantly superior to rest of the treatment by registering lowest larval population (1.00 larvae/ plant). Fenvalerate 0.4 % DP and chlorpyriphos 20 EC were found next effective insecticides by exhibiting 1.51 and 1.79 larvae per plant, respectively. The plots treated with methomyl 40 SP (2.13 larvae/plant) and novaluron 10 EC (2.29 larvae/plant) as well as quinalphos 25 EC (2.69 larvae/plant) and emamectin benzoate 5 SG (2.89 larvae/plant) were the mediocre insecticides in reducing larval population and they were at par with each other. Of the tested insecticides, higher larval population (3.34 larvae/plant) was found in phenthoate 50 EC treated plots and it was at par with spinosad 45 SC (3.49 larvae/plant).

Manjula (2003) reported that spraying quinalphos @ 0.05% recorded 95.45% larval mortality of *A. albistriga* on groundnut. Again Manjula (2004) found that chlorpyriphos was most effective compound followed by monocrotophos, methomyl and quinalphos in controlling *A. albistriga.* Ganiger and Sannaveerappanavar (2007) reported fenvalerate 0.4 DP as most effective followed by malathion, methyl parathion, quinalphos and monocrotophos against *A. albistriga* on groundnut. The present findings are in the conformity with the findings of Kadapatti *et al.,* (1996) who reported that the dust formulation of fenvalerate was found more effective than the emulsify concentration against Bihar hairy caterpillar, *S. oblique* on sunflower.

(B) Based on leaf damage

The periodical data on leaf damage caused by *S. obliqua* infesting cowpea are presented in Table 14. The leaf damage was more or less equal before spray in all the treatments as difference was non-significant. All the insecticides significantly reduced the leaf damage compared to control up to 10 days of spray and even in pooled over periods analysis.

After three days of application (Table 14), the lowest (9.13 %) leaf damage was noticed in thiodicarb 75 WP treated plots and it was at par with chlorpyriphos 20 EC and fenvalerate 0.4 % DP which registered 11.14 and 11.80 per cent damage, respectively. However, chlorpyriphos 20 EC and fenvalerate 0.4 % DP were also found at par with methomyl 40 SP and novaluron 10 EC by exhibiting 12.88 and 13.68 per cent leaf damage, respectively. However, methomyl 40 SP and novaluron 10 EC were also found at par with quinalphos 25 EC and emamectin benzoate 5 SG by registering 15.10 and 15.75 per cent leaf damage, respectively. The highest leaf damage (17.61 %) was noted in plots treated with phenthoate 50 EC and it was at par with spinosad 45 SC (17.10 %).

After five days of spraying, all treatments were found superior to control. The lowest (11.13 %) leaf damage was recorded in the plots treated with thiodicarb 75 WP and it was at par with fenvalerate 0.4 % DP and chlorpyriphos 20 EC which registered 13.09 and 13.77 per cent damage, respectively. Methomyl 40 SP, novaluron 10 EC, quinalphos 25 EC and emamectin benzoate 5 SG treated plots registered 14.33 to 17.74 per cent leaf damage and they were at par with each other. The highest (19.80 %) leaf damage was observed in plots treated with phenthoate 50 EC and it was at par with spinosad 45 SC (19.11 %).

Table 14: Efficacy of different insecticides on leaf damage caused by *S. obliqua* in cowpea

