"PERSISTENCE AND DISSIPATION OF INSECTICIDES AGAINST CHILLI THRIPS AND BIOLOGY OF FRUIT BORER [*Helicoverpa armigera* (Hubner)]"

A

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Abstract

"PERSISTENCE AND DISSIPATION OF INSECTICIDES AGAINST CHILLI THRIPS AND BIOLOGY OF FRUIT BORER |*Helicoverpa armigera* (HUBNER)|"

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ABSTRACT

Studies were performed to investigate the bio-efficacy and persistency of commonly used insecticides, impact of processing on residues along with biology of chilli fruit borer (*Helicoverpa armigera* Hubner) during the year 2015-16 at Farmers field, Food Quality Testing Laboratory and Post Graduate Research Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari.

Among the tested insecticides, fipronil 0.005 per cent and fenpropathrin 0.03 percent were equally and significantly superior in controlling chilli thrips and resulted in higher yield.

The persistence studies on insecticides on chilli fruit revealed that, half-life period of 11.67 days for fipronil (0.005%) and 6.98 days for lambda-cyhalothrin (0.005%). This period was 4.68 days for ethion (0.088 %), 2.6 days for cypermethrin (0.012%), 8.14 for fenpropathrin (0.03%) and 6.57 days for

fenazaquin (0.005%). The processing factor (sun drying followed by powdering) obtained was 5.02 to 8.57.

Studies on biology of fruit borer (*H. armigera*) in chilli revealed that, the eggs were hemispherical with yellowish white in colour. The incubation period ranged from 2 to 5 days while, hatchability noted was 52.57 ± 11.22 per cent. The neonate larva was of dirty white while, full grown larva was pinkish brown and pale green in colour. Larvae passed through six distinct instar. The duration of first, second, third, fourth fifth and sixth instar larva was 2.88 ± 0.73, 3.46 ± 0.51, 3.91 ± 0.79, 3.73 ± 0.70, 4.55 ± 0.51 and 4.71 ± 0.72 days, respectively. The total larval period was completed in 23.14 ± 1.28 days. Pupation took place in the soil in an earthen cocoon. The average pupal period was 12.67 ± 1.28 days. Male moth was of greenish-grey in colour, whereas female moth of orange brown colour and characterized by tuft of hairs on the tip of abdomen. The sex ratio (Male: female) was 1:2.08. The average pre-oviposition, oviposition and post- oviposition periods were 2.86 ± 0.85, 8.14 ± 0.85 and 1.52 ± 0.51 days, respectively. The average fecundity of the female recorded as 1048.40 ± 193.58 eggs. Longevity of male recorded as 8.67 ± 1.06 days while that of female was 10.90 ± 1.22 days. The total life cycle occupied 40 to 59 days (48.43 ± 2.44 days) by male and 42 to 62 days (50.67 ± 2.13 days) by female.

The larvae were parasitized by tachinid fly, *Jriniopsis adusta* in field and 7.14 per cent parasitization was recorded during present investigation.

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CERTIFICATE

This is to certify that the thesis entitled **"PERSISTENCE AND DISSIPATION OF INSECTICIDES AGAINST CHILLI THRIPS AND BIOLOGY OF FRUIT BORER [*Helicoverpa armigera* (Hubner)]"** submitted by Mr. PATIL VIPUL MANGESH in partial fulfillment of the requirements for the award of the degree of Master of Science in the discipline of Agricultural Entomology of the Navsari Agricultural University is a record of bonafide research work carried out by him under my guidance and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari
Date : 10 / 08 /2016

(Z. P. Patel)
Major Advisor

DECLARATION

This is to declare that the whole of the research work submitted in this thesis for the partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agricultural Entomology is the result of investigation done by the undersigned under the direct guidance and supervision of DR. Z. P. PATEL, Principal, College of Agriculture, Navsari Agricultural University, Waghai and that no part of the work has been submitted for any other degree so far.

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Place : Navsari

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Patil V M

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SYMBOLS AND ABBREVIATIONS USED

%	:	Per cent
&	:	And
@	:	At the rate of
^{o}C	:	Degree Celsius
$^{-1}$	:	Per
a.i.	:	Active ingredient
Anon	:	Anonymous
C. D.	:	Critical Difference
Conc.	:	Concentration
C.V.	:	Coefficient of Variation
DAS	:	Days After Application
DBA	:	Day Before Application
et al.	:	Co-worker
Etc	:	Etcetera
Fig	:	Figure
G	:	Gram
Ha	:	Hectare
i.e.	:	id est (That is)
Kg	:	Kilogram
Lit	:	Litre
No.	:	Number
NS	:	Non- significant
S.Em ±	:	Standard Error of Mean
Viz	:	Namely
$\mu g\ g^{-1}$	:	micro gram per gram
$mg\ kg^{-1}$	:	milligram per kilogram
Ppm	:	part per million
®	:	Registered trade mark
v/v	:	Volume by volume
mL	:	Milliliter
X	:	Multiplie
>	:	Greater than
<	:	Less than
M	:	Meter
N	:	Nitrogen
P	:	Phosphorous
K	:	Potassium
vis-a-vis	:	Vice-a-versa

Introduction

I. INTRODUCTION

Chilli, (*Capsicum annuum* L.) popularly known as *'mirch'* in Hindi, belongs to the family Solanaceae originated from Latin American region and currently used throughout the world as a spice and is an important condiment crop grown in Gujarat. It was introduced in India by the Portuguese in 16th century and since then it had rapidly spread throughout the country (Anon., 2015a). From ancient time chillies has been used as food, spice and household medicine for several common problems such as high cholesterol, high blood pressure, pain to joint, skin problem, relief of pain in neuropathy, counter irritant in treatment of rheumatism, lumbago and used as carminative, appetizer, stomachic and beverages. While it's biological function is to repel herbivores animals and fungi. Capsicum is derived from the Greek word *"Kapsimo"* meaning "to bite. The therapeutic effect of chillies is due to capsaicin, protein, fixed oil, thiamine and ascorbic acid (Pawar, 2011).

India is the largest producer, consumer and exporter of chilli, which contributes to about 40 per cent of total world production. Among the states, Andhra Pradesh is the largest producer of chilli in India, contributing to about 44 per cent to the total production, followed by Karnataka (12%), West Bengal (8%), Madhya Pradesh (7%), Maharashtra (4%) and Tamil Nadu (2%). Exports have touched record high of 2.81 lakh tonnes in 2012-13 and during April-June 2013 exports were 65500 tonnes. About 10-15% of total domestic production is meant for exports with domestic consumption of 85-90 per cent (Anon., 2015b).

Chilli occupies a pride place among the vegetables for its delicious taste and pleasant flavour. In India, chilli is mainly grown for its fruits which are used prior to its maturity in various culinary preparations and also in stuffing, pizza and burger. Both green and dry chillies are produced world over from the chilli crop. The cultivation of chilli has become capital intensive due to many production constrains of which the losses caused by pests in paramount. Nearly 25 insects have been recorded attacking chilli leaves and fruits in India, which includes thrips, aphid, whitefly, fruit borer, cutworm, plant bug and other minor pests, of which, thrips, *Scirtothrips dorsalis* Hood is considered as the most serious and important pest (Butani, 1976). In Gujarat, thrips, aphid, cutworm, whitefly and mites have been reported to infest the chilli crop (Patel *et al.*, 1970).

Among the various sucking pests, chilli thrips, *Scirtothrips dorsalis* Hood is extremely small insect and it is a serious pest on chilli in India. These have become regular pests of the crop in traditional chilli growing tracts, known for monocropping, resulting in the qualitative and quantitative crop loss. However, *S. dorsalis* is known as a pest on many cultivated plants including *Actinidia chinensis* Planch., *Allium cepa* L., *Arachis hypogaea* L., *Camellia sinensis* L., *Citrus sinensis* L., *Gossypium hirsutum* L., *Fragaria vesca* L., *Hevea brasiliensis* Müll.Arg., *Hydrangea macrophylla* L., *Mangifera indica* L., *Nelumbo nucifera* Adans., *Ricinus communis* L., *Rosa rubiginosa* L., *Tamarindus indica* L. and *Vitis vinifera* L. (Bournier, 1999).

Chilli thrips attacks all the above ground parts of its host plants. It preferentially on new growth of young leaves, buds and fruits. Both nymph and adult of thrips cause damage by scraping epidermis of the leaves and suck the cell sap from the leaves resulting in the margin of the leaves rolled upwards and the leaf size reduced (Rangarajan *et al.*, 1975), locally known as "*Kokadava*" in Gujarat. In extreme conditions, plants usually develop characteristic wrinkled leaves, with distinctive brown scarring along the veins of leaves, the buds of flowers, the calyx of fruit, the leaves to be shed, fresh buds become brittle and subsequently fall. Newer leaves are often shiny and older ones are frequently scarred from rasping. Infested plants become stunted and severe infestations can result in total defoliation of the host. The symptoms may be confused for a fungal disease and it is also responsible for leaf curl disease of chilli. Feeding damage can reduce the sale value of crop produced, and in sufficient numbers of plants and kill plants already aggravated by environmental stress. Thrips is one of the most serious pests causing about 60.5 to 74.3 per cent yield loss of green chilli (Patel and Gupta, 1998). Another important pest of chilli is fruit borer, *Helicoverpa armigera* (Hubner) is a polyphagous pest and the peak activity is noticed during October to June month in chilli ecosystem. Adult female lays eggs singly on buds, flowers, and small fruits and on young terminal. While, the damage caused by larvae of *H. armigera* during flowering and fruit formation is the most concern. Larvae feed on leaves, flower buds and flowers, developing pods, fruits and seeds by making a circular hole. Later, the larvae feed on seeds usually with its head

inside the pod and rest of the body outside. Young larvae graze on leaves alone, moving on to feeding on developing fruits. The fruit borers cause upto 90 per cent yield loss (Reddy and Reddy, 1999). Without a good control strategy, chilli thrips and fruit borer can be a difficult pests to manage.

The losses caused by various pests to chilli crop can be avoided by adopting proper pest control tactics. Insecticide application is one of the management options that can substantially reduce yield losses associated with insect pests infestation. There are number of insecticides available to control these pests. Foliar applications of systemic insecticides have been found effective than soil drenches in controlling sucking pests. Since chilli thrips and fruit borer feed on new growth, it is important to spray, when the plant is actively growing. However, indiscriminate use of insecticides have led to insecticide resistance, pest resurgence and environmental pollution besides upsetting the natural ecosystem. Sufficient work has been done on testing the bio-efficacy of conventional insecticides against pests of chilli. There is a paucity of information about the efficacy of newer insecticides against pests of chilli. Now it realized that many pesticide residues in agricultural produce cause health hazards. The presence of pesticide residues in spices, especially in chilli is a major non-tariff barrier against export of chilli to developed countries (Singh and Kumar, 1998).

Survey carried out by institutions spread throughout the Haryana state indicated that, 23 per cent of vegetables have been contaminated with organophosphorous compounds residues. In addition, long persistence of some

agrochemicals in the environment sets in a series of undesirable effects through contamination of food and feed. Bioaccumulations of pesticides and biomagnification processes have become the weak links in the food chain. Therefore, determination of residue status especially of newer insecticides in produce at harvest is equally important.

Over and above a polyphagous pest *i.e.* fruit borer (*H. armigera*) is also one of the potential pest of chilli. The information regarding its biology especially on chilli is also limited under south Gujarat condition. Therefore, present studies on **"Persistence and dissipation of insecticides against chilli thrips and biology of fruit borer (*Helicoverpa armigera* Hubner)"** was carried out with following objectives.

Objectives

1. Bioefficacy of various insecticides against chilli thrips (*S. dorsalis* Hood)

2. Persistence of different insecticides in chilli

3. Processing factor of different insecticides in chilli

4. Biology of fruit borer (*H. armigera*) in chilli

Review of Literature

II. REVIEW OF LITERATURE

Chilli, *Capsicum annuum* L. is one of the most commonly grown and economically important vegetable and spice in south Gujarat. This crop is cultivated throughout the year, and is one of the vegetable and spice that are available at affordable prices for both the rural and urban poor. Chilli is cultivated on small holdings, and sale of produce harvested almost daily over a 4-5 month season serves as a valuable source of income to farmers. Looking to the potential of pest in chilli crop, a retrospection of literature pertaining to bio-efficacy of insecticides against chilli thrips, persistence and processing factor of insecticides residues, and biology of fruit borer *H. armigera* are presented under following heads:

2.1 Bioefficacy of various insecticides against chilli thrips (*Scirtothrips dorsalis* Hood)

2.1.1 Fipronil

Reddy *et al.* (2007) evaluated fipronil against chilli thrips in field in A.P and found that fipronil 5% SC @ 2mL/lit was the best treatment with significantly highest yield. Ahmed and Prasad (2009) from Lam Guntur reported that fipronil 5 SC at 50 g a.i./ha was most effective against chilli thrips. Similarly, Srinivas *et al.* (2009) recorded lowest number of thrips population 1.64/leaf in fipronil 5 SC treated plot at the rate of 1.00 mL/l at Mumbai. Likewise, Ghosh *et al.* (2009) evaluated the efficacy of fipronil against thrips and reported the overall mean dimination of thrips population and consequently yield increase was 50.0%.

The percent reduction in curly leaves was also observed compared to control. Halder *et al.* (2016) evaluated fipronil under field condition at Varanasi and found that maximum reduction in thrips population (75.41%) and significant green chilli yield.

In cotton, Patil *et al.* (2009) studied the efficacy of fipronil 5% SC at 800 g/ha against sucking pest at Dharwad. They concluded that fipronil 5% SC registered least number of thrips (8.47/three leaves). Patil and his coworkers (2013) further tested fipronil against mulberry thrips and reported that, fipronil was most effective in reducing the population of thrips at Raichur. Pachundkar *et al.* (2013) from Anand also observed that fipronil 5 SC (0.005%) effectively managed thrips on cluster bean.

2.1.2 Lambda-cyhalothrin

No work has been done to test lambda cyhalothrin against chilli thrips. However, Soliman (2011) studied the efficacy of lambda-cyhalothrin against *Helicoverpa armigera* and *Etiella zinckenella*. He found that the same treatment was effective against tested insect and reduction of larvae population upto 76.55%.

In a comparative trial, Yousuf *et al.*, (2012) fond lambda-cyhalothrin as most effective against *Dysdercus koenigii* in malvaceae and poaceae crop. They also reported that, fecundity of adult *D. koenigii* was found inhibited.

2.1.3 Ethion

There are no recent reports about ethion against chilli thrips. However, Chinniah and Ali (2000) evaluated the efficacy of different insecticides against carmine spider mite, *Tetranychus cinnabarinus* among them, ethion 50EC and 50EW (0.1%) was highly effective against the pest. Likewise, ethion (50% EC) reduced 82.64 % insect population of *Helicoverpa armigera* and *Etiella zinckenella* by Soliman (2011).

2.1.4 Cypermethrin

Soliman (2011) studied the efficacy of cypermethrin against *Helicoverpa armigera* and *Etiella zinckenella.* He recorded 80.91% population reduction in cypermethrin treated plot. Whereas, Mahmood *et al.* (2014) observed the reduction of spotted boll worm population upto 59.44% on okra crop in cypermethrin treated plot. Lal and Jat (2015a) found that cypermethrin (25EC @ 188 mL ha^{-1}) was promising in managing adult blister beetle in pigeon pea. Likewise population of tur pod bug was lowest in cypermethrin treated plots even at 10 days after application (Lal and Jat, 2015b).

2.1.5 Ethion + cypermethrin

Patel *et al.* (2009) revealed that ethion + cypermethrin (0.045%) was most effective treatmentagainst chilli thrips. While, Parmar *et al.* (2013) evaluated ethion + cypermethrin (0.045 %) against pest complex of okra at Anand and found significantly effective against red mite, *Tetranychus telarius*.

2.1.6 Fenpropathrin

Adult of stored grain pest, *Alphitobius diaperinus* was reduced by fenpropathrin @ 1.96 µg/cm^2 as reported by Tabassum *et al.* (1998). Likewise, Chinniah and Ali (2000) conducted field study on okra and reported that, fenpropathrin 10EC at 0.01% was highly effective to control the carmine spider mite. Further, Aslam and his coworker (2004) found that, fenpropathrin 20EC was most effective against *Earias insulana* (Boisd.), *E. vitella* (Fab.) and *Helicoverpa armigera* (Hub.). Similarly, Jana and Somchoudhury (2005) found fenpropathrin 30 EC exhibited excellent control of tea red spider mite at 0.75 and 1.0 mL/l. Against sucking insect pest complex in cotton, Shivanna *et al.* (2011) showed superior efficacy in bringing down all the sucking pest population by fenpropathrin 30 EC.

A mixture of fenpropathrin + buprofezin also found most effective against sucking insect pest complex of cotton (Afzal *et al.*, 2001). Whereas, Karmakar and Patra (2015) revealed that pyridalyl 15% + fenpropathrin 20% EC remained effective in controlling red gram pod borer complex.

2.1.7 Fenazaquin

Reza (2006) studied the efficacy of different pesticides against chilli thrips and observed that fenazaquin 10% EC at 0.005% was second best treatment after milbemectin 1% EC.

2.2 Persistence of different insecticides in chilli.

Table 1: Persistence of different insecticide in different commodities applied recommended dose

Sr. No.	Compound with formulation	Commodity	Dose	Half-life (Days)	Reference
1	Fipronil 5% SC	Chilli fruits	25 g a.i./ha	1.57	Kumar *et al.* (2013)
			50 g a.i./ha	1.71	
			40 g a.i./ha	4.22	Xavier *et al.* (2014)
			80 g a.i./ha	4.32	
		Peanut seedling	-	<1	Li *et al.* (2015)
		Chilli	50 g a.i./ha	3.50	Saini *et al.* (2015)
			100 g a.i./ha	3.53	
2	Lambda-cyhalothrin 5% EC	Lime juice	15 g a.i./ha	3.4	Mohapatra *et al.* (2006)
		Okra fruits	15 g a.i./ha	2.92	Singh *et al.*, (2007)
			30 g a.i./ha	2.86	
3	Ethion 50%	Cowpea pods	-	2.90	Soliman (2011)
		Okra fruits	-	1.27	Parmar *et al.* (2012)
		Chilli fruits	500 g a.i./ha	1.81	Sharma and Parihar (2013)
			1000 g a.i./ha	2.32	
4	Cypermethrin 25% EC	Okra fruits	60 g a.i./ha	3.3	Deen *et al.* (2009)
			-	2.59	Parmar *et al.* (2012)
		Chilli fruits	20 g a.i./ha	1.98	Kumar *et al.* (2013)
			40 g a.i./ha	2.68	
5	Fenpropathrin 20% EC	Squash fruits	-	1.78	Romeh and Hendwai (2013)
6	Fenazaquin 10% EC	Acid lime	100 g a.i./ha	1.9 to 5.3	Sharma *et al.* (2006)
			200 g a.i./ha	3.6 to 5.2	

2.3 Processing factor of different insecticides in chilli.

Table 2: Processing of different insecticide in different commodities applied at recommended dose

Sr. No.	Insecticides	Commodity	Processing	% Reduction in insecticide residue concentration	Processing factor	Reference
1	*Fipronil 5% SC*	*Chilli*	Washing with tap water	42.05	0.58	Saini *et al.* (2015)
			Sun dried chilli	-	3.09	Xavier *et al.* (2014)
2	Lambda-cyhalothrin	*Tomato*	Washing one time with tap water	45.29	0.55	Elbashir *et al.* (2013)
			Washing three time with tap water	67.11	0.33	
		Cardamom	Sun dried	-	4.58	George and Kumar (2013)
		Okra fruits (ODAA)	Washing with tap water	40.0	0.60	Singh *et al.* (2007)
		Wheat	Flouring	31.5	0.69	Pal and Shah (2008)
			Chappatti making	71.0	0.29	
			Bread making	74.9	0.25	
3	Ethion 50% EC	Chilli fruits	Drying	-	3.52	Pathan *et al.* (2009)
		Okra fruits	Rubbing with wet cloth, dipping in normal water, washing with normal water, washing with 2% brine solution and cooking	29.28-61.88	0.38-0.70	Parmar *et al.* (2012)
4	Cypermethrin	Brinjal	Grilling	50.12	0.50	Walia *et al.* (2010)
			cooking in oil	45.2	0.55	
			cooking in water	41.4	0.59	
			microwave cooking	40.89	0.59	

		Brinjal	Washing with water, 2.0% NaCl, 1.0 % NaHCO3, 0.5 % acetic acid and boiling in water	30.2-92.10	0.08.0-0.70	Chandra *et al.* (2015)
		okra fruits		27.2-92.2	0.08-0.73	
5	Fenpropathrin	Tomato	Washing one time with tap water	37.51	0.37	Elbashir *et al.* (2013)
			Washing three time with tap water	51.47	0.51	
		Green peppers	Tap water at low concentration	92.04	0.08	Hai *et al.* (2013)
			Egg yolk lecithin at high concentration			
5	Fenazaquin	Okra fruits (0 day)	Washing	32.46	0.68	Duhan *et al.* (2010)
			Boiling	40.26	0.60	
			washing+ boiling	61.03	0.39	
		Tea	Processing of making tea	42-70	0.3-0.58	Kumar *et al.* (2004)
6	Chlorfenapyr, clothianidin, diethofencarb, folpet, imidacloprid, indoxacarb, methomyl, methoxyfenozide and tetraconazole	Chili	Drying	-	2.45 –5.14	Noh *et al.* (2015)
7	Acetamiprid	Cardamom	Curing	-	2.43	Pratheeshkumar and Chandran (2015)
		Eggplant fruits	Washing	24.73	0.75	Romeh and Hendwai (2013)
			Boiling	56.99	0.43	
			Frying	46.24	0.54	
			Grilling,	56.99	0.43	

2.4 Biology of fruit borer (*H. armigera*) in chilli.

2.4.1 Egg

2.4.1.1 Site and pattern of ovipostion

Ali *et al.* (2009) from Aligarh, India, observed that *H. armigera* laid eggs singly on chickpea during night time due to nocturnal behaviour.