Treatments		Leaf damage (%) (days after spray)					
		Before	3	5	7	10	Pooled over period
Chlorphyrifos 20 EC @ 0.04 %		14.92 (6.63)	19.50ab (11.14)	21.78ab (13.77)	23.40abc (15.77)	24.88ab (17.70)	22.39ab (14.51)
Thiodicarb 75 WP @ 0.015 %		14.71 (6.45)	17.59a (9.13)	19.49a (11.13)	21.25a (13.14)	22.90a (15.14)	20.31a (12.05)
Quinalphos 25 EC @ 0.005 %		17.09 (8.64)	22.87cd (15.10)	24.43bc (17.10)	25.92bcd (19.11)	27.80bcd (21.75)	25.26cd (18.21)
Emamectin benzoate 5 SG @ 0.0025 %		14.71 (6.45)	23.37cde (15.75)	24.91bc (17.74)	26.39cd (19.76)	27.82bcd (21.78)	25.60de (18.67)
Phenthoate 50 EC @ 0.01 %		13.29 (5.28)	24.96e (17.61)	26.42cd (19.80)	27.84de (21.81)	29.20cd (23.80)	27.10e (20.75)
Spinosad 45 SC @ 0.0135 %		15.59 (7.22)	24.43e (17.10)	25.92cd (19.11)	27.35de (21.11)	29.65cd (24.47)	26.84e (20.39)
Fenvalerate 0.4% DP %		14.92 (6.63)	20.09bc (11.80)	21.21ab (13.09)	22.87ab (15.10)	24.43ab (17.10)	22.15b (14.22)
Novaluron 10 EC @ 0.01 %		13.16 (5.18)	21.78cd (13.68)	23.40abc (15.77)	25.44bcd (18.45)	26.40abc (19.77)	24.25cd (16.87)
Methomyl 40 SP @ 0.08 %		14.92 (6.63)	21.03bcd (12.88)	22.24ab (14.33)	24.94bcd (17.18)	26.39abc (19.76)	23.65bc (16.09)
Control (water spray)		15.59 (7.22)	27.37f (21.14)	28.75d (23.14)	30.09e (25.14)	31.37d (27.10)	29.40f (24.10)
S. Em. ±	T	1.37	1.05	1.03	0.87	1.10	0.44
	P	-	-	-	-	-	0.32
	T×P	-	-	-	-	-	1.07
C.D. at 5 %	T	NS	3.13	3.04	2.58	3.27	1.23
	P	-	-	-	-	-	NS
	T×P	-	-	-	-	-	NS
C.V. (%)		**15.90**	**8.19**	**7.44**	**5.90**	**7.03**	**7.12**

*** Figures outside the parenthesis are arcsine transformed values, those inside are retransformed values**
Treatment means with the letter(s) in common are not significant by DNMRT at 5 % level of significance

After seven days of application, the lowest (13.14 %) leaf damage was noticed in thiodicarb 75 WP treated plots and it was at par with fenvalerate 0.4 % DP which registered 15.10 per cent leaf damage. However, fenvalerate 0.4 % DP was also found at par with chlorpyriphos 20 EC and methomyl 40 SP which registered 15.77 and 17.18 per cent damage, respectively. However, methomyl 40 SP was also found at par with novaluron 10 EC, quinalphos 25 EC and emamectin benzoate 5 SG treated plots registered 17.18 to 19.76 per cent leaf damage (Table 20). Among the evaluated insecticides, the highest (21.81 %) leaf damage was noticed in the treatment of phenthoate 50 EC and followed by spinosad 45 SC (21.11 %).

All treatments were significantly superior to control after ten days of spraying, the lowest (15.14 %) leaf damage was noticed in thiodicarb 75 WP treated plots and it was at par with fenvalerate 0.4 DP and chlorpyriphos 20 EC which registered 17.10 and 17.70 per cent damage, respectively. However, The treatments of fenvalerate 0.4 % DP and chlorpyriphos 20 EC were also found at par with methomyl 40 SP and novaluron 10 EC noticed 19.76, 19.77 per cent leaf damage, respectively. However, methomyl 40 SP and novaluron 10 EC were also found at par with quinalphos 25 EC and emamectin benzoate 5 WG treated plots registered 21.75 to 21.78 per cent leaf damage, respectively. Of the evaluated insecticides, the highest (24.47 %) leaf damage was found in plots treated with spinosad 45 SC followed by phenthoate 50 EC (23.80 %).

Result obtained from Pooled data (Table 14) clearly showed that the plots treated with thiodicarb 75 WP was proved significantly superior (12.05 %) to all the tested insecticides in checking the leaf damage caused by *S. obliqua* on cowpea. The treatments of fenvalerate 0.4 % DP and chlorpyriphos 20 EC exhibited leaf damage 14.22 and 14.51 per cent and they were at par with each other (Fig. 9). Methomyl 40 SP, novaluron 10 EC, quinalphos 25 EC and emamectin benzoate 5 SG treated plots registered 16.09 to 18.67 per cent leaf damage and they were at par with each other. Among the tested insecticides, the highest (20.75 %) leaf damage was recorded in plots treated with phenthoate 50 EC and it was at par with spinosad 45 SC (20.39 %). No information is available on leaf damage caused by *S. obliqua* infesting cowpea in the literature and hence the present findings are not discussed with the reports of earlier workers.

4.3.3 Yield, avoidable losses and economics

The main goal of pest management is to suppress the target pests by using different components and to increase yield and economics. Therefore, to determine the effects of various synthetic insecticides the data on green pod yield were recorded from various treatments. On the basis of yield, increase in yield over control and avoidable losses were calculated, whereas by using cost of treatments, Incremental Cost Benefit Ratio (ICBR) was calculated. Thus, data obtained on yield, avoidable losses and economics are presented in Table 15 to 16.

Yield

The maximum cowpea green pods yield (94.97 q/ha) was obtained from the plots treated with thiodicarb 75 WP. It was significantly superior to rest of the insecticidal treatments in producing green pods. The yield produced in fenvalerate 0.4 % DP, chlorpyriphos 20 EC, methomyl 40 SP and novaluron 10 EC were 84.07, 80.18, 71.70 and 70.73 q/ha, respectively and they were at par with each other (Table 15 and fig. 6) but significantly higher than remaining insecticides. The treatments of emamectin benzoate 5 SG and quinalphos 25 EC produced 59.73 and 56.06 q/ha yield of cowpea green pods, respectively. The lowest (46.31 q/ha) yield was harvested from the treatment of phenthoate 50 EC and it was at par with spinosad 45 SC (47.61 q/ha).

Increase yield over control

The increased in yield over control ranged from 18.67 to 60.34 per cent due to the application of different insecticides (Table 15). Maximum (60.34 %) green pods yield was increased in the plots treated with thiodicarb 75 WP followed by fenvalerate 0.4 % DP (55.20 %), chlorpyriphos 20 EC (53.03 %), methomyl 40 SP (47.47 %), novaluron 10 EC (46.75 %), emamectin benzoate 5 SG and quinalphos 25 EC treated plots increased yield between 56.06 and 59.73 per cent. The lowest (18.67 %) yield increased in phenthoate 50 EC treatment followed by spinosad 45 SC (20.89 %).

Table 15: Effect of different insecticides on yield and avoidable losses due to *S. obliqua* infesting cowpea

Insecticides	Conc. (%)	Green pod yield (q/ha)	Increased in yield over control (%)	Avoidable loss (%)
Chlorpyrifos	0.04	80.18	53.03	15.57
Thiodicarb	0.015	94.97	60.34	00.00
Quinalphos	0.005	56.06	32.82	40.97
Emamectin benzoate	0.0025	59.73	36.94	43.10
Phenthoate	0.01	46.31	18.67	51.53
Spinosad	0.0135	47.61	20.89	49.86
Fenvalerate	-	84.07	55.20	11.47
Novaluron	0.01	70.73	46.75	25.52
Methomyl	0.08	71.70	47.47	24.50
Control	-	37.66	0.00	60.34
S. Em. ±	-	2.91	-	-
C. D. at 5%	-	8.64	-	-
C. V. %	-	7.76	-	-

Table 16: Economics of different insecticides used for the control of *S. obliqua* in cowpea