Patel *et al.* (2011) from Navsari, Gujarat, observed eggs of *H. armigera* (Hubner) are laid singly on buds and leaves of rose and female mostly preferred laying eggs on buds.

Sharma *et al.* (2011) observed eggs of *H. armigera* (Hubner) are laid on twig of tomato plant and some time eggs were laid on the walls of the chimney and on the muslin cloth.

Female moth of *H. armigera* laid the eggs singly on tender parts of the ground nut plant, reported by Ghadiya *et al.* (2014) from Anand, Gujarat.

2.4.1.2 Colour, shape and size

Freshly laid eggs of *H. armigera* were yellowish white which become dark brown before hatching as observed by Ali *et al.* (2009), Patel *et al.* (2011), Sharma *et al.* (2011) and Ghadiya *et al.* (2014).

The size of eggs were hemispherical and round with flat base and smooth apical area. The rest of the surface was sculptured in the form of longitudinal ribs. The egg size varied from 0.42 to 0.60 mm in length and 0.40 to 0.55 mm in breadth (Ali *et al.*, 2009), 0.45 to 0.51 mm with an average of 0.49 ± 0.04 mm in length and 0.50 to 0.58 with an average of 0.54 ± 0.2 mm in breadth

(Patel *et al.*, 2011), 0.47 + 0.04 mm in length and 0.48 + 0.05 mm in breadth (Sharma *et al.*, 2011) and 0.44 to 0.50 mm with an average of 0.47 ± 0.02 mm in length and from 0.046 to 0.53 mm with an average of 0.49 ± 0.02 mm in breadth (Ghadiya *et al.*, 2014).

2.4.1.3 Incubation period

The incubation period of *H. armigera* varied from 2 to 4 days (Ghadiya *et al.*, 2014), 3 to 4 days (Ali *et al.*, 2009), 3 to 5 days (Patel *et al.*, 2011) and 4 to 7 days (Sharma *et al.*, 2011). The hatching percentage observed as 53.33 ± 0.47 % by Ali *et al.* (2009).

2.4.2 Larva

The length and breadth of *H. armigera* varied from 1st to 6th instar larvae was reported to be 1.40 ± 0.06 and 0.45 ± 0.01; 3.88 ± 0.11 and 0.75 ± 0.01; 7.90 ± 0.19 and 2.28 ± 0.04; 12.83 ± 0.45 and 2.85 ± 0.04; 20.97 ± 0.61 and 3.24 ± 0.04; 32.50 ± 0.35 and 4.03 ± 0.04, respectively (Ali *et al.*, 2009), 1.47 ± 0.02 and 0.51 ± 0.02; 3.52 ± 1.08 and 0.82 ± 0.01; 9.42 ± 0.66 and 2.81 ± 0.02; 23.02 ± 1.36 and 3.24 ± 0.01; 34.50 ± 1.29 and 5.11 ± 0.07; 43.89 ± 1.24 and 6.59 ± 0.56, respectively (Patel *et al.*, 2011). Whereas, length and breadth of *H. armigera* varied from 1st to 6th instar larvae was reported to be 1.44 + 0.03 and 0.49 + 0.02; 3.43 + 0.44 and 0.78 + 0.29; 8.3 + 0.07 and 2.95 + 0.51; 17.8 + 0.34 and 2.99 + 0.31; 32.40 + 0.92 and 5.20 + 0.02, respectively (Sharma *et al.*, 2011). The length and breadth of head capsule measured as 1.56 to 1.92, 0.28 to 0.35 and 0.25 to 0.29; 4.00 to 5.20, 0.56 to 0.68 and 0.47 to 0.55; 7.80 to 9.30, 0.70 to 1.22

and 0.66 to 0.75; 15.90 to 18.70, 2.00 to 2.41 and 1.12 to 1.30; 26.50 to 30.30, 3.00 to 4.20 and 2.55 to 2.63, respectively (Ghadiya *et al.*, 2014).

The average duration of 1st to 6th instar was 2.27 ± 0.08, 2.42 ± 0.08, 2.67 ± 0.07, 2.83 ± 0.07, 3.40 ± 0.10 and 3.37 ± 0.11 days, respectively in chickpea (Ali *et al.*, 2009), 2.16 ± 0.37, 2.84 ± 0.37, 3.80 ± 1.00, 4.60 ± 0.76, 4.16 ± 0.69 and 6.60 ± 1.22 days, respectively in rose (Patel *et al.*, 2011). Whereas a average duration of 1st to 5th instar 2.84 ± 0.37, 2.80 ± 0.76, 4.16 ± 0.69, 5.20 ± 0.87 and 5.44 ± 0.96 days, respectively with the total larval period varied from 15 to 26 days with an average of 22.44 ± 2.75 days (Ghadiya *et al.*, 2014). Whereas, the average duration of 1st to 5th instars took 8.39, 9.0, 4.30, 4.0 and 4.70 days, respectively, with the total larval period 30 to 39 days in 1st generation. However, it was 9.25, 9.22, 9.75, 6.22 and 6.80 days in 1st to 5th instars, respectively, in the 2nd generation with a total duration of 38.24 days. But 4.30 days for 1st to 5th instars, respectively, with a total larval duration of 23 to 28 days (Sharma *et al.*, 2011).

2.4.3 Pre-pupa

The full grown larvae become sluggish, wrinkled with suspended feeding and movement while, the colour pattern become light green yellowish to light brownish with less prominent strips before formulation of pupa and contracted its length and appendage, become quiescent and then the pupal formation took place (Ali *et al.*, 2009; Patel *et al.*, 2011; Sharma *et al.*, 2011). Whereas, length and width of pre-pupal varied from 22.50 to 29.00 and 3.90 to

5.00 mm with an average of 25 ± 0.49 and 4.56 ± 0.09 mm, respectively (Ali *et al.*, 2009), 22.42 to 28.38 mm and 4.92 to 4.98 mm with an average 25.01 ± 1.5 mm 4.96 ± 0.02 mm, respectively. While, total duration of pre-pupal stage lasted for 1 to 3 days with an average of 2.15 ± 0.16 and 2.28 ± 0.61 days by (Ali *et al.*, 2009 and Patel *et al.*, 2011), 24.40 + 2.83 mm and 4.85 + 0.65 mm while, total duration of pre-pupal stage ranged between 4.17, 4.04 and 4.75 days during 3 different generations (Sharma *et al.*, 2011), 21.50 to 26.80 mm and 2.70 to 4.30 mm while, total duration of pre-pupal stage varied from 1 to 4 days with an average of 2.68 ± 0.855 days (Ghadiya *et al.*, 2014).

2.4.4 Pupa

The pupa was obtect type with machogany colour. Surface was smooth anterior and posteriorly with two tapering parallel spines at the posterior tip (Ali *et al.*, 2009; Patel *et al.*, 2011; Sharma *et al.*, 2011). The newly formed yellowish green pupa become light brown within 24 hours and further darkened prior to emergence of moth (Patel *et al.*, 2011 and Sharma *et al.*, 2011).

The length and breadth of pupa varied from 17.00 to 20.50 mm and 5.40 to 6.30 mm with an average of 19.00 to 0.30 and 5.72 ± 0.08 mm respectively (Ali *et al.*, 2009), 19.9 to 23.10 mm and 5.90 to 6.50 mm with an average of 20.93 ± 1.09 and 6.09 ± 0.8 mm (Patel *et al.*, 2011). Whereas length, breadth and weight of male pupa varied from 22.5 + 0.94 mm, 5.98 + 0.24 mm and 130.0 + 2.50 mg and in case of female pupa it varied from 18.20 + 0.45 mm, 6.42 + 0.54 mm and 138.15 + 1.80 mg respectively (Sharma *et al.*, 2011).

Similarly, length, breadth and genital pore of male pupa varied from 18.20 to 22.10 mm and 4.90 to 6.20 mm and 0.58 to 0.65 mm and in case of female pupa it varied from 19.30 to 23.70 mm, 4.95 to 6.60 mm and 1.66 to 1.79 mm, respectively.

Ali *et al.* (2009) observed that the pupal stage took period varied from 10 to 14 days with an average of 13.15 ± 0.27 days. While, total duration of pupal stage varied from 9 to 14 days with an average of 10.44 ± 1.36 days as reported by Patel *et al.* (2011).

Sharma *et al.* (2011) show that the pupal period was reported to be influenced by the rearing temperature being 21.25, 34.38 and 13.78 days in October to November, December to February and April to May, respectively.

Ghadiya *et al.* (2014) reported that the duration of male pupae varied from 15 to 18 days with an average of 16.60 ± 1.12 days while that of female pupa varied from 14 to 20 days with an average of 17.36 ± 1.75 days, which was slightly higher than male pupal duration.

2.4.5 Adult

Ali *et al.* (2009) observed that adult moth was stout bodied with broad thorax. While, it was medium in size as observed by (Patel *et al.*, 2011).

The forewings had a series of dots on the margins and a black comma-shaped marking in the middle underside of each forewing. However, the hind wings were light in colour with a broad dark-brown border at apical end: they had yellowish margins and strongly marked veins while, there was distinguished

colour pattern between male and female moths. Males were recorded greenish-grey in colour, whereas female with orange-brown and also the presence of tuff of hairs on the tip of abdomen (Ali *et al.*, 2009; Sharma *et al.*, 2011 and Patel *et al.*, 2011).

The average length and width of male and female was measured as 17.65 ± 0.18mm and 34.73 ± 0.59 mm as well as 20.08 ± 0.38 mm and 40.93 ± 0.55 mm, respectively (Ali *et al.*, 2009). The body length and width of male moths ranged from 15.40 to 18.75 mm and 33.40 to 39.15 mm with an average of 17.09 ± 0.77 mm and 36.2 ± 1.55 mm, respectively and in case of female 18.40 to 22.20 mm and 38.39 to 49.99 mm with an average of 20.57 ± 1.22 mm, and 41.61 ± 2.86 mm, respectively (Patel *et al.*, 2011). The length and width varied from 18.42 + 0.58 mm and 38.30 + 0.35 mm in male and 19.82 + 0.75 mm, 42.15 + 0.65 mm in female, respectively (Sharma *et al.*, 2011), the length and width in male varied from 16.40 to 18.50 mm and 31.70 to 36.50 mm and 17.90 to 22.50 mm and 37.60 to 42.10 mm in female, respectively (Ghadiya *et al.*, 2014).

2.4.6 Pre-oviposition, oviposition and post-oviposition

The pre-oviposition recorded as 2.00 to 2.80 days (Ali *et al.*, 2009), 2 to 4 days (Patel *et al.*, 2011 and Ghadiya *et al.*, 2014). Likewise, Oviposition observed as 4.60 to 5.80 days (Ali *et al.*, 2009), 4 to 7 days (Patel *et al.*, 2011) and 6 to 8 days (Ghadiya *et al.*, 2014). Similarly, post oviposition period reported as 1.30 to 2.30 days (Ali *et al.*, 2009) and 0 to 2 days (Patel *et al.*, 2011, Ghadiya *et al.*, 2014).

2.4.7 Fecundity

The female of *H. armigera* laid 405.00 to 420.00 eggs (Ali *et al.*, 2009), 290 to 910 eggs (Patel *et al.* 2011) and 163 to 318 eggs (Ghadiya *et al.*, 2014).

2.4.8 Hatching percentage

The significant variation in the fecundity of female 256.60 to 490.66 eggs/female during different months, while the per cent hatchability of egg was very much influenced by the temperature prevailing in the laboratory. 89.0 per cent during April, 87.8 per cent during October and 77.80 per cent during November, respectively, (Sharma *et al.* 2011). Similarly, the hatching period varied from 51 to 55 % (Ali *et al.*, 2009), 66 to 96 % (Patel *et al.*, 2011) and 50 to 75 % (Ghadiya *et al.*, 2014).

2.4.9 Longevity

The longevity of male and female of *H. armigera* varied from 7 to 11 and 10 to 14 days (Ali *et al.*, 2009).

According to Patel *et al.* (2011) both male and female of were alive for about 4.00 to 8.00 and 5.00 to 11.00 days.

The average longevity of male moth during December to February, October to November and April to May was reported to be 55.89, 4.33 and 2.44 days, respectively. While in case of female varied from 11.33, 9.78 and 8.79 days, respectively (Sharma *et al.* 2011).

Ghadiya *et al.* (2014) observed that the male and female survived 7 to 8 days with an average 7.64 ± 0.49 days and 8 to 10 days respectively. While male: female sex ratio recorded in laboratory and field condition varied from 1: 1.08 to 1: 1.15 days respectively.

2.4.10 Sex ratio

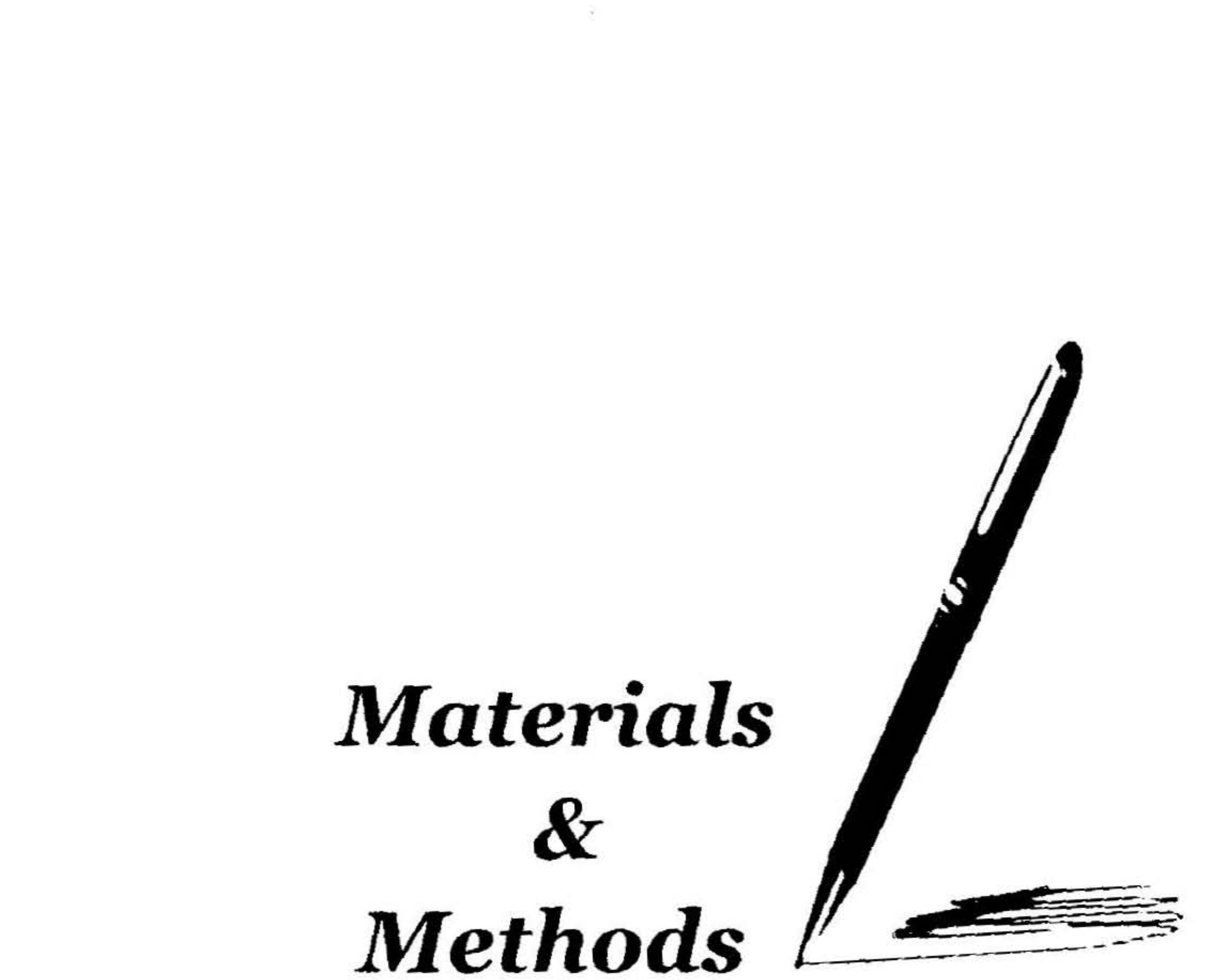
The sex ratio of male: female observed as 1:0.72 by (Patel *et al.*, 2011). While, it was 1: 1.08 in laboratory and 1: 1.15 in field condition according to (Ghadiya *et al.* 2014).

2.4.11 Total life cycle

Ali *et al.* (2009) observed that the total life cycle of *H. armigera* from egg to emergence of adults varied from 37 to 52 days. Similarly, Patel *et al.* (2011) reported that the total life cycle of male was 35 to 45 days and 37.00 to 48.00 days in female respectively.

Sharma *et al.* (2011) noted that the *H. armigera* took minimum of 44.25 days in third generation (first week of April to second week of May) and maximum of 65.25 days in second generation (first week of December to second week of February) while in first generation during first week of October to last week of November, however the life cycle was completed in 56.69 days.

Total life cycle occupied 40 to 61 days in case of male, while 43 to 65 days in female as reported by Ghadiya *et al.* (2014).



Materials & Methods

III. MATERIALS AND METHODS

Chilli, *C. annuum* is seriously threatened by attack of many pests, among them a chilli thrips (*S. dorsalis*) attacks at various growth stage of a crop, while, a fruit borer (*H. armigera*) causing considerable damage especially at fruiting stage. Both these pests are considered as major pests of chilli in south Gujarat and hence aimed during present investigation to generate relevant information. The studies includes, bio-efficacy of different insecticides against chilli thrips, persistence of insecticides, processing factors of insecticides and biology of fruit borer. The materials used and experimental techniques adopted during the course of investigation to fulfill the objectives set forth are elucidated here under in this chapter. The field experiment was conducted at farmers field in village Kesali of Gandevi taluka in Navsari district during *rabi* 2015-16, while studies on persistence and processing factor of insecticides used against chilli thrips were undertook in Food Quality Testing Laboratory and studies on biology of fruit borer was carried out in Post Graduate Research Laboratory of Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during the year 2015-16.

The details of research techniques used for following experiments are narrated hereunder.

Plate 1: Insecticides used for the bioefficacy experiment

Plate 2: Application of insecticidal treatment in bioefficacy plot

Plate 3: Field experiment on bioefficacy of insecticides against chilli thrips

Plate 4 (A)

Plate 4 (B)

Plate 4 (C)

Plate 4: (A) Damaging thrips (B) nymph (C) adult

Plate 5: Sampling of treated chilli

3.1 Bioefficacy of various insecticides against chilli thrips (*S. dorsalis*)

To study the bioefficacy of various insecticides, a field experiment was conducted at farmers field, of which the details are here under.

3.1.1 Application of insecticides

First spray of respective insecticides was made on appearance of pests and subsequent spray was given after 15 days using manually operated hydraulic Knapsack sprayer fitted with hollow cone nozzle. To avoid drift of insecticides among treatments, a polyethylene sheet was held between adjacent plots as barrier (Plate-1 and 2).

3.1.2 Method of observations

Five plants were randomly selected and tagged from net plot area to record the observation of thrips (Plate-3). The number of nymphs as well as adults were counted on three leaves each from top, middle and bottom of each tagged plants (Plate-4). Observation was recorded at a day before spray and 3, 5 and 7 days after each spray and the data was subjected to the statistical analysis by employing suitable transformation. Yield of green chilli fruits per plot was recorded at each picking and the data thus, obtained were converted to quintal per hectare. The yield data were also subjected to the statistical analysis.

3.1.3 Experimental details

1	Location	:	Farmers field, Village Kesali, Ta. Gandevi, Dist. Navsari
2	Season	:	*Rabi* (2015)
3	Date of transplanting	:	16/01/2015
4	Design	:	Randomized Block Design (RBD)
5	Treatments	:	Six (6)
		T_1	Fipronil 5% EC (0.005%)
		T_2	Lambda-cyhalothrin 5% EC (0.005%)
		T_3	Ethion 40% EC + cypermethrin 5% EC (0.1%)
		T_4	Fenpropathrin 30% EC (0.03%)
		T_5	Fenazaquin 10% (0.005%)
		T_6	Control (water spray)
6	Replications	:	4
7	No. of spray	:	2 at 15 days interval
8	Date of spraying	:	1st: 17/02/2015 2nd: 03/03/2015
9	Crop	:	Chilli
10	Variety	:	SHP 4884
11	Spacing	:	60 cm x 60 cm
12	No. of plants per plot	:	5 rows x 10 plant = 50 plants
13	Plot size		
	A. Gross Plot	:	3.0 x 6.0 m
	B. Net Plot	:	2.4 x 5.4 m
14	Method of sowing	:	Transplanting
15	Fertilizer Dose	:	100: 50:50 NPK kg/ha

Table 3: Detail of insecticides used against chilli thrips in bio-efficacy trial

Sr. No.	Name of insecticide	Trade Name	Lot/ Batch no.	Date of Manufacturing	Expiry Date	Conc. (%)	Dose (mL a.i./ha)	Manufactures
1	**Fipronil 5SC**	Socin Flo	AB00021	14/8/2013	8/9/2015	0.005	25	Rallis India Limited
2	**Lambda-Cyhalothrin 5 EC**	Reeva-5	AN0011	22/6/2012	3/8/2014	0.005	25	Rallis India Limited
3	**Ethion 40 EC + Cypermethrin 5 EC**	Nagata	AK00209	23/7/2013	11/5/2015	0.1	499.5	Rallis India Limited
4	**Fenpropathrin 30 EC**	Meothrin	AU00096	3/9/2013	26/8/2015	0.03	150	Sumitom of India Pvt. Ltd.
5	**Fenazaquin 10 EC**	Magister	AC000103	15/2/2013	19/5/2015	0.005	50	DuPont India

3.2 Persistence of different insecticides in chilli

3.2.2 Sampling procedure

In order to study the persistence of insecticidal treatment, the chilli fruits (250g) were picked up during morning hours from each replication (Plate-5) and brought to Food Quality Testing Laboratory, Navsari Agricultural University. Navsari on 0 days (2 hours), thereafter further samples were drawn subsequently at 1, 3, 5, 7, 10 and 15 days after the last spray. Collected samples were processed as soon as possible, preferably on the sampling day to avoid any degradation of insecticide residues. The detail of sampling at different time interval is shown hereunder.