Insecticides	Conc. (%)	Qty. of insecticides required for one sprays (liter or kg/ha)	Total cost of treat. for one sprays (₹/ha)	Yield (q/ha)	Gross realization (₹/ha)	Net Realization over control (₹/ha)	Net profit (₹/ha)	ICBR	NICBR
Chlorpyrifos	0.04	1.0	828	80.18	120270	63780	62952	1:76.02	1:75.02
Thiodicarb	0.015	1.0	2492	94.97	142455	85965	83473	1:33.50	1:32.50
Quinalphos	0.005	1.0	956	56.06	84090	27600	26644	1:27.87	1:26.87
Emamectin benzoate	0.0025	0.25	3030.5	59.73	89595	33105	30074.5	1:9.92	1:8.92
Phenthoate	0.01	1.0	1188	46.31	69465	12975	11778	1:9.91	1:8.91
Spinosad	0.0135	0.15	2698.05	47.61	71415	14925	1226.95	1:0.45	1:0.95
Fenvalerate	-	25	1493	84.07	126105	69615	68122	1:45.62	1:44.62
Novaluron	0.01	0.50	2218	70.73	106095	49605	47387	1:21.36	1:20.36
Methomyl	0.08	1.0	1988	71.70	107550	51060	49072	1:24.68	1:23.68
Control	-	-	-	37.66	56490	-	-	-	-

Labour charge: **For spraying- ₹ 234 /labour/day** **Market price of cowpea green pods: ₹ 1500 /quintal**

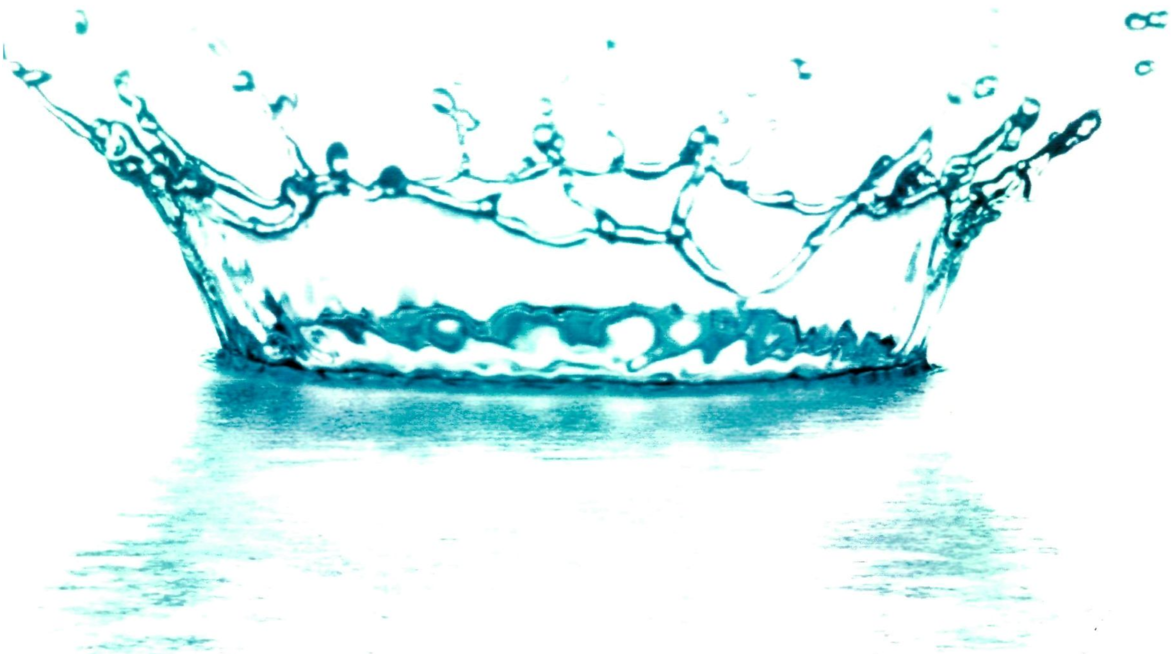
Avoidable losses

An avoidable loss in yield of cowpea green pods was varied from 11.47 to 51.53 per cent in different treatments. The avoidable loss was lowest (11.47 %) in the treatment of fenvalerate 0.4 % DP followed by chlorpyriphos 20 EC (15.57 %). The treatments of methomyl 40 SP, novaluron 10 EC, emamectin benzoate 5 SG and quinalphos 25 EC registered avoidable losses between 24.50 and 43.10 per cent (Table 15). The highest (51.53 %) avoidable loss noted in plots treated with phenthoate 50 EC followed by spinosad 45 SC (49.86 %).