Table 4: Sampling schedule

Sr. No.	Sampling interval	Date of sample collection
1	0 day (2 hr after the last spray)	03/02/2015
2	1 day after spray	04/02/2015 (10 A.M)
3	3 days after spray	06/02/2015 (10 A.M)
4	5 days after spray	08/02/2015 (10 A.M)
5	7 days after spray	10/02/2015 (10 A.M)
6	10 days after spray	13/02/2015 (10 A.M)
7	15 days after spray	18/02/2015 (10 A.M)

3.2.3 Methodologies employed for insecticide residue analysis

The extraction and cleanup of insecticide residues in/on chilli fruits were performed according to the molecules (insecticides).

3.2.4 Statistical analysis

The residue data were subjected to statistical analysis as given by Handa *et al.* (1999). The half life values of each insecticide as indices of the rates of dissipation were calculated.

3.2.5 Chemicals, glasswares and instruments used for the analysis of insecticide residues

3.2.5.1 Chemicals (Standards, Solvents and Reagents)

Insecticide standards of high purity (≥99%) (Technical Grade) supplied by Sigma Aldrich India Ltd. were used for analytical purpose. The certified reference material (CRM) of different insecticide standards were kept in deep freezer at -200^{0}C and used when required for preparation of stock solutions or individual standards. Moreover, different organic solvents and reagents like acetone, *n*-hexane, iso-octane, acetonitrile, dichloromethane, ethyl acetate, acetic acid, hydrochloric acid, toluene, methanol, anhydrous magnesium sulphate, anhydrous sodium acetate, PSA (Primary Secondary Amines), anhydrous sodium sulphate, florosil, sodium hydroxide pellets, disodium hydrogen phosphate and potassium dihydrogen orthophosphate of HPLC grade and high purity were used for the preparation of standards as well as extraction and clean up methodologies during the present investigation.

3.2.5.2 Glasswares

Glasswares like beaker, measuring cylinder, conical flask, volumetric flask and test tubes (graduated) and glass column used were as Merk®

and Borosil® make. The above mentioned glassware's were washed twice, first with double distilled water followed by washing with organic solvent (acetone) and dried at 120^{0}C temperature in oven to avoid cross contamination of insecticides.

3.2.5.3 Equipments and instrume::ts

The details of equipments and instruments used during extraction and clean up methodologies as well as quantification of insecticide residues during the study period are described hereunder.

Homogenizer

Popular make homogenizer of 1kg capacity was used for homogenization and fine grinding of sample.

Analytical balance

Sartorius made analytical balances having capacity of 210 ± 0.1 g and 200 ± 0.01 mg to weigh the samples and reagents, respectively.

Blender

A vertical high speed blender (make Remi) was used for blending the homogenized samples.

Vortex

Vortex mixture (make Mac) used for proper mixing of samples and standards.

Centrifuge

Thermo Scientific (Multifuge X1R) make centrifuge machine was used for the centrifugation of the samples.

N_2 based concentrator

Nitrogen generator and cylinder based evaporator (make Caliper) was used for preparation of final volume of the sample under inert atmosphere.

Gas Chromatograph

Thermo Scientific make Trace GC ultra with auto sampler TriPlus was used for quantitative analysis of insecticide residues (Plate-7).

High Performance Liquid Chromatograph (HPLC)

Surveyor Plus with auto sampler (Thermo Scientific make), HPLC was used for quantitative analysis of fenazaquin insecticide (Plate-8).

3.2.6 Preparation of insecticides standard

The standards (Technical Grade) of five insecticides *viz.*, fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin with more than 99 per cent purity were used for preparation of standard solutions of different (desirable) concentration for quantitative estimation. Mixture of three GC-amenable insecticides standards *viz.*, fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin were prepared to reduce the analysis time and other valuable resources. The quantitative and qualitative analysis of mixture of five insecticides was performed on GC-ECD while, fenazaquin was quantified on HPLC equipped with PDA detector, respectively.

Chopped chilli sample

Homogenized sample

Sample storage

Addition of 6 g $MgSO_4$ and 1.5 g NaOAc

Addition of 15 mL 1% acetic acid in acetonitrile

Weighing of 15 g sample

Vortex for 1 min

Centrifuge for 1 min at 3500 rpm

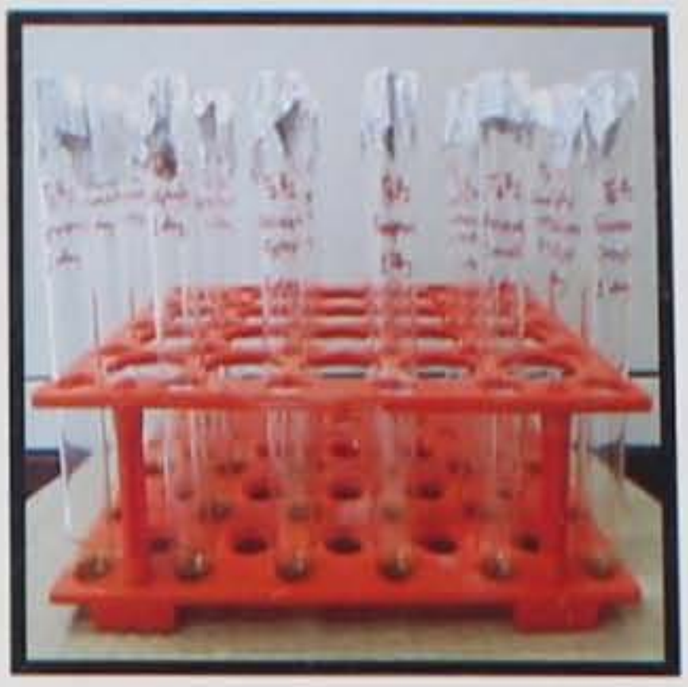
Drawing aliquot of 6 mL in 300 mg PSA and 900 mg $MgSO_4$

Draw 2 mL aliquot

Centrifuge for 1 min at 2500 rpm

Vortex for 1 min

Solvent evaporation in Terbovap



Make up 2 mL with toluene

Ready vials to inject in GC/HPLC

Plate 6: Extraction and clean-up steps for multiresidue analysis (QueChERS) method

Plate 7: Gas Chromatograph equipped with ECD/F PD

Plate 8: High Performance Liquid Chromatograph equipped with PDA

3.2.6.1 Primary standards

Considering the handling and ease of work, a GC-amenable mixture of five insecticides *viz*., fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin as well as HPLC-amenable insecticide fenazaquin was prepared separately.

3.2.6.1.1 Stock solution of GC amenable insecticide

Twenty gram of technical grade CRMs of four insecticides standards (fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin) were accurately weighed with the help of Top loading balance on aluminium foil. The standards were then gently transferred to 100 ml. volumetric flask. Standards were dissolved with 10 to 15 ml. binary mixture of N-hexane and acetone in the ratio of 9:1ml. v/v, shaken well until dissolved, vortexed and then make up the volume up to 100 ml.. In this way, a stock standard mixture solution of 200 ppm was prepared.

3.2.6.1.2 Stock solution of HPLC amenable insecticide

Likewise, appropriate amount of fenazaquin stock solution was also prepared in HPLC grade water and acetonitrile in the ration of 60:40 ml. v/v. Thus, stock solutions of standards were prepared for further studies and stored in deep freezer (-200 ^{0}C).

3.2.6.1.3 Intermediate standards

The intermediate standards were prepared from stock solution (with suitable dilutions). Five ml aliquot of stock solution was diluted to 50 ml. with

n-hexane and acetone, 9:1 mL v/v in volumetric flask, which gave a intermediate standard solution of 20 ppm concentration. However, same method of dilution was used for Fenazaquin which was diluted in the solvents like water: acetonitrile (60:40 mL v/v) and 0.1 N hydrochloric acid with 100 mL acetonitrile, respectively.

3.2.6.1.4 Working standards

The intermediate standards were used for the preparation of working standards. Suitable aliquot was diluted to obtain final concentration of 0.01, 0.025, 0.05, 0.1, 0.25, 0.5, 1.0 and 2.0 ppm.

3.2.7 Method validation

3.2.7.1 Linearity study

The calibration curve for fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin were evaluated by assessing the signal response of target analytes from the calibration solutions of 0.01, 0.025, 0.05, 0.1, 0.25, 0.5, 1.0 and 2.0 ppm. Lateron, the standard solutions of fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin of each concentration were injected in to Gas Chromatograph equipped with Electron Captured Detector (GC-ECD). Moreover, fenazaquin was performed by using High Performance Liquid Chromatography equipped with Photo Diode Array Detector (HPLC-PDA). The volume of standard concentrations used for injection was 1 µl on Gas Chromatography, whereas, it was 20 µl on High Performance Liquid Chromatography.

During the linearity study, parameters of instruments were set according to the response obtained by detector for above mentioned analytes. Thus, the correlation coefficient (R^2) for each insecticide was calculated by plotting the graph of response of area (or height) v/s concentrations of standard used.

3.2.7.2 Accuracy (% recovery) and Precision (% RSD)

The recovery study provides accuracy (% recovery) and precision of the method (% Relative Standard Deviation), which are the indicators of the efficiency of the analytical method employed. In order to ensure quality assurance information, before taking up analysis of test samples, the analytical method was standardized by processing spiked (fortified) samples in seven replicates for each insecticide. For this purpose, chilli fruit samples were taken from the untreated control where no insecticides have been sprayed. The obtained samples of chilli fruits were cut into small pieces of about 1-1.5 cm which were thoroughly mixed in grinder. After quartering, 15 gm sample was weighed accurately in a 50 mL polyphenol test tube with seven replicates and was spiked with individual insecticide standard solution with fortification levels of 0.01, 0.05 and 0.1 ppm for fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin, whereas 0.01, 0.25 and 0.50 for fenazaquin was used for the analysis to test the efficiency of the method employed for the extraction and recovery study of different insecticides. Following formulae were used for calculation of per cent recovery and relative standard deviation.

$$\% \text{ Recovery} = \frac{\text{mg kg}^{-1} \text{ of insecticide obtained in a fortified sample}}{\text{mg kg}^{-1} \text{ of insecticide fortified}} \times 100$$

$$\% \text{ RSD} = \frac{\text{SD}}{\text{Mean of replicates}} \times 100$$

Where, SD is the standard deviation among different replicates.

3.2.7.3 Limit of detection (LOD) and limit of quantitation (LOQ)

In order to detect the insecticide followed quantitation in the samples, LOD and LOQ were worked out by the following formula.

$$\text{LOD} = \frac{\text{SD X Fortification level}}{100} \times 3.14$$

$$\text{LOQ} = \text{LOD X } 3.0$$

Where, SD is the standard deviation among different replicates

3.2.7.4 Sample Processing (QuEChERS)

In order to extract the insecticide residues of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in/on chilli fruits, samples collected were subjected to analyse by QuEChERS (Quick, Easy, Cheap, Effective, Rougged and Safe) method (Plate-6). The chilli fruits were cut into small pieces and homogenized on high speed blender. A homogenized macerated

sample (15 ± 0.1 g) was weighed in a polypropylene centrifuge tube (50 mL capacity) with the help of Sartorius make analytical balance (capacity 200 g ± 0.1 g). These 50 mL centrifuge tubes were kept under deep freezer for 10 minutes at -10°C after adding 15 mL extractant (1 % acetic acid in acetonitrile) and adsorbents (6.0 g $MgSO_4$ + 1.5 g sodium acetate). The centrifuge tubes were shaken vigorously and vortexed for 1 minute to avoid clumping and were centrifuged at 3500 rpm for 1 minute. Six mL of supernatant layer was transferred to another centrifuge tube (15 mL capacity having 300 mg primary and secondary amines (PSA and 900 mg $MgSO_4$). These were again shaked and vortexed for 1.0 min and centrifuged at 2500 rpm for 1 minute. Thereafter, 2 mL supernatant was transferred to a graduated glass test tube of 15 mL capacity. These test tubes were subjected to concentration under the gentle stream of N_2 and 40°C of water with the help of the turboVap, a calliper made N_2 concentrator. These samples were evaporated to dryness and reconstituted with toluene up to 2.0 mL and transferred in glass vials and subjected to quantitative analysis on chromatographic instruments.

3.2.7.4.1 GC parameters

3.2.7.4.1.1 GC parameters for fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin

The instrument parameters were adjusted in relation to the signal response given by detector during the present investigations.

Instrument (model)	:	Thermo made Trace GC Ultra
Autosampler	:	Triplus
Capillary Column	:	DB-5 (30 m, id.-0.25 µm and FT.- 0.25 µm)
Oven temperature	:	150°C ⟶ 290 °C 2°C/min (2.0 min)
Injector	:	230 °C (1.0 min)
Mode	:	PTV splitless
Split flow	:	10 mL min^{-1}
Carrier gas	:	Helium
Carrier flow rate	:	1.2 mL min^{-1}
Flow mode	:	Constant Flow
Detector	:	ECD
ECD temperature	:	300 °C
Reference current	:	1.0 Ma
Makeup gas	:	Nitrogen
Makeup gas flow	:	40 mL. min^{-1}

3.2.7.4.1.2 HPLC parameters for fenazaquin

Residue of fenazaquin was quantified on HPLC by adopting below mentioned parameters.

Instrument (model)	:	Thermo made Finnigan Surveyor HPLC
Autosampler	:	Finnigan Autosamplerplus
Column	:	Thermo Scientific; Hypersil Gold C18; Particle Size: 5µm; 250 mm x 4.0 mm I.D.
Mobile phase	:	Water: Acetonitrile (40: 60%)
Flow mode	:	Isocratic
Flow rate	:	1 mL min^{-1}

Detector	:	PDA
wave length	:	310 nm

3.2.7.5 Quantitation of insecticide residues

The concentration of insecticide residues was worked out by following formulae.

$$\textbf{Residue (ppm)} = \frac{\text{Height/Area of sample}}{\text{Height/Area of standard}} \times \frac{\text{Standard injected (µl.)}}{\text{Sample injected (µl)}} \times \frac{\text{Final volume (ml.)}}{\text{Weight of sample (gm)}} \times \text{Conc. of std.}$$

3.3 Processing factor of different insecticides in chilli

3.3.1 Processing factor

Chilli fruit samples (250 g) were collected on 0 day after treatment from each treatment separately and sundried. The dried chilli samples were ground to powder with different insecticide residues *viz.*, fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in ground chilli powder was determined, which was used to establish the processing factor of respective insecticide in chilli.

$$\textbf{Processing factor} = \frac{\text{Residues in cured chilli powder (ppm)}}{\text{Residues in fresh chilli fruit (ppm)}}$$

3.3.2 Analytical procedure

To a representative sample of 2.0 g, 8 mL of water was added to make weight equal to 10g. To this, 10 mL acetonitrile was added. The content was shaken vigorously for 1 min, centrifuged at 3500 rpm for 2 min after adding 4 g $MgSO_4$ and 1.0 g NaCl. From this, 6 mL aliquot was transferred to 15 mL centrifuge tube followed by addition of 1.5 g $MgSO_4$ and 0.25g PSA. Again the sample was centrifuged at 2500 rpm for 2 min. An aliquot of 4 mL from supernatant was transferred to the test tube (weight of sample 0.8 g) and evaporated to dryness. The residues were reconstituted with 2 mL HPLC grade acetonitrile and quantified on HPLC-PDA.

3.3.3 HPLC analysis

For the analysis of fenazaquin, Thermo surveyor plus HPLC equipped with PDA detector, autosampler and Hypercil gold® (C-18 column (250mm x 0.6 mm i.d. x 5.0 μ film thickness) was used. The sample was run in isocratic mode. The mobile phase was consisting of acetonitrile and water (80:20 v/v) with constant flow of 0.5 mL/min. The absorbance of fenazaquin molecule was recorded at 269 nm. The retention time of fenazaquin was 2.44 min.

$$\text{Residues (ppm)} = \frac{A_1 \times V_1 \times C}{A_2 \times W}$$

Where,

A_1 = Area/Height of sample in the Chromatogram

A_2 = Area/Height of standard in the Chromatograph

V_1 = Total volume of sample in mL.

C = Concentration of analytical standard in ppm (µg/mL)

W = Weight of the sample in g

3.3.4 Method validation studies

3.3.4.1 Linearity study

Linearity study of fenazaquin was conducted on HPLC-PDA. The working standards of fenazaquin were injected on HPLC-PDA and graphs between concentration and instruments response were plotted. The correlation equations (following linear relationship) and co-efficient of determination (R^2) were calculated.

3.3.4.2 Recovery study

Recovery studies were performed to determine the accuracy (% Recovery), Precision (% RSD) and sensitivity (LOD and LOQ) of the method employed. The known amount of fenazaquin was spiked in chilli fruit, chilli powder and soil samples.

3.4 Biology of fruit borer (*H. armigera*) in chilli

The details of the material used and techniques employed to study the different aspects of biology of fruit borer are as under.

3.4.1 Rearing techniques

Initially, the larvae of *H. armigera* were collected from chickpea field at College Farm, N. M.College of Agriculture, Navsari and reared on same crop under laboratory condition till pupation. Larvae were reared individually to

avoid cannibalism. Simultaneously, chilli plants were also raised individually in pot for further studies on various aspects of biology of the pest on chilli.

Newly emerged male and female moths were released in pair in the oviposition cage (20 cm diameter x 45 cm height) for mating. A pot of chilli plant was kept in oviposition cage for females to provide resting and oviposition site. Piece of black colour muslin cloth (1 sq. ft.) was hanged in an oviposition cage for egg laying. Oviposition cage was covered with black coloured muslin cloth (Plate-9A and B) to create darkness. Cotton swab dipped in five per cent honey solution was kept in small vial and placed in oviposition cage as food to the male and female moths. The eggs were collected with camel hair brush from the leaf, shoots, pot surface, black coloured muslin cloth and also from the bottom of the cage. Collected eggs were used for further study. Simultaneously, a general culture of the pest is also maintained in the laboratory during the study.

3.4.2 Egg

Colour and morphology of egg was determined with the help of Stereo Trinocular microscope Olympus-SZ (16) fitted with Brand Catcam-130 camera having software power Scopephoto (Plate-10) for measuring the size of egg.

Freshly laid 25 eggs were separately kept on chilli leaf placed on wet cotton piece in Petri dish (10 cm diameter) (Plate-11A). The eggs were observed twice a day (8.00 am and 4.00 pm) until the emergence of larvae and incubation period was recorded.

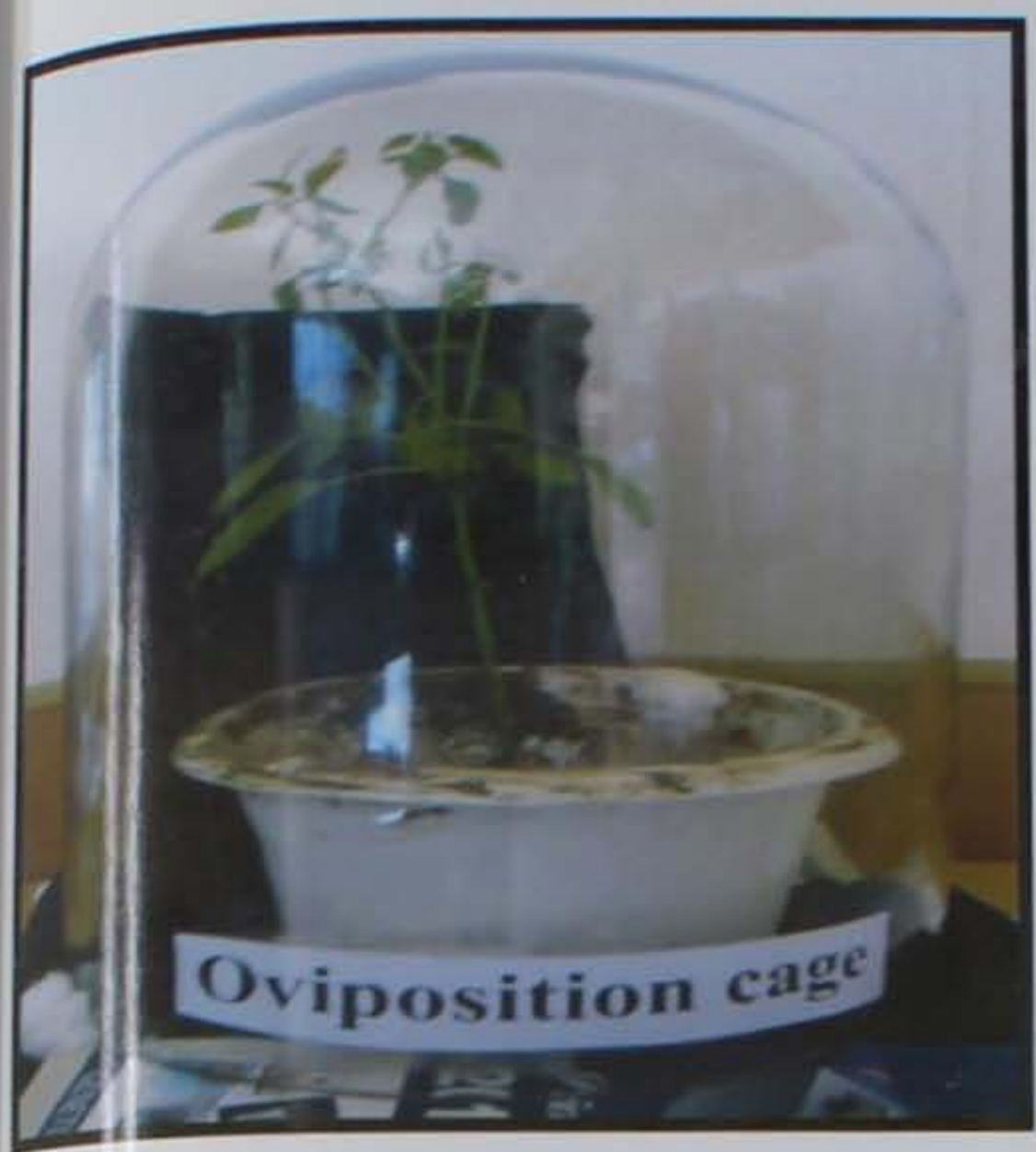


Plate 9 (A)

Plate 9 (B)

Plate 9: (A) Oviposition cage with chilli plant (A) oviposition cage covered with muslin cloth

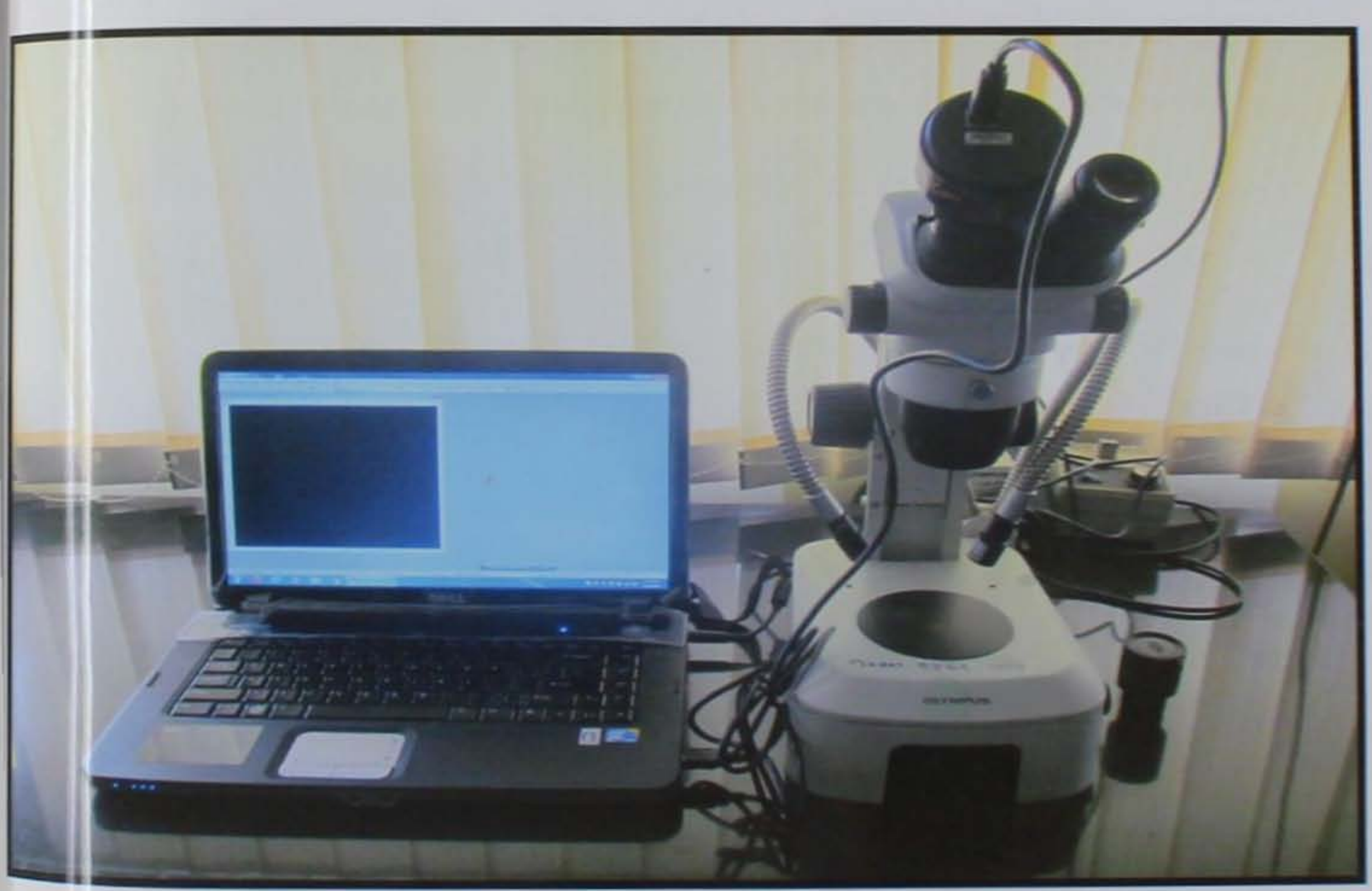


Plate 10: Stereo Trinocular microscope Olympus-SZ (16) fitted with Brand Catcam-130 camera having software power Scopephoto

3.4.3 Larvae

With a view to determine the number and duration of different larval instars and total larval period, the newly emerged larvae were placed individually in plastic culture tubes (2.5 cm diameter x 7.5 cm height) with the help of fine camel hair brush. A small twig with tender leaves was provided as food to the larvae (first and second instar) and the end of twig was wrapped with moist cotton swab to maintain a turgidity. Thereafter, fresh and tender green chilli fruits were provided as food to the larvae to onward instars (third, fourth and fifth).The food was replaced every alternate day (Plate-11B).

All the larvae were kept under observation daily for their change of instars. A change of instar was confirmed by presence of casted head capsule and sometimes exuviae in the rearing tube. The duration of each instar was worked out and length as well as breadth of each instar were also measured.

3.4.4 Pre-pupa

About 2.5 to 3.0 cm thick layer of moist soil was provided in the glass jar (10 cm diameter x 13 cm hight) to full grown larvae for pupation (Plate-12A). To record the pre-pupal period, the larvae were observed from the time when it stops feeding and become sluggish to the time when it undergoes soil for pupation.

3.4.5 Pupa

Pupae were collected from earthen cocoon and separated sex wise on the basis of morphometric differentiation. The male and female pupae were kept in

Plate 11 (A)

Plate 11 (B)

Plate 11: Studies on biology: (A) individual egg (B) individual larva

Plate 12 (A)

Plate 12 (B)

Plate 12: (A) Moist soil for pupation (B) pupae

plastic jar (12 cm diameter x 15 cm height) (Plate-12B). Pupal period was recorded from time of larva underwent soil to the emergence of adult. The colour and size of pupae were also recorded.

3.4.6 Adult

The moths emerged were observed for their colour and size. Male and female were confirmed by presence of tuft of hairs at the end of abdomen in case of female which was absent in male. Ten pairs of male and female moth of the same age group were paired separately in oviposition cage to study their preoviposition, oviposition and post oviposition periods as well as longevity of adults and fecundity. The length and breadth with their expanded wings were also measured with the help of vernier caliper (Plate-13 and 14). The sex ratio was worked out on the basis of male and female moths emerged from the general culture maintained in the laboratory.

3.4.7 Pre-oviposition, oviposition and post-oviposition period, fecundity and longevity

Pre-oviposition period was calculated from the date of emergence of female adult to the date of starting laying eggs. Likewise, a period from starting of laying eggs to the ceasing of laying eggs was considered as oviposition period while ceasing of laying eggs to the death of female was considered as post oviposition period.

Plate 13: Measurement (length) of adult of *H. armigera*

Plate 14: Measurement (breadth) of adult of *H. armigera*

3.4.8 Total life cycle

Total life cycle was considered as the period between date of laid egg to the date of adult died.

Results & Discussion

IV. RESULTS AND DISCUSSION

Chilli is one of the important major vegetable as well as spices crop of south Gujarat. The farmers commonly used many types of insecticides, which are being used to control chilli thrips, *S. dorsalis* and chilli fruit borer, *H. armigera* in chilli crop. All the insecticidal compounds potentially pose hazards to human being, animals and environment, as they are chemically tailored to be toxic. Looking to the potential of insecticides against chilli thrips, bio-efficacy of insecticides, determine their residues in/on fresh chilli fruits as well as dry chilli powder, persistence and processing factor and to know the activity of different life stages of pest, studies on biology of *H. armigera* were carried out during *rabi*, 2015-16. It can helps to decide the strategy of management practices. The results on various investigations are presented and discussed in the light of available literature after statistical analysis of data under the following head.

4.1 Biocfficacy of various insecticides against chilli thrips (*S. dorsalis*)

The data on thrips population after 3, 5 and 7 days after 1st and 2nd spray and their pooled are presented in Table-5 and depicted in Figure-1.

4.1.1 First spray

The data on mean population before commencement of spray are consistent among different treatments (14.25 to 15.45 thrips/leaf) as the data are statistically non-significant. Moreover, there was a significant difference in the

data of mean population of thrips in treated plot and untreated control, which showed efficacy of insecticidal treatments.

At 3 DAS, all the insecticidal treatments were significantly superior over untreated control. The lowest thrips population was recorded in the treatment of fipronil 0.005 per cent at 25 mL a.i./ha (0.55 thrips/leaf) and was at par with the treatment of fenpropathrin 0.03 per cent at 150 mL a.i./ha (0.55 thrips/leaf) and ethion + cypermethrin 0.1 per cent at 499.5 mL a.i./ha (0.90 thrips/leaf). Latter was also at par with the treatment of lambda-cyhalothrin 0.005 per cent at 25 mL a.i./ha (1.05 thrips/leaf). The treatment of fenazaquin 0.005 per cent at 50 mL a.i./ha (3.85 thrips/leaf) recorded significantly higher population than rest of the treatments, however it was significantly superior than untreated control.

After 5 DAS, fipronil 0.005 per cent recorded the lowest thrips population (0.55 thrips per leaf) and was also at par with the treatment of ethion + cypermethrin 0.1 per cent (1.10 thrips/leaf). Latter was also found at par with lambda-cyhalothrin 0.005 per cent (1.45 thrips/leaf). Fenpropathrin 0.03 per cent (2.50 thrips/leaf) and fenazaquin 0.005 per cent (2.70 thrips/leaf) remained equally effective against thrips, though they were significantly superior than untreated control.

Table 5: Bioefficacy of various insecticides against thrips

Treatment	Dose (mL a.i./ha)	No. of thrips/plant day after spray										Overall Pooled
		I Spray					II Spray					
		1DBA	3DAA	5DAA	7DAA	Pooled	1DBA	3DAA	5DAA	7DAA	Pooled	
Fipronil 5 SC	25	3.98 (15.40)	1.02 (0.55)a	1.02 (0.55)a	1.39 (1.45)a	1.15 (0.85)a	4.06 (16.05)	1.22 (1.00)a	1.39 (1.45)a	2.82 (7.45)a	1.81 (3.30)a	1.48 (2.08)a
Lambda-cyhalothrin 5 EC	25	3.86 (14.45)	1.24 (1.05)b	1.39 (1.45)b	2.23 (4.55)bc	1.64 (2.35)c	4.21 (17.25)	1.85 (3.00)b	2.01 (3.55)c	3.66 (12.95)b	2.51 (6.50)b	2.07 (4.43)c
Ethion 40 EC + Cypermethrin 5 EC	499.5	3.99 (15.45)	1.18 (0.90)ab	1.26 (1.10)ab	1.51 (1.85)a	1.27 (1.28)ab	4.14 (16.65)	1.69 (2.35)b	1.84 (2.90)bc	3.80 (14.00)b	2.44 (6.42)b	1.86 (3.85)bc
Fenpropathrin 30 EC	150	3.84 (14.25)	1.02 (0.55)a	1.72 (2.50)c	1.80 (3.10)ab	1.49 (2.05)bc	4.04 (15.90)	1.28 (1.15)a	1.61 (2.10)ab	2.93 (8.10)a	1.94 (3.78)a	1.71 (2.92)ab
Fenazaquin 10 EC	50	3.92 (14.85)	2.08 (3.85)c	1.79 (2.70)c	2.52 (5.85)c	2.04 (4.13)d	4.07 (16.05)	1.90 (3.15)b	2.82 (7.55)d	3.94 (15.05)b	2.88 (8.58)c	2.46 (6.36)d
Control	-	3.85 (14.35)	3.8 (14.00)d	4.01 (15.65)d	4.05 (15.90)d	3.98 (15.18)e	4.07 (16.05)	3.63 (12.85)c	4.02 (15.75)e	5.07 (25.20)c	4.24 (17.93)d	4.11 (16.56)e
S.Em ± (T)		0.10	0.06	0.10	0.17	0.09	0.11	0.12	0.09	0.11	0.09	0.09
CD at 5% (T)		NS	0.18	0.29	0.50	0.29	NS	0.37	0.28	0.33	0.28	0.32
S.Em ± (P x T)		-	-	-	-	0.10	-	-	-	-	0.09	0.11
CD at 5% (P x T)		-	-	-	-	NS	-	-	-	-	NS	NS
C.V.%		5.06	6.79	10.43	14.89	11.49	5.31	12.79	8.09	5.87	8.20	10.05

Figure in the parenthesis are original values while those outside square root transformed values (Add value = 0.5)

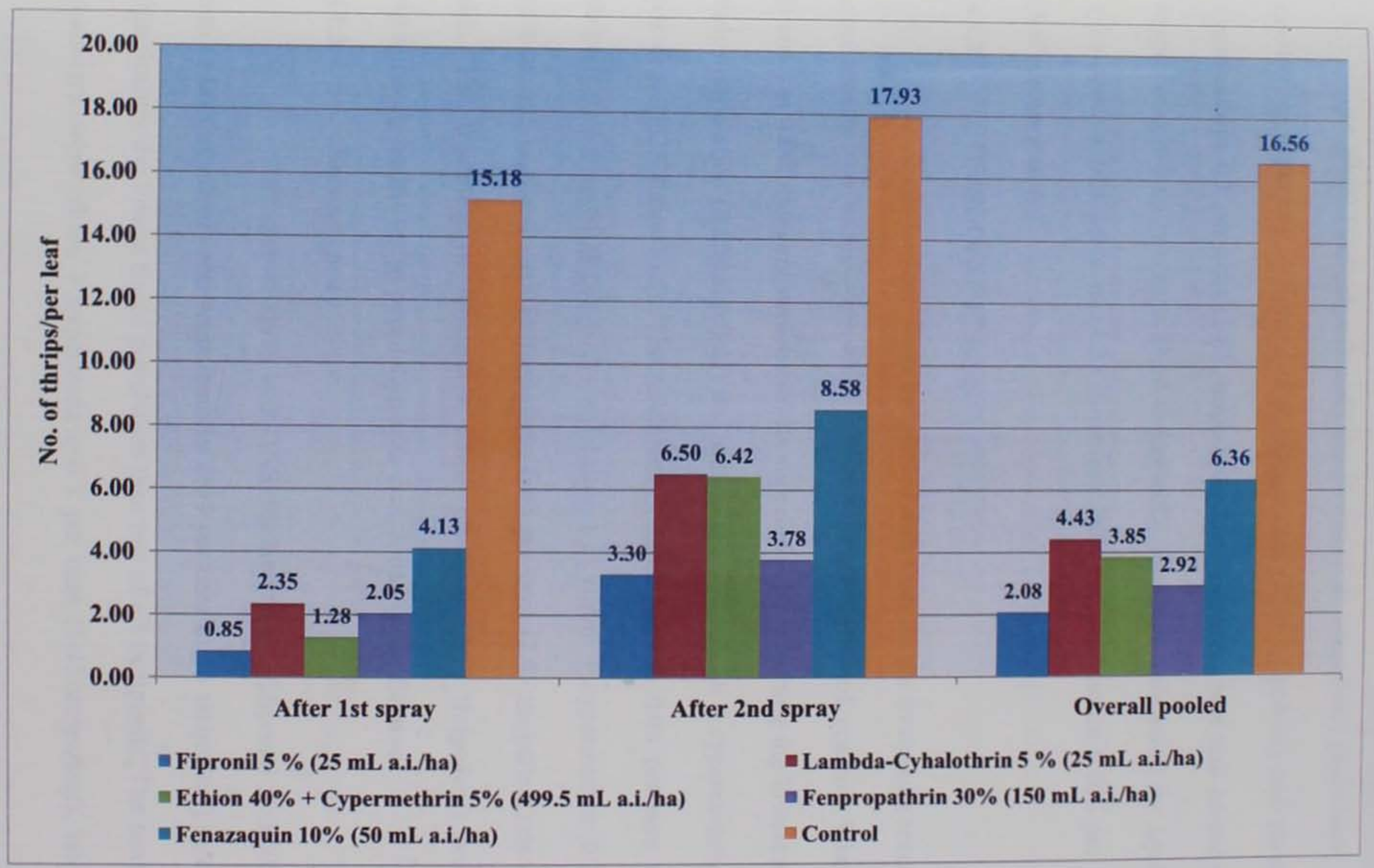


Figure 1: Efficacy of various insecticides against chilli thrips.

At 7 DAS, significantly the lowest (1.45 thrips/leaf) population was counted in treatment of fipronil at 0.005 per cent (1.45 thrips/leaf) and ethion + cypermethrin 0.1 per cent (1.85 thrips/leaf), however latter was also at par with fenpropathrin 0.03 per cent (3.10 thrips/leaf). These was followed by lambda-cyhalothrin 0.005 per cent (4.55 thrips per leaf) and fenazaquin 0.005 per cent (5.85 thrips/leaf).

4.1.2 Pooled over 1st spray

It can be seen from the pooled data that, all the treatments recorded significantly the lowest population of thrips than untreated control. Wherein, fipronil at 0.005 per cent established its superiority by imparting the lowest mean thrips population (0.85thrips/leaf) and was at par with ethion + cypermethrin 0.1 per cent (1.28 thrips/leaf). The treatment of fenpropathrin 0.03 per cent (2.05 thrips/leaf) remained at par with the treatment of ethion + cypermethrin 0.1 per cent on one side and with fenpropathrin 0.03 per cent (2.05 thrips/leaf) on other side. The treatment of fenazaquin 0.005 per cent (4.13 thrips/leaf) recoded significantly higher thrips population and, thus, found least effective.

4.1.3 Second spray

After second spray at 3 DAS, the treatment of fipronil at 0.005 per cent (1.00 thrips/leaf) and fenpropathrin 0.03 per cent (1.15 thrips/leaf) recorded significantly the lowest thrips population than rest of all treatments. The next best treatments were ethion + cypermethrin 0.1 per cent (1.45 thrips/leaf), lambda-

cyhalothrin 0.005 per cent (3.00thrips/leaf) and fenazaquin 0.005 per cent (3.15thrips/leaf).

At 5 DAS, fipronil at 0.005 per cent (1.45 thrips/leaf) recorded the lowest thrips population, however, it was at par with the treatment of fenpropathrin 0.03 per cent (2.10 thrips/leaf). The treatment of ethion + cypermethrin 0.1 per cent (2.90 thrips/leaf) was found equally effective with the treatment of fenpropathrin 0.03 per cent and lambda-cyhalothrin on either side. Fenazaquin 0.005 per cent found the least effective by recording higher thrips population (7.55 thrips/leaf).

Seven days after spraying, fipronil 0.005 per cent (7.45 thrips/leaf) and fenpropathrin 0.03 per cent (8.10 thrips/leaf) recorded significantly lowest thrips population and proved their superiority. The next best treatments were lambda-cyhalothrin 0.005 per cent (12.95 thrips/leaf), ethion + cypermethrin 0.1 per cent (14.00 thrips/leaf) and fenazaquin 0.005 per cent (15.05 thrips/leaf).

4.1.4 Pooled over 2nd spray

It is evident from the pooled data that, all the insecticidal treatments played significant role in minimizing the thrips population. Among them, after two sprays, treatments of fipronil at 0.005 per cent (3.30 thrips/leaf) and fenpropathrin 0.03 per cent (3.78 thrips/leaf) established their superiority to control the thrips. While, the next effective treatments found were ethion + cypermethrin 0.1 per cent (6.42 thrips/leaf) and lambda-cyhalothrin 0.005 per cent (6.50 thrips/leaf). The

treatment of fenazaquin 0.005 per cent found the least effective by recording highest population (8.58 thrips/leaf) even after two sprays.

4.1.5 Pooled over two sprays

Glance through the data on pooled over two sprays, all the insecticidal treatments proved effective over untreated control. A non significant result of Treatment X Period showed consistent performance of the treatments over period and sprays. It is also clear from the data that a treatment of fipronil 0.005 per cent (2.08 thrips/leaf) and fenpropathrin 0.03 per cent (2.92 thrips/leaf) found significantly superior in controlling the chilli thrips population. A treatment of ethion + cypermethrin 0.1 per cent (3.85 thrips/leaf) proved as the second best treatment, though, it was equally effective to fenpropathrin 0.03 per cent and lambda-cyhalothrin 0.005 per cent (4.43 thrips/leaf). Fenazaquin 0.005 per cent (6.36 thrips/leaf) remained the least effective among all the treatments during present investigation.

Earlier, superiority of fipronil has been proved against chilli thrips by Reddy *et al.* (2007) and Ahmed and Prasad (2009). Similarly, Chinniah and Ali (2000) observed superiority of ethion and fenpropathrin against carmine spider mite. While, Parmar *et al.* (2013) reveled that the ethion + cypermethrin proved significantly effective against red mite, *Tetranychus telarius* on okra. Thus, the above reports regarding efficacy of insecticides confirms the present findings.

A treatment of fenazaquin found least effective against chilli thrips during present investigation but Reza (2006) recorded it as second best treatment

on same pest and crop. From this, it can be assume that the pest might have develop resistance against the chemical, which needs further investigation.

4.1.6 Fruit yield

The data on yield of chilli fruit (Table-6 and Figure-2) revealed that, all the insecticidal treatments have effectively controlled the thrips in chilli crop which ultimately reflected by increase in yield. It observed that, fipronil (0.005 %) treated plot recorded highest yield (421.95 quintal/hectare) and was at par with fenpropathrin (403.26 q/ha). It was followed by treatments of lambda-cyhalothrin 0.005 per cent (375.04 q/ha), ethion + cypermethrin 0.1 per cent (328.43 q/ha) and fenazaquin 0.005 per cent (304.19 q/ha). Significantly, the lowest yield was recorded in untreated control plot with 172.84 q/ha. Reddy *et al.* (2007) also reported increase in yield in fipronil treated plot in chilli.