Economics

Maximum (85965 ₹/ ha) net realization (Table 16) was obtained in case of thiodicarb 75 WP treated plots followed fenvalerate 0.4 % DP (69615 ₹/ ha) and chlorpyriphos 20 EC (63780 ₹/ ha). The methomyl 40 SP, novaluron 10 EC, emamectin benzoate 5 SG and quinalphos 25 EC treated plots registered net realization of 51,060, 49,605, 33,105 and 27,600 ₹/ha, respectively. The lowest (12975 ₹/ ha) net realization was obtained in plots treated with phenthoate 50 EC followed by spinosad 45 SC. Highest (75.02) NICBR was obtained in the treatment of chlorpyriphos 20 EC but this treatment was next effective after thiodicarb 75 WP against the pest. The NICBR was recorded between 20.36 and 44.62 ₹ in the treatments of novaluron 10 EC, methomyl 40 SP, quinalphos 25 EC, thiodicarb 75 WP and fenvalerate 0.4 DP. The remaining insecticides *viz.* Phenthoate 10 EC, emamectin benzoate 5 SG and spinosad 45 SC exhibited NICBR below 10.

Summary and Conclusion



V. SUMMARY AND CONCLUSION

Investigations on biology and management of Bihar caterpillar, *Spilosoma obliqua* Walker on cowpea, *Vigna unguiculata* (Linnaeus) Walpers and its population dynamics on various pulse crops were carried out at farm of Department of entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during 2013-14. The important findings emerged from the studies are summarized here in this chapter.

5.1 Biology of *S. obliqua* on cowpea

Biology of *S. obliqua* was studied on cowpea in the laboratory condition at the temperature ranging from 25.20 to 33.40 ^{0}C with an average of 28.80 ± 1.32 ^{0}C and relative humidity of 64.75 to 71.40 with an average of 66.91 ± 12.97 per cent.

It was observed that the female adults of *S. obliqua* deposited egg in masses on lower surface of the upper as well as middle leaves. They were greenish in colour and look like seed of grape from upper side and flattened at base. The dimension of freshly laid egg was measured 0.34 ± 0.04 mm in diameter with an average incubation period of 3.68 ± 0.63 days. The hatching percentage was recorded to be 78 to 92 percent on cowpea.

The newly hatched larvae of *S. obliqua* feed gregariously on lower surface of leaves by scraping its surface which resulted in to papery leaves. Larvae of third, fourth and fifth instars fed the whole leaves except veins and veinlets.

Larva passed through six instars. The freshly hatched first instar larva was creamy whitish with shining brown head and having brown spots over entire body from which white hair arises which later turn black and transparent abdominal segment distinct three pairs of prologs were clearly observed. The larva in second instar slightly increased in size having light yellow colour body with brown markings on thoracic and last abdominal segment, more hairs on the body compared to first instar and thoracic legs were black with brown abdominal legs. Third instar larva was similar to second instar but the colouration of head and body segments were little darker compared to the second instar. The fourth instar larva was uniformly yellowish in colour as the segments were brown and tuft of brownish white hairs arose from reddish brown verrucae and the head turned dark brownish black. The fifth instar larva was dark yellow with reddish tinge in colour and the heads and thoracic shields were dark brown in colour while the legs were reddish brown. The full-grown sixth instar larva had dark black head with brownish legs and uniformly reddish brown body with brownish black verrucae on which there were whitish hairs.

The larval duration of respective instars were 3.12 ± 0.78, 3.44 ± 0.51, 3.56 ± 0.51, 2.56 ± 0.51, 3.72 ± 0.46 and 2.72 ± 0.46 days, respectively. The total larval period was 19.12 ± 1.54 days.