4.2. Persistence study of different insecticides against chilli thrips

4.2.1 Method validation for fresh chilli

The main objective of any method validation study (analytical measurement) is to obtain consistent, reliable and accurate data. The results from method validation can be used to judge the quality, reliability and consistency of analytical results, which is an integral part of any good analytical practice. Therefore, prior to determine the insecticide residues in chilli, method validation studies were performed to establish the accuracy (% recovery), precision (% RSD), limit of detection, limit of quantitation of the analytical method employed

Table 6: Effect of different insecticide on chilli fruit yield

Sr. No.	Treatment	Fruit yield (kg/ha)	Fruit yield (q/ha)
1	Fipronil 0.005% (25 mL a.i./ha)	218.7	421.95a
2	Lambda-cyhalothrin 0.005% (25 mL a.i./ha)	194.4	375.04b
3	Ethion + cypermethrin 0.1% (499.5 mL a.i./ha)	170.3	328.43c
4	Fenpropathrin 0.03% (150 mL a.i./ha)	209.1	403.26a
5	Fenazaquin 0.005% (50 mL a.i./ha)	157.7	304.19d
6	Control (water spray)	89.6	172.84e
	ANOVA		
S.E.m ±		0.91	6.99
C.D. @ 5%		2.73	21.07
C.V. (%)		4.18	4.18

Note: Treatment means with letter(s) in common are not significant at 5% level of significance in respective columns

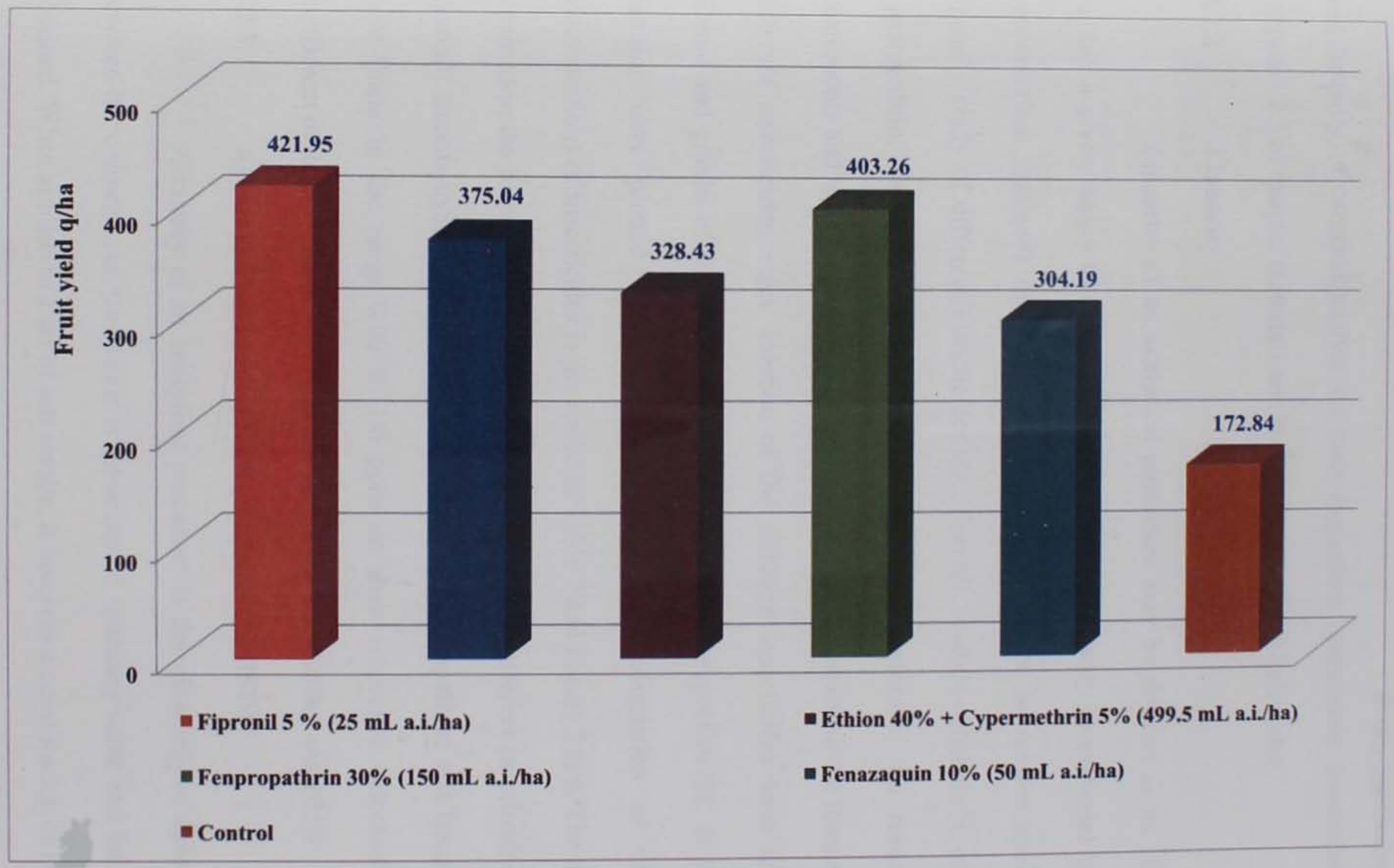


Figure 2: Impact of insecticides on chilli fruit yield.

and linearity of targeted analyte on their respective instruments mentioned in section 3.2.5 of chapter materials and methods is discussed hereunder.

4.2.2 Linearity

Linearity of an analytical procedure may be defined as its ability (within a given range) to obtain test results that are directly proportional to the concentration (amount) of analytes in the sample. Prior to residue analysis, linearity study of different insecticides *viz.*, fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin were performed on respective instruments and detectors to obtain their linear range. To establish the linearity of different insecticides, stock solution of the different insecticides were serially diluted and graphs of concentration *Vs.* response of the respective GC or HPLC detector were plotted. The graphical depiction of correlation of various concentrations of insecticides is presented in Table 7 and Figure 3 to 8. The results obtained in the linearity study revealed that response of different insecticides *viz.*, fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin were linear in the range 0.05 to 1.0 ppm on their respective detectors. The coefficient of determination (R^2) recorded for all the insecticides were 0.99.

4.2.3 Accuracy (% recovery) and precision (% RSD)

Accuracy of an analytical procedure is the closeness of agreement between the conventional true value or an accepted reference value and the value obtained. When applied to a set of test results, it involves a combination of random

Table 7: Details of linearity study of insecticides used in persistence

Sr. No.	Insecticide	Instrument	Linearity range ($\mu g\ g^{-1}$)	Coefficient of determination (R^2)	Regression equation
1	**Fipronil**	GC-ECD	0.05 to 1.0	0.99	y = 1027.5x + 20.797
2	**Lambda-cyhalothrin**	GC-ECD	0.05 to 1.0	0.99	y = 144934x - 1726.4
3	**Ethion**	GC-ECD	0.05 to 1.0	0.99	y = 64091x + 1758.5
4	**Cypermethrin**	GC-ECD	0.05 to 1.0	0.99	y = 39975x - 344.98
5	**Fenpropathrin**	GC-ECD	0.05 to 1.0	0.99	y = 326468x - 3802.2
6	**Fenazaquin**	HPLC-PDA	0.05 to 1.0	0.99	y = 35642x - 1239.7

error (estimated as precision) and a common systematic error (trueness or bias). Precision of the method employed is the closeness of agreement between independent analytical results obtained by applying the experimental procedure under stipulated conditions. The smaller the random part of the experimental errors which affect the results, the more precise is the procedure. Per cent relative standard deviation is considered as the measure of precision. Generally, these parameters are assessed by analyzing a sample with known concentrations and comparing the measured value with the true value.

Considering this, recovery studies of different insecticides in/on chilli fruit were performed to establish the accuracy and precision of the method applied for extraction and clean up. For this purpose, the recovery study was performed with three levels of fortification with seven replicates along with

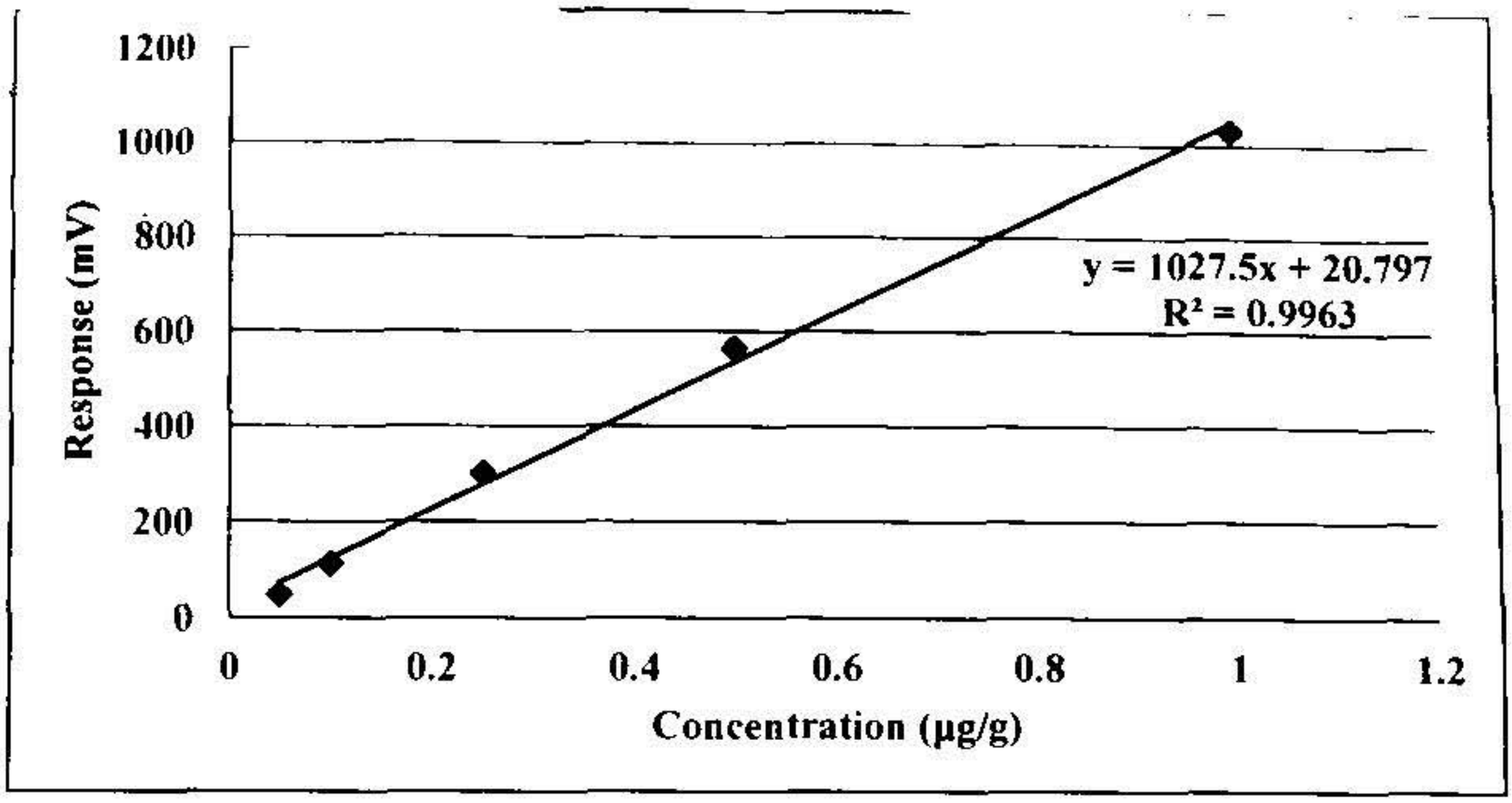


Figure 3: Linearity study of fipronil on GC-ECD

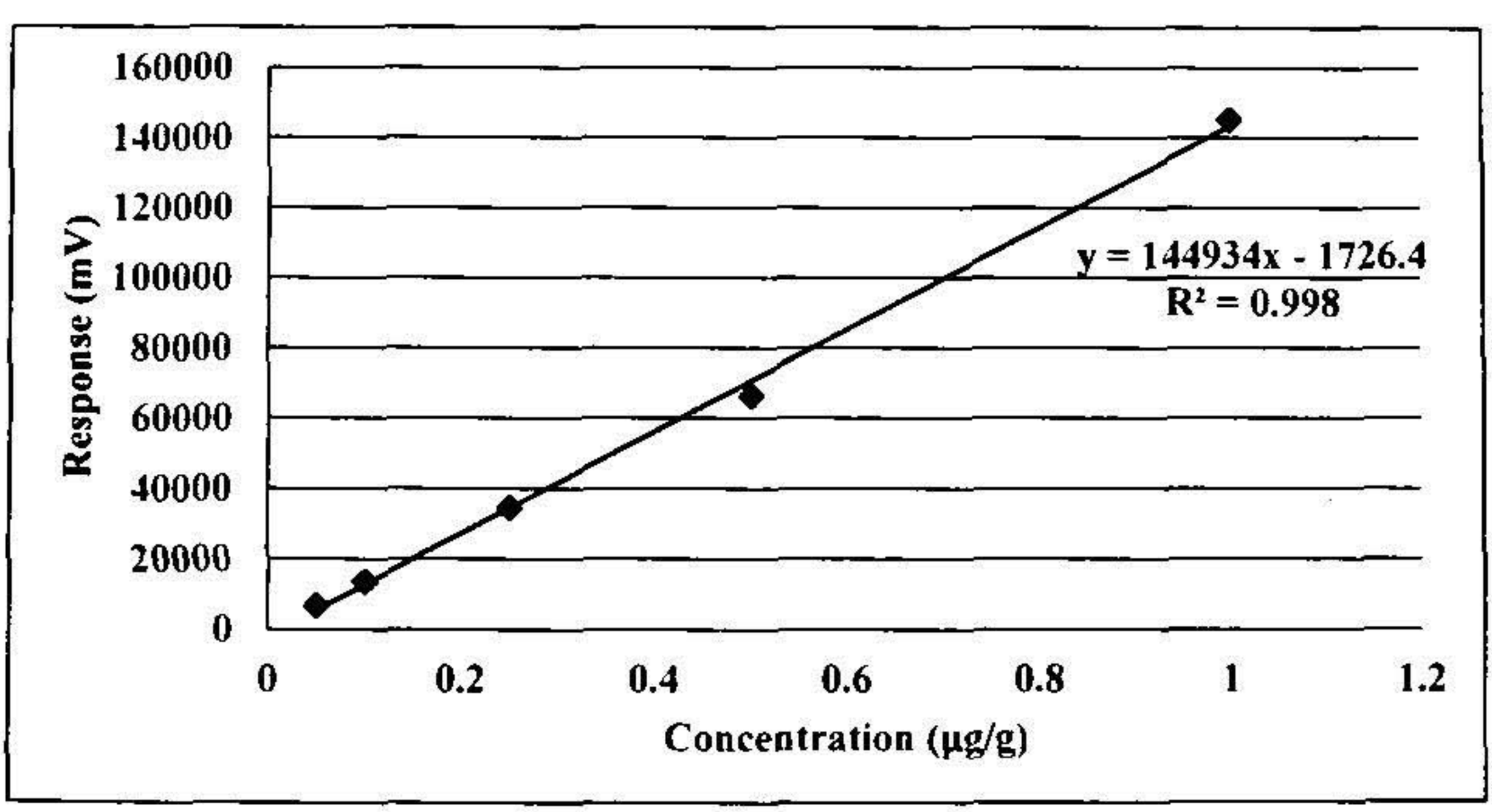


Figure 4: Linearity study of lambda-cyhalothrin on GC-ECD

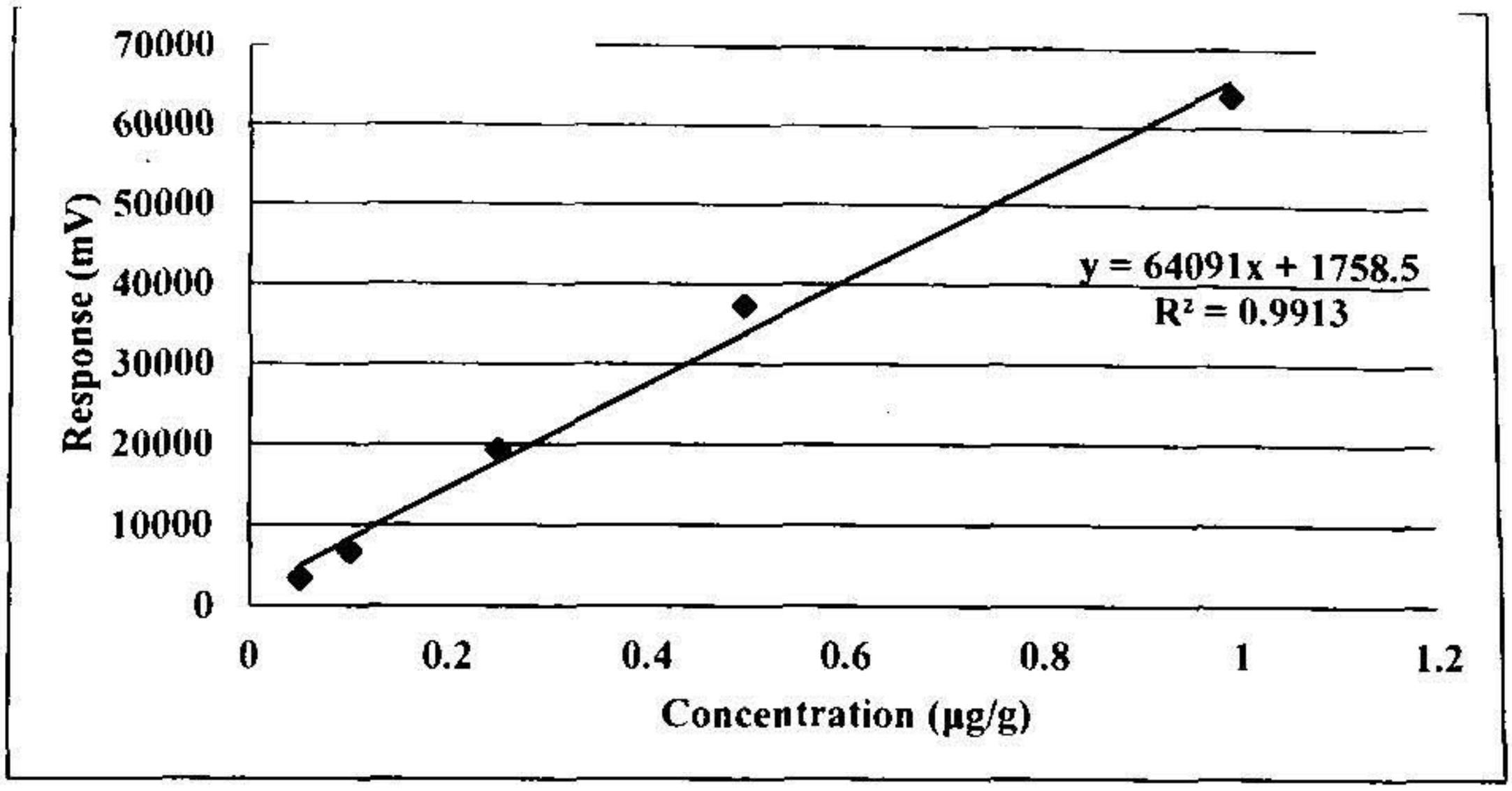


Figure 5: Linearity study of ethion on GC-ECD

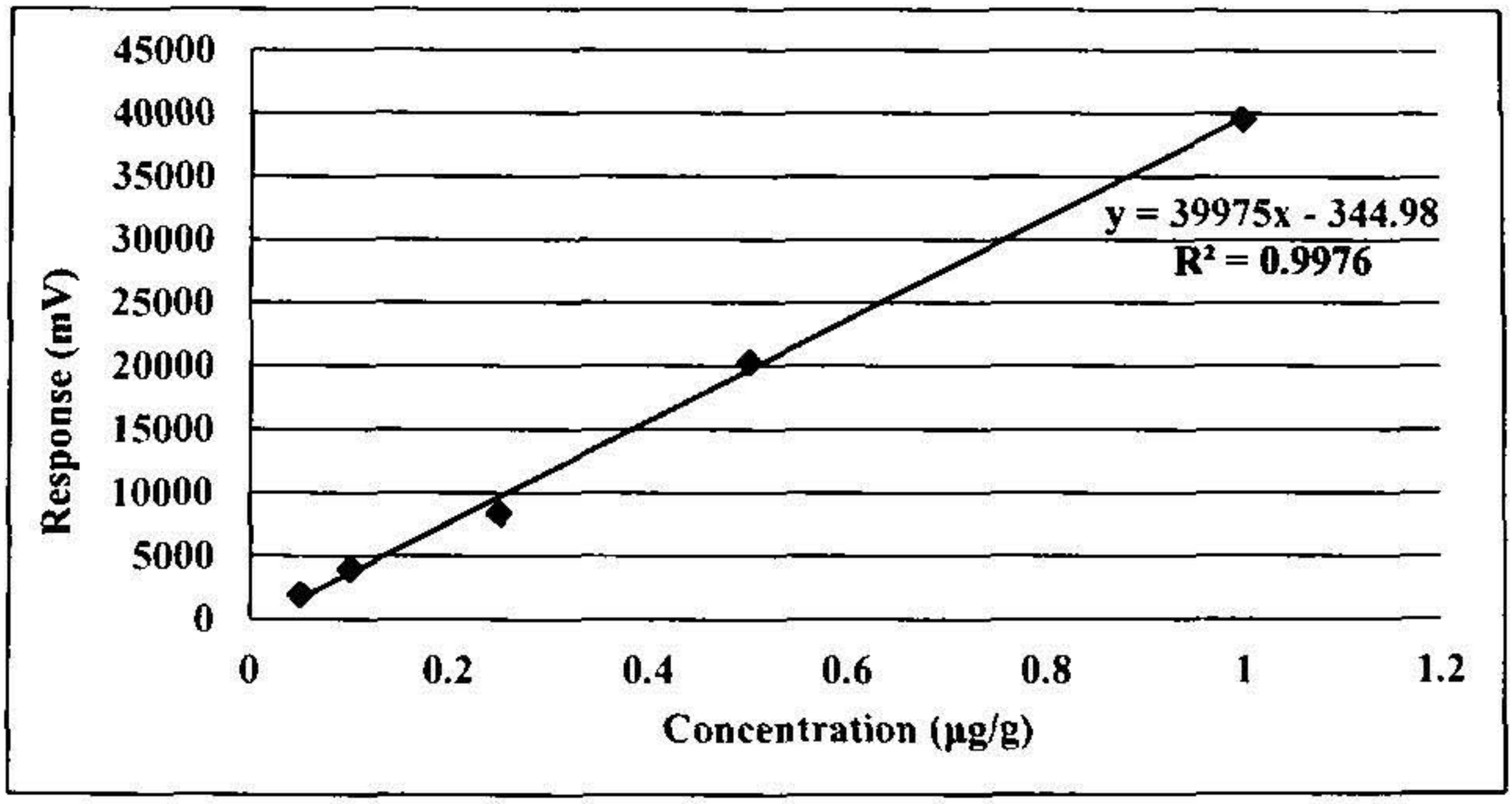


Figure 6: Linearity study of cypermethrin on GC-ECD

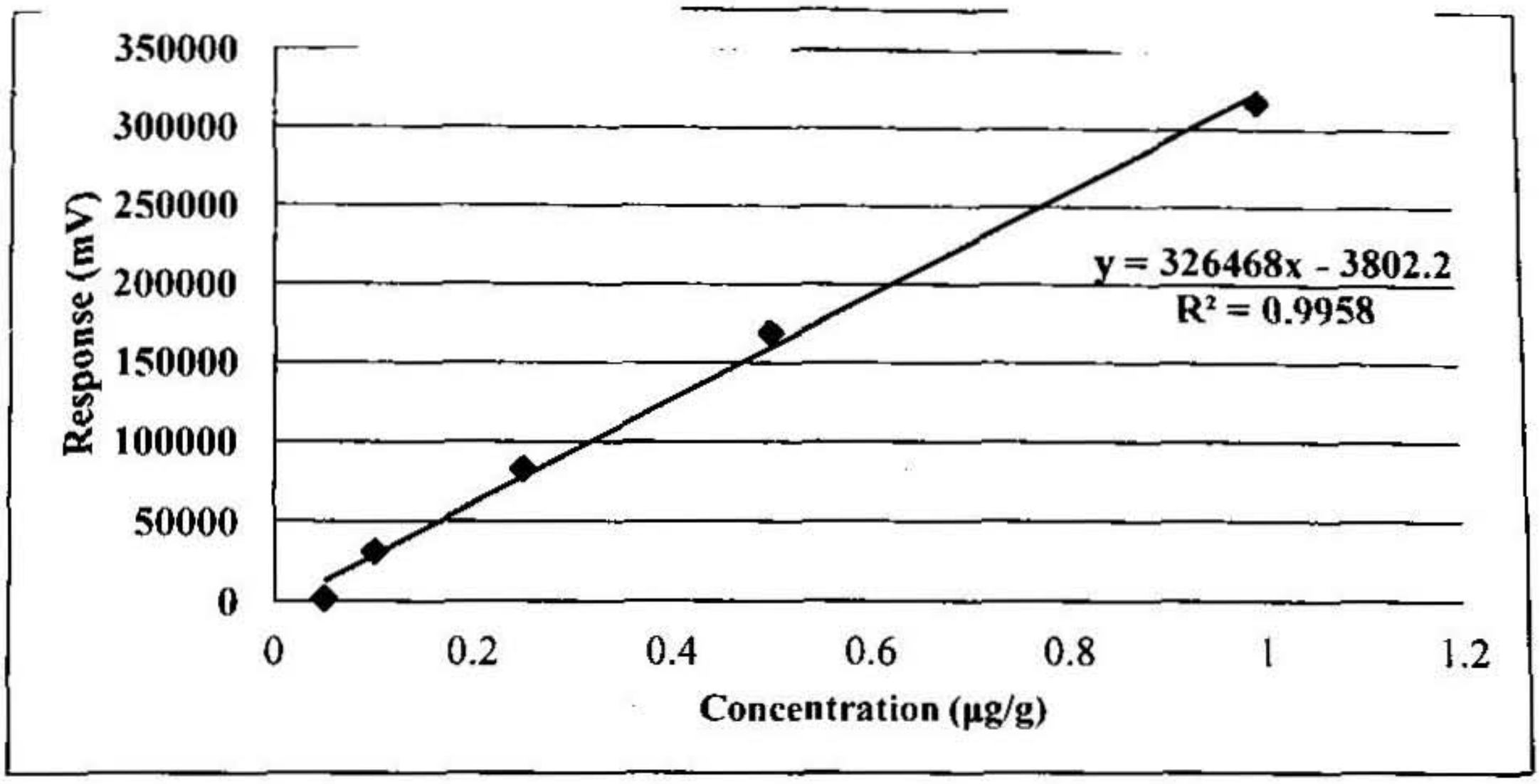


Figure 7: Linearity study of fenpropathrin on GC-ECD

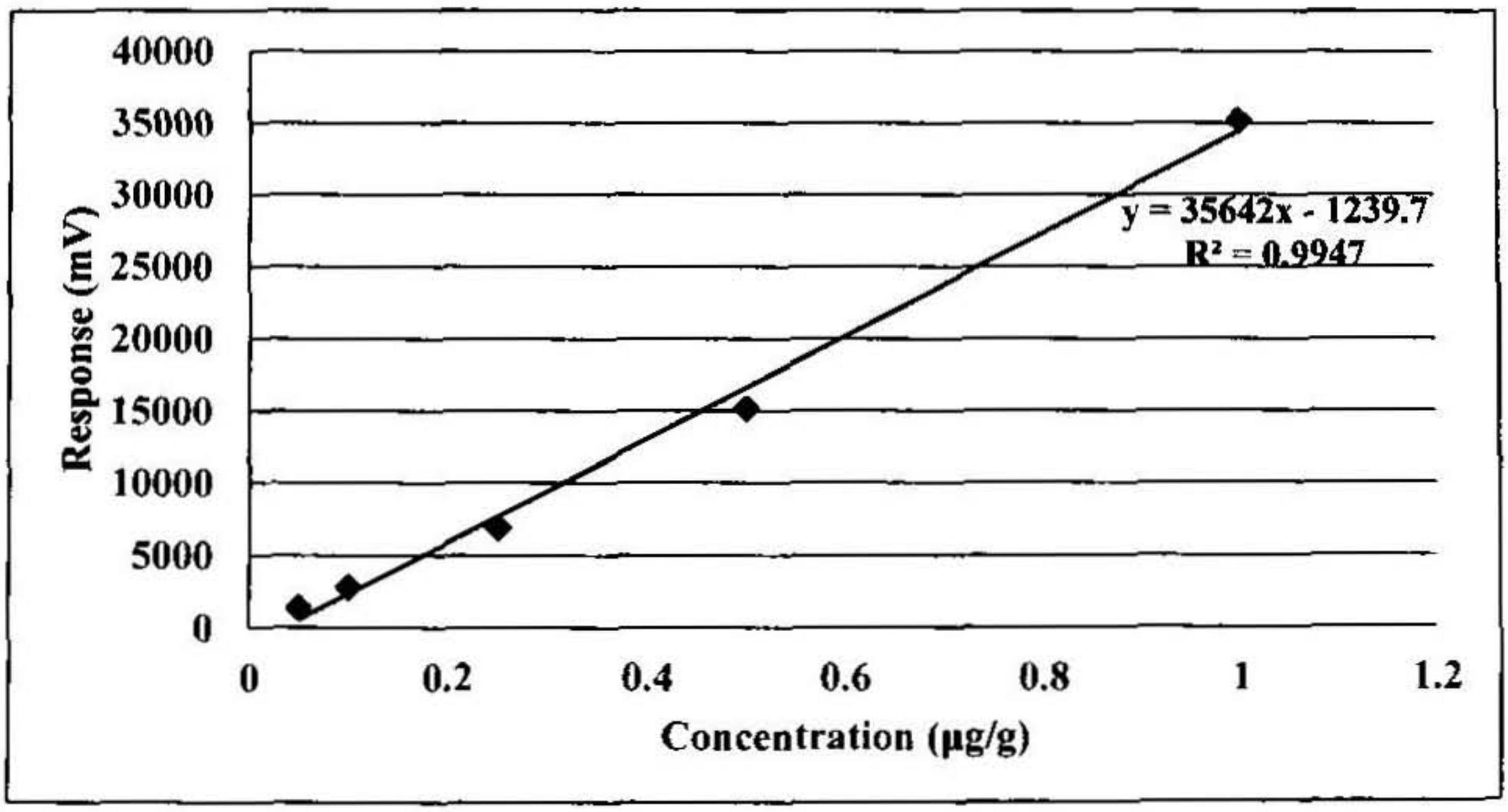


Figure 6: Linearity study of fenazaquin on HPLC-PDA

control as well as reagent blank. The detailed methodology is mentioned in the section (3.2.7.2) of materials and methods chapter.

The data obtained from recovery study, limit of detection and limit of quantification of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in fresh chilli fruits and sun dry chilli powder are described hereunder Table-8 and 9.

4.2.3.1 Fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin

Chilli fruits samples were fortified with fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin 0.1, 0.25 and 0.5 µg/g concentration levels. The results obtained in the study reveals that the fortified samples of chilli on GC-ECD imparted mean recovery of 88.14 ± 5.12, 91.10 ± 5.86 and 95.58 ± 3.63 per cent with 5.81, 6.43 and 3.80 per cent RSD at above mentioned fortification levels, respectively. The per cent mean recovery RSD data obtained for lambda-cyhalothrin were 90.40 ± 3.57 (RSD 3.95 per cent) 105.46 ± 4.63 (4.39 RSD per cent) and 97.36 ± 3.34 (3.43 RSD per cent) at 0.1. 0.25 and 0.5 µg/g level of fortification. 80.70 ± 4.73 with 5.87 per cent RSD, 77.50 ± 5.12, 6.61% RSD and 84.07 ± 4.11, 4.89% RSD, respectively in case of recovery of ethion. The per cent mean recoveries along with per cent RSD obtained in the study were 76.94 ± 5.23, 80.01 ± 4.23 and 74.65 ± 4.02 with 6.80, 5.28 and 5.38 per cent RSD. respectively at corresponding fortification level of cypermethrin. Whereas, in case

of fenpropathrin per cent mean recovery data obtained from samples fortified obtained were 86.42 ± 2.81 (3.26% RSD), 110.32 ± 3.37 (3.05% RSD) and 106.54 ± 4.11 (3.85% RSD) per cent, respectively.

4.2.3.2 Fenazaquin

The recovery study of fenazaquin was performed at 0.1, 0.25 and 0.5 ppm concentration level on HPLC-PDA and the per cent mean recoveries along with per cent RSD obtained in the study were 90.40 ± 3.57 (3.95% RSD), 105.46 ± 4.63 (4.39% RSD) and 97.36 ± 3.34 (3.43% RSD), respectively, in corresponding fortification level.

4.2.4 Limit of detection and limit of quantification (LOD and LOQ)

During the present investigation, limit of detection and limit of quantification was also performed for different insecticides. The LOD and LOQ of different insecticides were as follow: fipronil 0.02 and 0.05 μg g^{-1} (GC-ECD), lambda-cyhalothrin 0.01 and 0.04 μg g^{-1} (GC-ECD), ethion 0.016 and 0.047 μg g^{-1}(GC-ECD), cypermethrin 0.01 and 0.04 μgg^{-1} (GC-ECD), fenpropathrin 0.01 and 0.03 μgg^{-1} (GC-ECD) and fenazaquin 0.01 and 0.04 μgg^{-1} (HPLC-PDA), respectively.

4.2.5 Method validation of sun dried chilli powder

4.2.5.1 Fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin

Dry chilli powder samples were fortified with fipronil, lambda-cyhalothrin, ethion, cypermethrin and fenpropathrin 0.1 and 0.5 ppm concentration level. The results obtained in the study revealed that, the fortified samples of chilli on GC-ECD imparted mean recovery of 89.62 ± 4.31 and 93.34 ± 3.39 with 4.81 and 3.63 per cent at above mentioned fortification levels, respectively. The per cent mean recovery data obtained for lambda-cyhalothrin were 97.93 ± 2.91 with RSD 2.97 per cent and 97.74 ± 2.16 (2.21 per cent RSD). While, 80.11 ± 3.16 with 3.95 per cent RSD at 0.1 and 82.96 ± 3.56 (4.30 per cent RSD) at 0.5 level of ethion, respectively. The per cent recovery along with RSD obtain in the study were 78.48 ± 2.80 with 3.57 per cent RSD and 77.33 ± 3.69 with 4.78 per cent RSD at 0.1 and 0.5 fortification level of cypermethrin, respectively. While, in case of fenpropathrin per cent mean recovery data obtained from samples, fortified obtained data were 101.09 ± 1.90 (1.87 per cent RSD) and 105.98 ± 2.28 (2.15 per cent RSD) per cent, respectively.

4.2.5.2 Fenazaquin

The recovery study of fenazaquin was performed at 0.1 and 0.5 ppm concentration level on HPLC-PDA and the per cent mean recoveries along with per cent RSD obtained in the study were 97.93 ± 2.91 (2.97 per cent RSD) and 101.41± 2.82 (2.78 per cent RSD) per cent, respectively in corresponding fortification level.

Compound	Fortification level (µg g-1)	Recovery (%)							Mean	SD	RSD%	LOD (µg g-1)	LOQ (µg g^{-1})
		R-1	R-2	R-3	R-4	R-5	R-6	R-7					
Fipronil	0.1	84.09	85.23	91.56	89.67	80.45	90.55	95.45	88.14	5.12	5.81	0.02	0.05
	0.25	94.28	85.34	93.43	80.73	91.83	95.55	96.54	91.10	5.86	6.43	0.02	0.06
	0.5	95.92	97.23	98.67	96.41	87.89	94.85	98.12	95.58	3.63	3.80	0.01	0.04
												0.02	**0.05**
L-Cyhalothrin	0.1	89.04	93.49	91.88	90.14	86.41	95.73	86.11	90.40	3.57	3.95	0.01	0.04
	0.25	100.21	103.09	109.63	99.17	110.54	108.75	106.82	105.46	4.63	4.39	0.02	0.05
	0.5	102.66	96.78	100.23	94.55	98.82	94.91	93.58	97.36	3.34	3.43	0.01	0.03
												0.01	**0.04**
Ethion	0.1	75.65	85.74	75.80	86.32	84.36	80.12	76.93	80.70	4.73	5.87	0.016	0.047
	0.25	78.87	70.12	73.89	78.33	80.65	74.76	85.87	77.50	5.12	6.61	0.017	0.051
	0.5	85.81	79.84	76.87	86.16	88.28	85.19	86.37	84.07	4.11	4.89	0.014	0.041
												0.016	**0.047**
Cypermethrin	0.1	70.56	80.34	73.76	79.67	70.34	82.36	81.56	76.94	5.23	6.80	0.02	0.05
	0.25	82.23	73.87	75.44	80.89	85.12	78.65	83.87	80.01	4.23	5.28	0.01	0.04
	0.5	80.54	70.45	73.78	75.12	79.56	71.34	71.76	74.65	4.02	5.38	0.01	0.04
												0.01	**0.04**
Fenpropathrin	0.1	88.87	84.23	85.65	90.87	87.12	85.68	82.51	86.42	2.81	3.26	0.01	0.03
	0.25	107.23	112.67	105.71	111.05	109.18	110.60	115.78	110.32	3.37	3.05	0.01	0.03
	0.5	108.07	100.37	102.52	106.64	112.93	108.44	106.83	106.54	4.11	3.85	0.01	0.04
												0.01	**0.03**
Fenazaquin	0.1	89.04	93.49	91.88	90.14	86.41	95.73	86.11	90.40	3.57	3.95	0.01	0.04
	0.25	100.21	103.09	109.63	99.17	110.54	108.75	106.82	105.46	4.63	4.39	0.02	0.05
	0.5	102.66	96.78	100.23	94.55	98.82	94.91	93.58	97.36	3.34	3.43	0.01	0.03
												0.01	**0.04**

Table 8: Method validation study of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in chilli fruit

4.2.6 Limit of detection and limit of quantification (LOD and LOQ)

During the processing study, limit of detection and limit of quantification was also worked out for different insecticides. The LOD and LOQ of different insecticides were as follow: fipronil 0.01 and 0.04 $\mu g\ g^{-1}$ (GC-ECD), lambda-cyhalothrin 0.01 and 0.03 $\mu g\ g^{-1}$ (GC-ECD), ethion 0.011 and 0.034 $\mu g\ g^{-1}$(GC-ECD), cypermethrin 0.01 and 0.03 μgg^{-1} (GC-ECD), fenpropathrin 0.01 and 0.02 μgg^{-1} (GC-ECD) and fenazaquin 0.01 and 0.03 μgg^{-1} (HPLC-PDA), respectively.

4.2.7 Persistence of different insecticides used in/on chilli

In order to study the persistence of five insecticides in/on chilli, a field trial was conducted at Farmers field, Village Kesali, Ta. Gandevi, Dist. Navsari. Two foliar sprays of five insecticides *viz*., fipronil, lambda-cyhalothrin, ethion + cypermethrin, fenpropathrin and fenazaquin were applied at recommended doses. A representative samples were drawn from each treatment in triplicate along with control. The samples were taken on 0 days (2 hours after application), 1, 3, 5, 7, 10 and 15 days after application.

The dissipation kinetic of the different insecticides was determined by plotting residue concentration against time and the maximum coefficient of determination found were used to ascertain the equations of best fit curves. For all the samples studied in present investigation, the exponential relationships were applied, corresponding to a first-order rate equation mentioned hereunder.

Compound	Spiking level (µg g-1)	Recovery (%)							Mean	SD	RSD%	LOD (µg g-1)	LOQ (µg g^{-1})
		R-1	R-2	R-3	R-4	R-5	R-6	R-7					
Fipronil	0.1	89.19	85.29	92.50	85.20	86.14	93.05	96.00	89.62	4.31	4.81	0.01	0.04
	0.5	95.10	91.29	96.05	88.57	89.86	95.20	97.33	93.34	3.39	3.63	0.01	0.03
												0.01	**0.04**
L-Cyhalothrin	0.1	94.63	98.29	100.76	94.66	98.48	102.24	96.47	97.93	2.91	2.97	0.01	0.03
	0.5	97.30	97.79	100.58	94.62	98.59	99.80	95.50	97.74	2.16	2.21	0.01	0.02
												0.01	**0.03**
Ethion	0.1	80.11	78.57	75.52	83.60	84.43	80.02	83.06	80.11	3.16	3.95	0.011	0.032
	0.5	82.96	79.20	76.20	84.88	86.36	82.61	84.71	82.96	3.56	4.30	0.012	0.036
												0.011	**0.034**
Cypermethrin	0.1	76.40	77.11	74.60	80.28	77.73	80.51	82.72	78.48	2.80	3.57	0.01	0.03
	0.5	81.39	72.16	74.61	78.01	82.34	75.00	77.82	77.33	3.69	4.78	0.01	0.04
												0.01	**0.03**
Fenpropathrin	0.1	101.39	99.09	97.96	102.85	103.08	101.57	101.71	101.09	1.90	1.87	0.01	0.02
	0.5	105.56	104.04	102.06	106.85	108.40	106.87	108.11	105.98	2.28	2.15	0.01	0.02
												0.01	**0.02**
Fenazaquin	0.1	94.63	98.29	100.76	94.66	98.48	102.24	96.47	97.93	2.91	2.97	0.01	0.03
	0.5	101.44	99.94	104.93	96.86	104.68	101.83	100.20	101.41	2.82	2.78	0.01	0.03
												0.01	**0.03**

Table 9: Method validation study of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in dried chilli powder

$$C_t = C_0 e^{-kt}$$

Where, C_t = Residues of pesticide at time 't'

C_0 = Initial deposition of pesticide

k = degradation constant

The half-life ($t_{1/2}$) was calculated from the k value for each experiment being $t_{1/2} = \log (2) k$.

4.2.7.1 Fipronil

Residue data on recommended dose of fipronil in on chilli fruits recorded at **0** days (2 hours of exposure), 1st, 3rd, 5th, 7th,10th and 15th days exhibited 0.27 (initial deposition), 0.25, 0.22, 0.19, 0.17, 0.14 and 0.09 µg g^{-1}, respectively. The corresponding losses for fipronil residues in on chilli varied from 8.82 to 65.81 per cent at different time intervals. The regression equation of fipronil obtained in the present investigation by adopting the statistical model mentioned as follow: $y = -0.0258x + 1.4119$ ($R^2 = 0.98$). On the basis the regression equation, the half life worked out was 11.67 days (Table-10).

The residue data obtained in persistence study of fipronil in chilli fruits indicated 65.81 per cent residues of fipronil residues were lost within 15 days after application with half-life 11.67 days. Contrary to our findings pertaining to the persistence of fipronil in chilli fruits, several studies observed a fasier dissipation which is reflected from the half-life values e.g. 1.71 (Kumar *et al.*, 2013), 4.22 (Xavier *et al.*, 2014) and 3.50 (Saini *et al.*, 2015) days in chilli.

In addition to this, degradation of fipronil is also affected by other abiotic factors such as environmental temperature and rainfall. At lower temperature, fipronil is converted to its oxon metabolite. The chilli crop was taken in the winter season; therefore, fipronil residues were less and also dissipated at faster rate. Henceforth, this might be a probable reason that the half life of fipronil was detected 11.67 days in the present investigation.