The lengths of first, second, third, fourth, fifth and sixth instar larva were 4.54 ± 0.82, 7.56 ± 1.11, 9.90 ± 0.40, 18.34 ± 0.80, 22.08 ± 1.91 and 26.29 ± 1.14 mm, whereas breadths were 0.79 ± 0.22, 1.59 ± 0.11, 2.01 ± 0.16, 2.36 ± 0.28, 3.30 ± 0.56 and 5.10 ± 0.56 mm. The widths of the head capsule of respective instars were 0.61 ± 0.11, 1.09 ± 0.25, 1.68 ± 0.19, 2.06 ± 0.14, 2.84 ± 0.13 and 3.71 ± 0.41 mm, respectively.

The prepupal period ranged from 2 to 3 days with an average 2.60 ± 0.50 days. The lengths and widths of the pre-pupae were on an average of 24.71 ± 1.58 and 4.06 ± 0.32 mm, respectively. The newly formed pupae were soft and green or pale brown in colour. Later on, the pupa turned brownish in colour. The pupal period ranged from 8 to 10 days in case of male with an average of 9.04 ± 0.73 days while in case of female it was 9 to 10 with an average of 9.36 ± 0.49 days. The lengths and breadths of male pupae were 21.02 ± 1.90 and 5.54 ± 0.43 mm where as in case of female they were 22.19 ± 0.84 and 5.73 ± 0.48 mm, respectively.

The average longevity of male moth was recorded to be 5.00 ± 0.82 days while that of female was recorded 7.08 ± 0.81 days. Thus, the female moth lived longer than the male moth.

The pre-oviposition, ovipositional and post-ovipositional period were 2 to 4, 4 to 6 and 2 to 4 days with an average of 2.40 ± 0.50, 5.16 ± 0.85 and 2.84 ± 0.75 days, respectively.

The average longevity of male and female moths were 5.00 ± 0.82 and 7.08 ± 0.81 days, respectively. The female moth laid on an average of 976.84 ± 194.58 eggs during its entire life period. The total life span of male and female were 33 to 40 and 42 to 47 days with an average of 36.57 ± 2.29 and 43.30 ± 3.94 days, respectively.

5.2 Population dynamics of Bihar hairy caterpillar, *S. obliqua* on various pulse crops

5.2.1 cowpea

The activity of pest commenced from the 3rd week of July and continued till 1st week of October which was also reflected on damage on crop. The higher activity (35.70 to 68.13 gregrous larvae/ plant and 3.06 to 12.17 larvae/ 3 branches) and leaf damage (22.12 to 30.45 %) was found during 1st week of August to 3rd week of September. Among different weather parameters, no any parameters showed significant correlation with pest population.

5.2.2 Green gram

The pest first appeared in the 3rd week of July and continued till 2nd week of October. The higher activity (33.65 to 72.35 gregrous larvae/ plant and 8.66 to 14.55 larvae/ 3 branches) and leaf damage (21.64 to 30.57 %) was found during 2nd week of August to 3rd week of September. Among different weather parameters, bright sunshine hours and maximum temperature were found significantly positively correlated with the pest population. Whereas, evening relative humidity were found highly significantly negatively correlated with the pest population.

Black gram

The pest activity started from 3rd week of July and continued till 1st week of October. The higher activity (46.74 to 68.12 gregrous larvae/ plant and 10.36 to 17.46 larvae/ 3 branches) and leaf damage (21.10 to 29.75 %) was found during 3rd week of August to 3rd week of September. Among the different weather parameters, bright sunshine hours exhibited significant positive correlation. Whereas, evening relative humidity showed highly significant negative correlation.

Soybean

The pest first appeared in 3rd week of August and continued till 4th week of October. The higher activity (48.14 to 78.42 gregrous larvae/ plant and 12.58 to 17.64 larvae/ 3 branches) and leaf damage (21.05 to 30.45 %) was found during 1st week of September to 2nd week of October. Among different weather parameters, no any parameters showed significant correlation with pest population.