4.2.7.2 Lambda-cyhalothrin

To investigate the dissipation pattern of lambda-cyhalothrin in chilli, the foliar spray of lambda-cyhalothrin was performed applied at the rate of 0.005 per cent (recommended dose). The spray concentration @ 0.005 per cent resulted in 0.33 µg g^{-1} of initial deposition which dissipated to 0.27, 0.25, 0.23, 0.23, 0.13 and 0.07 µg g^{-1} at 1st, 3rd, 5th, 7th, 10th and 15th day after application, respectively. In terms of per cent dissipation, it was observed that within 1st day after spray 16.26 per cent of initial deposition was dissipated followed by 23.01, 28.53. 30.67, 60.12 and 79.14 per cent at 1st, 3rd, 5th, 7th, 10th and 15th days, respectively. The regression equation obtained showing dissipation pattern is as follow: $y = -0.0431x + 1.5401$ ($R^2 = 0.92$). Half-life period worked out for lambda-cyhalothrin at recommended dose was 6.98 days (Table-11). The dissipation half-life obtained in the present study (6.98 days) is more or less similar to the finding of earlier studies *viz.*, 3.4 days (Mohapatra *et al.*, 2006) and 2.92 days (Singh *et al.*, 2007).

4.2.7.3 Ethion

Ethion was applied at the rate of 0.088 per cent at recommended dose in chilli to establish its persistence behaviour in chilli fruits. The residues of ethion obtained at different time interval in/on chilli fruits. The initial deposition of 0.20 ± 0.05 µg g^{-1} of ethion was detected in/on chilli fruits on zero days after application. The residues of ethion were progressively decreased from 1st day onward and maximum of 76.73 per cent reduction was recorded at 10th day while, its residues become BDL on 15th days. The regression equation of ethion was fitted as y = -0.0642x +1.2774 by giving 0.9656 as R^2. Moreover, the half life period for this insecticide was 4.68 days (Table-12).

The ethion was found moderately persistent (DT_{50}; 4.68 days) in chilli, while other workers had reported a rapid degradation of ethion in several crops, e.g. cowpea pods ($t_{1/2}$ = 2.90 days, Soliman, 2011), okra ($t_{1/2}$ = 1.27 days by Parmar *et al.*, 2012) and chilli fruits ($t_{1/2}$ = 1.81 days by Sharma and Parihar, 2013) which is contradictory to the finding of present investigation. The rate of dissipation depends on several parameters such nature of molecule, weather conditions, nature of vegetation etc. In South Gujarat condition, the temperature is remaining mild across the season. This might be a probable reason for the moderate persistence of ethion in chillies.

4.2.7.4 Cypermethrin

The initial deposition of cypermethrin when applied at the rate of 0.011 per cent recorded on zero day was 0.55 µg g^{-1} and which gradually

dissipated to 0.48, 0.27, 0.13 and 0.10 µg g^{-1} at 1st, 3rd, 5th and 7th day after application, respectively. It was observed 13.95 per cent of initial deposition was lost on 1st day after application followed by 51.81, 76.81 and 82.43 per cent within 3rd, 5th and 7th days, respectively. The residues of this treatment reached to BDL on 7th day after application. The regression equation for cypermethrin was fitted as y = -0.1162x + 1.7591 (R^2 = 0.98) with a half life period of 2.6 days (Table-13).

Likewise, many workers have reported the half life ($t_{1/2}$) of 3.3, 2.59 and 1.98 days which is in agreement of present investigation (Deen *et al.*, 2009; Parmar *et al.*, 2012 and Kumar *et al.*, 2013), respectively.

The higher dissipation rate may be due to differences in environmental effect arising from the use of open field site. Growth dilution factor might be a potential factor of fast degradation and less persistence of cypermethrin residues in chilli fruits.

4.2.7.5 Fenpropathrin

The initial deposits of fenpropathrin detected on zero day was 1.58 µg g^{-1} when fenpropathrin was sprayed at the rate of 0.03% (Table-14). The initial deposit of recommended dose was dissipated to the extent of 77.33 per cent on 15th day. The regression equation for fenpropathrin was fitted as y = -0.0397x + 2.2241 (R^2 = 0.9772) with a half life period of 8.14 days.

Similar findings were also reported by Romeh and Hendawi (2013a) where residues of fenpropathrin were below the detection limit on 15th days after application.

4.2.7.6 Fenazaquin

Fenazaquin was applied at the rate of 0.005 per cent in chilli to establish its dissipation behaviour in chilli fruits. The initial deposition was 2.33 µg g^{-1} at zero days which gradually decreased 1.68, 1.47, 1.22, 0.98, 0.58 and 0.19 µg g^{-1} at 1st to 15th days after deposition. Per cent degradation was ranged from 27.84 to 91.80 per cent within 1st to 15 days of exposure. The regression equation for fenpropathrin was fitted as $y = -0.0458x + 2.2723$ with R^2 value as 0.9161 with a half life period 6.57 days (Table-15).

More or less similar finding was reported by Sharma *et al.* (2006) with half life ranged from 1.9 to 5.3 days in different season.

4.3 Processing factor of different insecticides in chilli.

Although, chilli fruits are widely produced and consumed as raw but it's dried and powdered form is also used as spice/condiment throughout the world to impart pungency and taste to food and beverages. Among them the dry power is the major form, which is largely used by the consumer. There are reports on the detection of pesticide residues even in chilli and chilli product samples collected from retail outlets (Rao, 2005). Processing of chilli leads to increase in the concentration of the pesticides in final product. Hence, in view of the possible residue problems posed by these chemicals to the consumers, this study was taken up to find out the magnitude of increase in concentration of these insecticides (processing factor) in processed chilli, so as to prescribe the suitable processing factor for chilli. In present investigation, the effect of sun drying followed by

powdering on the residues of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in the chilli was studied.

The results obtained in the study reveals that the residues of all the insecticide concentrated by 5.02 to 8.57 per cent due to drying followed by powdering proces (Table-16). The result showed that initial deposits of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in the fresh chilli fruits were 0.27 ,0.07, 0.20, 0.55, 0.11 and 0.11 µg/g recorded on zero day (2 hrs after last spray), while these were 2.33, 0.62, 1.25, 2.77, 0.74 and 0.60 µg/g when subjected to processing (drying followed by powdering). This indicates that the residues of above insecticides concentrated, which indicates by processing factor. The processing worked out for fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin was 8.57, 9.13, 6.19, 5.02, 6.87 and 5.38, respectively. The results obtained in the study confirm that the dehydration process causes increase in the residues of insecticides with respect to fresh food commodities. Several earlier studies conducted on various crops *viz*., chilli (Pathan *et al.*, 2009), (Xavier *et al.*, 2014 and Noh *et al.*, 2015), cardamom (George and Kumar, 2013) and (Pratheeshkumar and Chandran, 2015) showed that residues of insecticides were concentrated due to drying or dehydration in lieu of 2.45-5.14 times.

The results obtained in the study were as per the expectation as due drying or dehydration a substantial moisture loss occurred in fresh chilli. Toontom *et al.* (2012) reported that drying causes moisture loss as moisture content in fresh

chillies were (85.15 %), which were merely 11 % after different drying processes. Therefore, loss in moisture content in due to processing (drying followed by powdering process) might be a probable reason for the concentration of residues of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in dried powdered chilli.

Days after application	Dose (mL a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LOD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.02	0.05
	25	0.26	0.22	0.34	0.27	0.06	-		
1	Control	-	-	-	-	-	-		
	25	0.21	0.24	0.29	0.25	0.04	8.82		
3	Control	-	-	-	-	-	-		
	25	0.20	0.20	0.27	0.22	0.04	18.01		
5	Control	-	-	-	-	-	-		
	25	0.18	0.16	0.23	0.19	0.04	30.51		
7	Control	-	-	-	-	-	-		
	25	0.16	0.14	0.21	0.17	0.04	37.87		
10	Control	-	-	-	-	-	-		
	25	0.16	0.12	0.13	0.14	0.02	49.26		
15	Control	-	-	-	-	-	-		
	25	0 15	0.09	0.04	0.09	0.05	65.81		
Persistence Pattern	Recommended dose								
Regression equation	y = -0.0258x + 1.4119								
R^2	$R^2 = 0.98$								
DT50 (Days)	11.67								

Table 10: Persistence of fipronil in/on chilli fruits

Days after application	Dose (mL a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LDD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.01	0.04
	25	0.30	0.29	0.39	**0.33**	**0.06**	-		
1	Control	-	-	-	-	-	-		
	25	0.24	0.32	0.26	**0.27**	**0.05**	**16.26**		
3	Control	-	-	-	-	-	-		
	25	0.23	0.22	0.31	**0.25**	**0.05**	**23.01**		
5	Control	-	-	-	-	-	-		
	25	0.27	0.20	0.23	**0.23**	**0.04**	**28.53**		
7	Control	-	-	-	-	-	-		
	25	0.28	0.22	0.18	**0.23**	**0.05**	**30.67**		
10	Control	-	-	-	-	-	-		
	25	0.12	0.09	0.17	**0.13**	**0.04**	**60.12**		
15	Control	-	-	-	-	-	-		
	25	0.05	0.07	0.08	**0.07**	**0.01**	**79.14**		
Persistence pattern	Recommended dose								
Regression equation	$y = -0.0431x + 1.5401$								
R^2	$R^2 = 0.92$								
DT50 (Days)	6.98								

Table 11: Persistence of lambda-cyhalothrin in/on chilli fruits

Days after application	Dose (mL a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LDD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.01	0.04
	444	0.20	0.16	0.25	0.20	0.05	-		
1	Control	-	-	-	-	-	-		
	444	0.12	0.15	0.17	0.15	0.03	27.23		
3	Control	-	-	-	-	-	-		
	444	0.12	0.13	0.16	0.14	0.02	31.68		
5	Control	-	-	-	-	-	-		
	444	0.10	0.05	0.11	0.09	0.03	56.93		
7	Control	-	-	-	-	-	-		
	444	0.04	0.07	0.07	0.06	0.02	70.79		
10	Control	-	-	-	-	-	-		
	444	0.05	0.03	0.06	0.05	0.02	76.73		
15	Control	-	-	-	-	-	-		
	444	BDL	BDL	BDL	BDL	BDL	BDL		
Persistence pattern	Recommended dose								
Regression equation	$y = -0.0642x + 1.2774$								
R^2	$R^2 = 0.96$								
DT50 (Days)	4.68								

Table 12: Persistence of ethion in/on chilli fruits

Days after application	Dose (mL. a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LDD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.01	0.04
	55.5	0.57	0.39	0.70	**0.55**	**0.16**	-		
1	Control	-	-	-	-	-	-		
	55.5	0.55	0.39	0.49	**0.48**	**0.08**	**13.95**		
3	Control	-	-	-	-	-	-		
	55.5	0.25	0.22	0.33	**0.27**	**0.05**	**51.81**		
5	Control	-	-	-	-	-	-		
	55.5	0.15	0.11	0.12	**0.13**	**0.02**	**76.81**		
7	Control	-	-	-	-	-	-		
	55.5	0.10	0.07	0.12	**0.10**	**0.02**	**82.43**		
10	Control	-	-	-	-	-	-		
	55.5	BDL	BDL	BDL	**BDL**	**BDL**	**BDL**		
15	Control	-	-	-	-	-	-		
	55.5	BDL	BDL	BDL	**BDL**	**BDL**	**BDL**		
Persistence pattern	Recommended dose								
Regression equation	$y = -0.1162x + 1.7591$								
R^2	$R^2 = 0.98$								
DT50 (Days)	2.6								

Table 13: Persistence of cypermethrin in/on chilli fruits

Days after application	Dose (mL a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LDD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.01	0.03
	150	1.99	1.61	1.14	**1.58**	**0.42**	-		
1	Control	-	-	-	-	-	-		
	150	1.20	1.15	1.59	**1.31**	**0.24**	**16.78**		
3	Control	-	-	-	-	-	-		
	150	1.14	1.13	1.51	**1.26**	**0.22**	**20.39**		
5	Control	-	-	-	-	-	-		
	150	1.37	1.01	1.07	**1.15**	**0.19**	**26.98**		
7	Control	-	-	-	-	-	-		
	150	1.38	1.04	1.02	**1.15**	**0.20**	**27.49**		
10	Control	-	-	-	-	-	-		
	150	0.70	0.53	0.88	**0.71**	**0.17**	**55.35**		
15	Control	-	-	-	-	-	-		
	150	0.48	0.41	0.19	**0.36**	**0.15**	**77.33**		
***Persistence* pattern**	Recommended dose								
Regression equation	$y = -0.0397x + 2.2241$								
R^2	$R^2 = 0.97$								
DT50 (Days)	8.14								

Table 14: Persistence of fenpropathrin in/on chilli fruits

Days after application	Dose (mL a.i./ha)	Residue (µg/g)			Mean	SD	Dissipation (%)	LDD (µg/g)	LOQ (µg/g)
		R-I	R-II	R-III					
0 (2 hrs after application)	Control	-	-	-	-	-	-	0.01	0.04
	50	2.10	2.09	2.80	**2.33**	**0.41**	-		
1	Control	-	-	-	-	-	-		
	50	1.87	0.98	2.19	**1.68**	**0.63**	**27.84**		
3	Control	-	-	-	-	-	-		
	50	1.34	1.29	1.77	**1.47**	**0.27**	**37.03**		
5	Control	-	-	-	-	-	-		
	50	1.44	1.05	1.17	**1.22**	**0.20**	**47.72**		
7	Control	-	-	-	-	-	-		
	50	0.96	0.75	1.22	**0.98**	**0.23**	**58.03**		
10	Control	-	-	-	-	-	-		
	50	0.68	0.49	0.56	**0.58**	**0.10**	**75.09**		
15	Control	-	-	-	-	-	-		
	50	0.15	0.21	0.22	**0.19**	**0.04**	**91.80**		
Persistence pattern	Recommended dose								
Regression equation	$y = -0.0458x + 2.2723$								
R^2	$R^2 = 0.91$								
DT50 (Days)	6.57								

Table 15: Persistence of fenazaquin in/on chilli fruits

Table 16: Effect processing of 0 (zero) days dry chilli sample

Compound	Residues in days			Mean	Mean (three replication) residues of green chilli	Processing factor (%)
	R1	R2	R3			
Fipronil	2.52	1.45	3.01	**2.33**	**0.27**	**8.57**
Lambda-cyhalothrin	0.65	0.42	0.79	**0.62**	**0.07**	**9.13**
Ethion	1.75	1.63	0.37	**1.25**	**0.20**	**6.19**
Cypermethrin	3.52	2.88	1.92	**2.77**	**0.55**	**5.02**
Fenpropathrin	0.36	1.13	0.73	**0.74**	**0.11**	**6.87**
Fenazaquin	0.62	0.34	0.85	**0.60**	**0.11**	**5.38**

4.4 Biology of fruit borer (*H. armigera*) in chilli

The present investigation was carried out to study the biology of *H. armigera* on chilli which provides information on various life stages through which they pass and behavior which they show. The results drawn from these studies are presented and discussed as below.

4.4.1 Egg

4.4.1.1 Site and pattern of egg laying

In laboratory, it was observed that, the female moth of *H. armigera* laid eggs singly or in batches of 2 to 3 eggs. The eggs were glued on tender leaf lower surface and shoots of the chilli plant (Plate-15A). Occasionally the eggs were also found on pot, piece of black colour muslin cloth and bottom of the cage (Plate-15B). The egg laying was slow and low in number in the initial stage, but it increased gradually and slower down at the later part of the oviposition period. Earlier, similar pattern of egg laying was recorded by Patel *et al.* (2011) and Sharma *et al.* (2011).

4.4.1.2 Colour, shape and size

The freshly laid eggs were yellowish white in colour, which changed to deep yellow after a day (Plate-16A) and become dark brown prior to hatching (Plate-16B). Eggs were hemispherical with flat base and prominently sculptured with numerous ridges running from one polar end to another. The present observation is more or less similar with that of Ali *et al.* (2009), Patel *et al.* (2011) and Sharma *et al.* (2011).

Plate 15 (A)

Plate 15 (B)

Plate 15: Site of oviposition: (A) on shoot (B) on muslin cloth

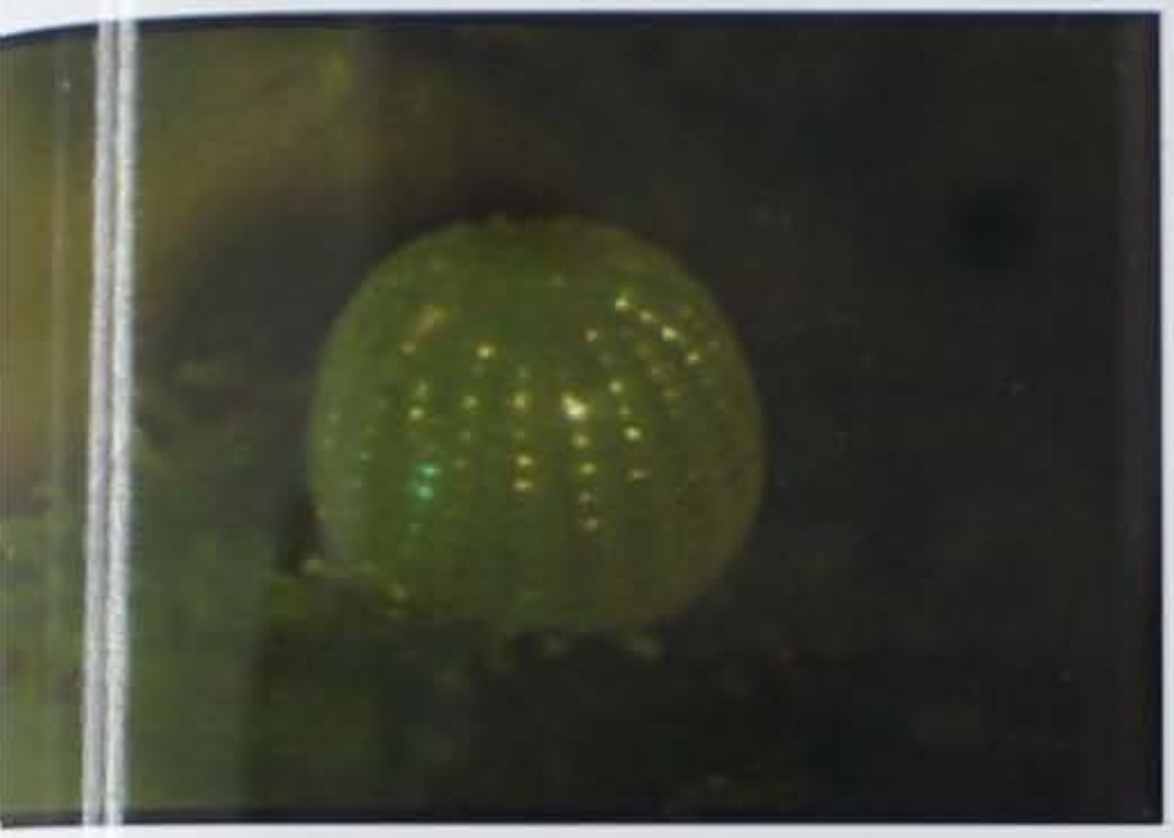


Plate 16 (A)

Plate 16 (B)

Plate 16: Eggs: (A) before hatching (B) after hatching

Plate 17 (A)

Plate 17 (B)

Plate 17: (A) First instar larva (B) head capsule

Size of egg measured under the Stereo Trinocular microscope Olympus-SZ (16) fitted with Brand Catcam-130 camera having software power Scopephoto. The result summarized in Table-17 revealed that, length and breadth of freshly laid eggs measured from 0.42 to 0.56 mm (0.49 ± 0.04 mm) and 0.44 to 0.57 mm (0.51 ± 0.04 mm) respectively. Patel *et al.* (2011), Sharma *et al.* (2011) and Gadhiya *et al.* (2014) also recorded little bit the same size of eggs.

4.4.1.3 Incubation period

It is clear from the data (Table-18) that the incubation period varied from 2 to 5 days with an average of 3.9 ± 0.74 days. The incubation period for eggs of *H. armigera* has been reported as 3 to 5 days (Ali *et al.*, 2009; Patel *et al.*, 2011) and 2 to 4 days (Gadhiya *et al.*, 2014) which are in close concurrence with present finding.

4.4.1.4 Hatching percentage

Out of 10484 eggs observed under laboratory conditions, 5577 eggs hatched with hatchability of 53.20 % when reared on chilli (Table-19). Similarly, Ghadiya *et al.* (2014) have also reported 59 percent hatchability on groundnut. While, it was 83 percent on rose according to Patel *et al.* (2011) and 77 to 89 percent on tomato, as recorded by Sharma *et al.* (2011).

Table 17: Measurement of eggs of *H. armigera*

Sr. No.	Length (mm)	Breadth(mm)
1	0.49	0.50
2	0.47	0.52
3	0.56	0.55
4	0.54	0.47
5	0.47	0.44
6	0.48	0.45
7	0.45	0.44
8	0.45	0.57
9	0.54	0.45
10	0.45	0.46
11	0.42	0.46
12	0.55	0.57
13	0.51	0.49
14	0.49	0.56
15	0.48	0.52
16	0.49	0.52
17	0.42	0.46
18	0.55	0.57
19	0.47	0.53
20	0.50	0.52
21	0.47	0.49
22	0.46	0.57
23	0.52	0.55
24	0.48	0.51
25	0.44	0.50
Min.	**0.42**	**0.44**
Max.	**0.56**	**0.57**
Av. ± S.D.	**0.49 ± 0.04**	**0.51 ± 0.04**

Table 18: Incubation period of *H. armigera*

Sr. No	Date of eggs laid	No of eggs observed	Date of eggs hatched	Incubation period (days)
1	5/2/2016	25	8/2/2016	3
2	6/2/2016	30	9/2/2016	3
3	7/2/2016	22	11/2/2016	4
4	7/2/2016	35	12/2/2016	5
5	8/2/2016	15	11/2/2016	3
6	9/2/2016	20	13/2/2016	4
7	9/2/2016	32	13/2/2016	4
8	10/2/2016	23	15/2/2016	5
9	11/2/2016	27	15/2/2016	4
10	12/2/2016	30	16/2/2016	4
Total		**259**	-	-
Min.				**2**
Max.				**5**
Av. ± S.D.				**3.9 ± 0.74**

Table 19: Hatching percentage of *H. armigera*

Sr. No.	No. of egg laid	Hatchability	
		No. of eggs hatched	Hatching percentage
1	1205	644	53.44
2	1235	785	63.56
3	851	367	43.13
4	1212	862	71.12
5	1200	623	51.92
6	852	422	49.53
7	1198	656	54.76
8	1114	431	38.69
9	875	319	36.46
10	742	468	63.07
Total	**10484**	**5577**	**-**
Av. percentage of hatching	**-**	**-**	**53.20**

4.4.2 Larva

4.4.2.1 Number of larval instar

In order to study the various larval instar of *H. armigera* in laboratory condition, newly hatched larvae were reared individually in plastic culture tube. The larvae passed through six distinct instars, when reared initially on chilli leaves and thereafter on fresh green fruits, till they pupated. Ali *et al.* (2009) and Patel *et al.* (2011) also recorded six instars in *H. armigera* reared on chickpea and rose, respectively.