5.3 Bio-efficacy of different insecticides against *S. obliqua* on cowpea in laboratory as well as field conditions.

5.3.1 Laboratory trial

The study on bio-efficacy of different insecticides against cowpea in laboratory revealed that maximum larval mortality (81.70 %) was found in treatment thiodicarb 75 WP which was followed by chlorphyrifos 20 EC (69.78 %), fenvalerate 0.4 % DP (69.46 %), novaluron 10 EC (67.46 %), methomyl 40 SP (67.18 %), emamectin benzoate 5 SG (60.02 %) and quinalphos 25 EC (58.96 %).

5.3.2 Field trial

(A) Larval population

Minimum larval population (1.00 larvae/ plant) was found in thiodicarb 75 WP which was significantly superior to rest of the treatments. Fenvalerate 0.4 % DP and chlorpyriphos 20 EC were found next effective insecticides.

(B) Leaf damage

The data clearly showed that the plots treated with thiodicarb 75 WP was proved significantly superior (12.05 %) to all the tested insecticides in checking the leaf damage caused by *S. obliqua* on cowpea. The treatments of fenvalerate 0.4 % DP and chlorpyriphos 20 EC were found next best effective insecticides.

5.4 Yield and economics

The highest green pods yield (94.97 q/ha) was obtained from the treatment of thiodicarb 75 WP and it was significantly superior to rest of the insecticidal treatments. The yield produced in fenvalerate 0.4 % DP, chlorpyriphos 20 EC, methomyl 40 SP and novaluron 10 EC were 84.07, 80.18, 71.70 and 70.73 q/ha, respectively.

Maximum (85965 ₹/ ha) net realization was obtained in case of thiodicarb 75 WP treated plots followed by fenvalerate 0.4 % DP (69615 ₹/ ha), chlorpyriphos 20 EC (63780 ₹/ ha), methomyl 40 SP (51,060 ₹/ha), novaluron 10 EC (49,605 ₹/ha), emamectin benzoate 5

SG (33,105 ₹/ha) and quinalphos 25 EC (27,600 ₹/ha). Highest (75.02) Net increment cost benefit ratio was obtained in the treatment of chlorpyriphos 20 EC but this treatment was found next effective after thiodicarb 75 WP against the pest.

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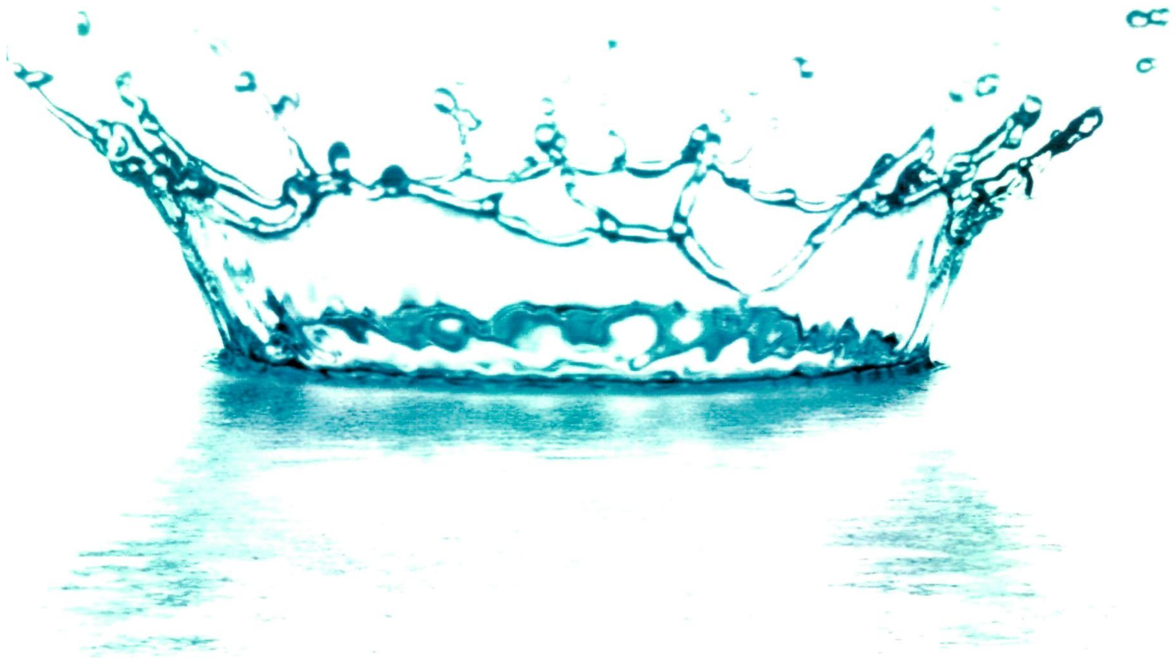

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Appendix

Appendix I: Weekly meteorological data (2013-14)

Month/ Week		SMW	EP (mm/ day)	RF (mm)	Temperature (°C)		BSS (hrs)	Vapour pressure deficit		WS (km/ hr)	Relative humidity (%)		Vapour pressure (mm)	
					Max	Min		Mor	Eve		Mor	Eve	Mor	Eve
July	I	**27**	3.5	106.0	32.4	25.6	1.6	1.45	8.29	5.9	94.6	75.0	25.3	24.9
	II	**28**	3.2	161.3	31.8	25.1	1.3	0.99	7.09	5.1	96.1	78.1	24.8	25.3
	III	**29**	2.6	52.0	31.0	25.5	2.1	1.32	6.38	5.5	95.0	80.3	25.1	26.0
	IV	**30**	1.6	172.2	29.9	25.3	0.5	0.33	2.73	5.5	98.7	90.6	25.0	26.3
Aug.	I	**31**	2.6	79.4	29.2	24.8	0.5	1.11	3.19	4.3	95.6	88.6	24.0	24.7
	II	**32**	3.6	68.0	30.6	24.8	2.7	0.54	6.32	5.5	97.9	79.9	24.6	25.0
	III	**33**	2.4	164.7	31.2	25.0	2.3	0.32	6.15	5.6	98.7	80.4	24.8	25.3
	IV	**34**	3.7	18.6	30.8	24.8	2.3	1.46	7.08	6.8	94.3	76.9	24.2	23.5
	V	**35**	4.9	0.3	32.7	24.7	7.0	1.81	13.51	6.9	92.9	61.9	23.5	21.9
Sept	I	**36**	0.8	62.4	33.4	24.7	7.3	0.94	15.18	5.2	96.3	58.9	24.3	21.7
	II	**37**	4.8	3.8	35.1	25.4	8.9	1.91	15.82	3.8	92.7	60.9	24.3	24.6
	III	**38**	5.4	45.4	34.4	25.7	6.6	2.79	10.37	6.0	89.7	70.7	24.3	25.0
	IV	**39**	2.2	288.8	29.1	24.4	1.3	0.74	4.81	7.2	97.0	83.6	23.9	24.5
Oct.	I	**40**	3.2	1.4	32.9	25.0	6.3	0.55	9.93	3.2	97.9	71.0	25.1	24.3
	II	**41**	2.0	18.7	31.2	23.7	5.1	0.38	8.46	2.4	98.4	73.6	12.4	13.5
	III	**42**	4.7	0.0	36.0	23.1	8.9	0.94	21.98	2.1	104.4	43.9	22.1	17.2
	IV	**43**	5.4	0.0	35.0	19.4	10.0	3.71	24.83	3.0	81.6	36.3	16.4	14.1
Nov.	I	**44**	3.6	0.0	34.4	17.9	8.4	1.13	20.38	1.4	93.9	45.3	17.3	16.9

EP: Evaporation, **RF**: Rainfall, **Eve**: Evening, **Min:** Minimum, **BSS:** Bright sunshine hours