4.4.2.2 First instar

At the time of hatching, larva came out from the egg by making hole on chorion with the help of mouthparts. The body of freshly emerged larva was semi-translucent and dirty white in colour with whitish longitudinal lines on the dorsal surface of the body (Plate-17A). Thoracic and anal shield were brown in colour. Whereas, thoracic legs were segmented with first two segments of light brown and tarsi were dark brown to black in colour. Zig-zag spotted line was present on dorsal side and black coloured spiny structure comes out from that spot. Almost similar observations were made by Ali *et al.* (2009) on chickpea. Patel *et al.* (2011) on rose and Sharma *et al.* (2011) on tomato.

The newly emerged larva remained sluggish and became active after 2 to 3 hours on leaves. Patel *et al.* (2011) also observed similar behaviour when reared on rose.

The neonate larva initially remained in egg shell and found to feed on chorion of the egg. Thereafter, in search of food, larva was found hanging on petridish, with the help of thread like substance secreted from mouth. In the beginning, larva found to feed on tender leaves with its chewing and biting type of mouth parts. The change in instar was confirmed by presence of only head capsule on leaf surface. The exuviae of whole body did not observe in this instar during the study.

It can be seen from the data (Table-20) that the length of first instar larva measured from 1.30 to 1.98 mm (1.60 ± 0.22 mm) and the breadth varied from 0.18 to 0.35 mm (0.26 ± 0.05). Ali *et al.* (2009) have measured on an average 1.40 mm length and 0.45 mm breadth on chickpea. While, it was 1.80 mm in length and 0.31 mm breadth as measured by Gadhiya *et al.* (2014) on groundnut.

The head capsule was large in size which was dark brown to black in colour (Plate-17B). The length and breadth of head capsule (Table-21) measured from 0.19 to 0.38 mm (0.28 ± 0.32 mm) and 0.23 to 0.40 mm (0.07 ± 0.06 mm), respectively.

The results summarized in Table-22 indicated that the duration of first instar larva ranged from 2 to 4 days on chilli (2.88 ± 0.73 days). Similarly it was also reported as 2 to 3 days on chickpea (Ali *et al.*, 2009); on rose (Patel *et al.*, 2011) and on groundnut (Gadhiya *et al.*, 2014).

Table 20: Measurement of different larval instar of *H. armigera* (in mm)

Sr. No.	1st instar		2nd instar		3rd instar		4th instar		5th instar		6th instar	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
1	1.49	0.19	3.36	0.57	7.30	1.11	13.43	2.14	16.34	2.2	20.13	3.25
2	1.30	0.21	4.14	0.54	9.93	1.31	8.55	1.80	17.57	2.92	26.10	3.87
3	1.30	0.20	4.62	0.53	10.75	1.43	10.58	1.65	15.92	2.12	30.40	4.12
4	1.69	0.29	5.07	0.72	9.87	1.57	12.48	1.71	17.30	2.56	28.77	4.08
5	1.82	0.34	4.68	0.71	9.65	1.16	11.19	1.58	19.76	3.08	30.60	4.27
6	1.78	0.30	5.23	0.76	8.81	0.98	15.90	2.38	16.77	2.67	20.11	3.19
7	1.62	0.28	3.78	0.51	7.66	0.87	9.68	1.78	16.45	2.79	25.13	3.41
8	1.33	0.22	4.66	0.52	11.28	1.78	13.13	1.98	17.98	2.81	30.26	4.18
9	1.98	0.35	5.11	0.74	10.82	1.41	14.72	2.06	18.42	2.88	23.13	3.52
10	1.46	0.18	4.61	0.7	8.99	1.03	8.90	1.52	16.89	2.35	21.63	3.38
11	1.31	0.21	4.84	0.84	10.25	1.13	13.67	2.04	17.96	2.76	22.49	3.40
12	1.33	0.21	4.58	0.63	10.74	1.11	10.12	1.62	15.99	2.23	29.37	4.06
13	1.34	0.21	3.50	0.5	11.16	1.11	11.89	1.47	16.82	2.84	30.48	4.13
14	1.78	0.31	4.38	0.65	7.78	0.85	8.79	1.33	19.87	3.14	26.87	3.22
15	1.69	0.29	5.20	0.72	7.90	0.87	12.85	1.99	17.52	2.65	23.68	3.61
16	1.57	0.25	4.48	0.64	10.57	1.03	10.72	1.56	16.43	2.21	28.25	3.98
17	1.69	0.29	5.34	0.8	10.12	1.23	15.62	2.16	19.49	3.08	21.53	3.27
18	1.82	0.32	4.89	0.89	11.20	1.55	14.25	2.09	18.68	2.73	25.62	3.57
19	1.53	0.22	3.43	0.53	7.69	1.16	8.63	1.41	19.10	2.98	30.11	4.18
20	1.48	0.20	4.85	0.82	8.76	0.78	10.69	1.72	16.32	2.61	20.56	3.64
21	1.93	0.28	5.12	0.78	9.32	1.02	14.65	2.25	17.38	2.41	23.77	3.42
22	1.39	0.22	5.20	0.8	7.58	0.96	15.28	1.96	19.18	3.05	29.86	4.32
23	1.97	0.35	3.89	0.56	10.89	1.48	12.86	2.04	17.91	2.75	27.31	3.67
24	1.78	0.28	4.21	0.54	8.98	0.83	9.62	1.97	19.76	3.16	22.68	3.55
25	1.56	0.26	4.98	0.9	10.68	1.20	11.41	1.52	16.95	2.57	29.36	3.78
Min.	1.30	0.18	3.36	0.50	7.30	0.78	8.55	1.33	15.92	2.12	20.11	3.19
Max.	1.98	0.35	5.34	0.90	11.28	1.78	15.90	2.38	19.87	3.16	30.60	4.32
Av. ± S.D.	1.60 ± 0.22	0.26 ± 0.05	4.57 ± 0.59	0.68 ± 0.13	9.55 ± 1.32	1.16 ± 0.26	11.98 ± 2.33	1.83 ± 0.29	17.71 ± 1.27	2.70 ± 0.31	25.93 ± 3.70	3.72 ± 0.37

Table 21: Measurement of head capsule of H. armigera (in mm)

Sr. No.	1st instar		2nd instar		3rd instar		4th instar		5th instar		6th instar	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
1	0.26	0.31	0.49	0.55	0.64	0.67	1.17	1.22	1.77	1.84	3.02	3.73
2	0.32	0.36	0.49	0.48	0.71	0.80	1.33	1.58	1.96	2.35	2.73	2.81
3	0.19	0.25	0.55	0.58	0.74	0.66	1.43	1.62	2.08	2.31	2.66	2.89
4	0.23	0.27	0.44	0.51	0.66	0.68	1.53	1.55	1.91	2.08	2.82	2.85
5	0.38	0.39	0.48	0.52	0.75	0.81	1.50	1.58	2.14	2.21	1.86	2.53
6	0.34	0.36	0.42	0.47	0.61	0.62	1.51	1.53	2.11	2.21	2.72	3.01
7	0.38	0.39	0.46	0.44	0.68	0.70	1.32	1.46	1.84	1.98	2.99	3.15
8	0.32	0.39	0.52	0.55	0.62	0.63	1.39	1.50	2.03	2.18	3.25	3.33
9	0.24	0.33	0.43	0.49	0.63	0.62	1.46	1.49	1.79	2.01	2.99	3.20
10	0.23	0.25	0.43	0.46	0.74	0.83	1.22	1.29	1.98	2.09	1.90	2.21
11	0.20	0.26	0.53	0.56	0.62	0.65	1.45	1.61	2.05	2.14	3.3	3.46
12	0.21	0.28	0.55	0.57	0.74	0.82	1.35	1.44	1.85	2.03	2.89	3.10
13	0.33	0.35	0.54	0.57	0.68	0.70	1.19	1.23	2.11	2.33	1.94	2.34
14	0.38	0.40	0.49	0.51	0.67	0.70	1.23	1.31	1.85	1.94	2.9	3.24
15	0.34	0.40	0.43	0.48	0.62	0.64	1.49	1.55	2.08	2.13	1.93	2.17
16	0.35	0.39	0.49	0.53	0.75	0.83	1.33	1.41	1.82	1.91	2.78	3.11
17	0.19	0.27	0.54	0.55	0.61	0.63	1.50	1.48	1.78	2.03	1.96	2.13
18	0.21	0.27	0.52	0.56	0.71	0.78	1.34	1.41	1.80	1.89	3.21	3.37
19	0.37	0.40	0.43	0.48	0.63	0.65	1.28	1.39	1.93	2.02	2.13	2.46
20	0.19	0.23	0.44	0.45	0.61	0.63	1.32	1.43	2.14	2.35	3.34	3.58
21	0.26	0.33	0.55	0.59	0.72	0.80	1.18	1.26	1.99	2.09	1.93	2.22
22	0.28	0.33	0.49	0.54	0.69	0.72	1.39	1.45	2.11	2.30	2.67	2.93
23	0.21	0.24	0.51	0.54	0.65	0.71	1.25	1.33	1.81	1.95	3.44	3.68
24	0.27	0.36	0.52	0.55	0.68	0.73	1.46	1.51	2.07	2.11	2.89	3.14
25	0.22	0.25	0.55	0.57	0.73	0.75	1.46	1.49	2.13	2.38	2.89	3.37
Min.	0.19	0.23	0.42	0.44	0.61	0.62	1.17	1.22	1.77	1.84	1.86	2.13
Max.	0.38	0.40	0.55	0.59	0.75	0.83	1.53	1.62	2.14	2.38	3.44	3.73
Av. ± S.D.	0.28 ± 0.32	0.07 ± 0.06	0.49 ± 0.05	0.52 ± 0.04	0.68 ± 0.05	0.71 ± 0.07	1.36 ± 0.11	1.44 ± 0.12	1.97 ± 0.13	2.11 ± 0.16	2.69 ± 0.51	2.96 ± 0.49

Table 22: Duration of different larval instar of *H. armigera*

Sr. No.	Date of hatching	Date of head capsule observed and duration (days) of instar												Date of pre-pupation	Total larval period
		1st instar		2nd instar		3rd instar		4th instar		5th instar		6th instar			
1	8/2/2016	10/2/2016	2	13/2/2016	3	16/2/2016	3	20/2/2016	4	25/2/2016	5	1/3/2016	5	1/3/2016	22
2	9/2/2016	13/2/2016	4	16/2/2016	3	20/2/2016	4	23/2/2016	3	27/2/2016	4	2/3/2016	4	2/3/2016	22
3	11/2/2016	14/2/2016	3	17/2/2016	3	21/2/2016	4	25/2/2016	4	29/2/2016	4	5/3/2016	5	5/3/2016	23
4	13/2/2016	16/2/2016	3	20/2/2016	4	24/2/2016	4	29/2/2016	5	5/3/2016	5	9/3/2016	4	9/3/2016	25
5	16/2/2016	18/2/2016	2	21/2/2016	3	24/2/2016	3	28/2/2016	4	4/3/2016	5	9/3/2016	5	9/3/2016	22
6	12/2/2016	16/2/2016	4	20/2/2016	4	24/2/2016	4	27/2/2016	3	2/3/2016	4	6/3/2016	4	6/3/2016	23
7	11/2/2016	14/2/2016	3	17/2/2016	3	20/2/2016	3	23/2/2016	3	28/2/2016	5	3/3/2016	4	3/3/2016	21
8	12/2/2016	14/2/2016	2	17/2/2016	3	22/2/2016	5	27/2/2016	5	2/3/2016	4	7/3/2016	5	7/3/2016	24
9	9/2/2016	13/2/2016	4	17/2/2016	4	21/2/2016	4	25/2/2016	4	1/3/2016	5	5/3/2016	4	5/3/2016	25
10	8/2/2016	11/2/2016	3	15/2/2016	4	20/2/2016	5	23/2/2016	3	28/3/2016	5	4/3/2016	5	4/3/2016	25
11	13/2/2016	15/2/2016	2	18/2/2016	3	23/2/2016	5	27/2/2016	4	2/3/2016	4	8/3/2016	6	8/3/2016	24
12	13/2/2016	15/2/2016	2	19/2/2016	4	23/2/2016	4	27/2/2016	4	3/3/2016	5	8/3/2016	5	8/3/2016	24
13	12/2/2016	15/2/2016	3	19/2/2016	4	22/2/2016	3	25/2/2016	3	1/3/2016	5	5/3/2016	4	5/3/2016	22
14	10/2/2016	18/2/2016	2	21/2/2016	3	25/2/2016	4	1/3/2016	5	5/3/3016	4	10/3/2016	5	10/3/2016	23
15	11/2/2016	15/2/2016	4	18/2/2016	3	21/2/2016	3	24/2/2016	3	29/2/2016	5	6/3/2016	6	6/3/2016	24
16	11/2/2016	14/2/2016	3	18/2/2016	4	21/2/2016	3	24/2/2016	3	28/2/2016	4	3/3/2016	4	3/3/2016	21
17	8/2/2016	11/2/2016	3	15/2/2016	4	19/2/2016	4	23/2/2013	4	27/2/2016	4	2/3/2016	4	2/3/2016	21
18	12/2/2016	15/2/2016	3	18/2/2016	3	21/2/2016	3	24/2/2016	3	29/2/2016	5	5/3/2016	5	5/3/2016	22
19	16/2/2016	19/2/2016	3	22/2/2016	3	27/2/2016	5	2/3/2016	4	6/3/2016	4	10/3/2016	4	10/3/2016	21
20	8/2/2016	10/2/2016	2	13/2/2016	3	18/2/2016	5	21/2/2016	3	26/2/2016	5	2/3/2016	5	2/3/2016	21
21	11/2/2016	14/2/2016	3	18/2/2016	4	22/2/2016	4	26/2/2016	4	1/3/2016	4	7/3/2016	6	7/3/2016	25
22	16/2/2016	18/2/2016	2	21/2/2016	3	24/2/2016	3	28/2/2016	4	4/3/2016	5	-	-	-	-
23	13/2/2016	16/2/2016	3	20/2/2016	4	25/2/2016	5	-	-	-	-	-	-	-	-
24	12/2/2016	16/2/2016	4	20/2/2016	4	-	-	-	-	-	-	-	-	-	-
25	8/2/2016	11/2/2016	3	-	-	-	-	-	-	-	-	-	-	-	-
Min.	-	-	2.00	-	3.00	-	3.00	-	3.00	-	4.00	-	4.00	-	21.00
Max.	-	-	4.00	-	4.00	-	5.00	-	5.00	-	5.00	-	6.00	-	25.00
Av. ± S.D.	-	-	2.88 ± 0.73	-	3.46 ± 0.51	-	3.91 ± 0.79	-	3.73 ± 0.70	-	4.55 ± 0.51	-	4.71 ± 0.72	-	23.13 ± 1.28

4.4.2.3 Second instar

Second instar larva was morphologically resembled to the first instar larva. The larva was yellowish to light brown in colour (Plate-18A). Thoracic legs were dark in colour as compared to abdominal legs. The larva was more active than previous instar. It was also observed that, larva of this instar preferred fresh and tender chilli fruit to feed (Plate-18C). Patel *et al.* (2011) also observed similar characteristics in *H. armigera* when reared on rose.

The larva measured (Table-20) from 3.36 to 5.54 mm (4.57 ± 0.59 mm) in length and 0.50 to 0.90 mm (0.68 ± 0.13 mm) in breadth. Ali *et al.* (2009) also recorded the body length ranged from 3.50 to 5.00 mm and breadth from 0.70 to 0.80 mm in breadth.

The head capsule was transparent having brown spot having (Plate-18B). The measurement of head capsule (Table-21) is ranged from 0.42 to 0.55 mm (0.49 ± 0.05 mm) in length and 0.44 to 0.59 mm (0.52 ± 0.04 mm) in breadth during the investigation.

The duration of second instar larva was ranged from 3 to 4 days (3.46 ± 0.51 days) in Table-22. The larval period of *H. armigera* ranged from 2 to 3 days of on chickpea and rose by Ali *et al.* (2009) and Patel *et al.* (2011). Whereas, 2 to 4 days on groundnut by Gadhiya *et al.* (2014).

4.4.2.4 Third instar

The third instar larva was similar to second instar in general appearance but differed in size. The colour of the body was yellowish to light

Plate 18 (A)

Plate 18 (B)

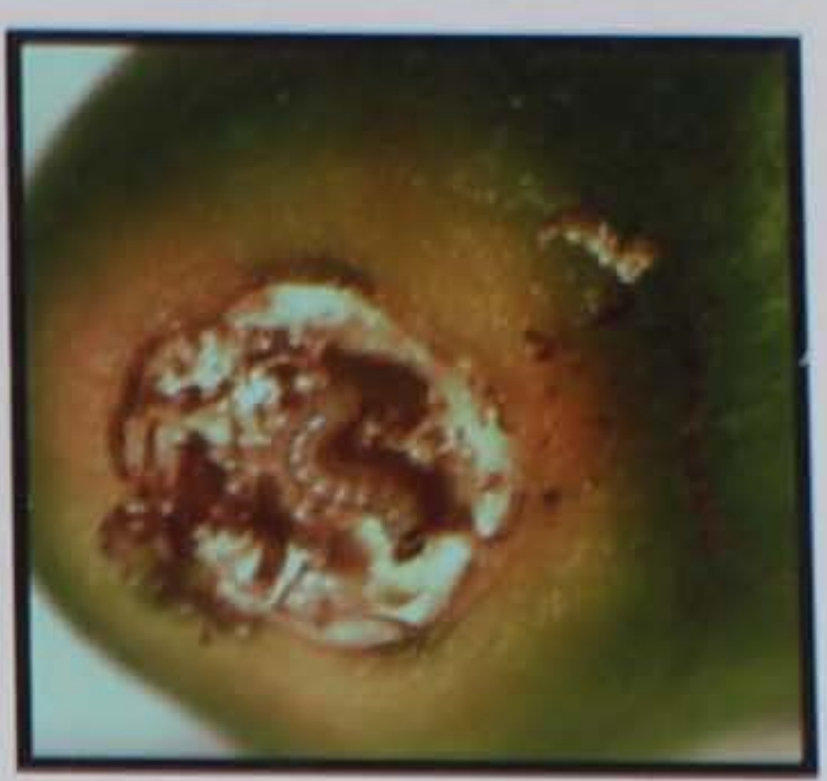


Plate 18 (C)

Plate 18: (A) Second instar larva (B) head capsule (C) larva feeding on fruit

Plate 19 (A)

Plate 19 (B)

Plate 19 (C)

Plate 19: (A) Third instar larva (B) moulting (C) head capsule with exuviae

Plate 20 (A)

Plate 20 (B)

Plate 20 (C)

Plate 20: (A) Fourth instar larva (B) moulting (C) and head capsule

brown, but it was darker than previous instar. A dorsal longitudinal line on either side was prominent in third instar. Moreover, a white coloured band was present on lateral side of the body (Plate-19A). Prior to moulting, cuticle turn black in colour (Plate-19B).

The length of third instar larva measured (Table-20) from 7.30 to 11.28 mm (9.55 ± 1.32 mm), while that of the breadth from 0.78 to 1.78 mm (1.16 ± 0.26 mm). The present findings are in close agreement with the finding of Gadhiya *et al.* (2014) who reported the average length of third instar larva of *H. armigera* on groundnut to be 8.46 mm with 1.01 mm in breadth.

The head capsule was more compact and transparent with light brown spots (Plate-19C). The data in Table-21 revealed that the length of head capsule of third instar larva measured from 0.61 to 0.75 mm (0.68 ± 0.05 mm), while that of the breadth from 0.62 to 0.83 mm (0.71 ± 0.07 mm).

The duration required to complete third instar (Table-22) ranged between 3 to 5 days (3.91 ± 0.79 days). This period was also reported as 3 to 5 days on groundnut by Gadhiya *et al.* (2014).

4.4.2.5 Fourth instar

Variation in colour was observed in fourth instar larva. It was of green, reddish brown, brown and greenish brown. Setae were also observed all over the body of fourth instar larva (Plate-20A). Generally the lateral strip on all the larvae were yellowish white, but dorsal strip was of variable in colours. The strips were either continues or broken (Plate-20B).

The data on measurement are summarized in Table-20. The length of fourth instar larva was ranged from 8.55 to 15.90 mm (11.98 ± 2.33 mm), while that of breadth ranged from 1.33 to 2.38 mm (1.83 ± 0.29 mm). The present findings are more or less similar to those of Ali *et al.* (2009), who reported the length and breadth of fourth instar larvae of *H. armigera* as 12.83 ± 0.45 mm and 2.85 to 0.04 mm on chickpea. respectively.

The head capsule was similar to third instar but size was differed (Plate-20C). The head capsule of fourth instar larva (Table-21) measured from 1.17 to 1.53 mm and 1.22 to 1.62 mm with an average of 1.36 ± 0.11 and 1.44 ± 0.12 mm, respectively.

The duration of fifth instar larva (Table-22) ranged from 4 to 5 days (4.55 ± 0.51 days). The present findings are more or less in confirmation with those of Ali *et al.* (2009), who reported 3 to 4 days of fifth instar when *H. armigera* reared on chickpea and 3 to 6 days when reared on rose (Patel *et al.*, 2011).

3.4.2.6 Fifth instar

The fifth instar larva was showed pinkish brown and pale green colour pattern with broken dorsal strips and continues lateral strips. The black spots were reduced in number (Plate-21A). Dorsal strip of pinkish brown larvae was thick and black in colour. while in pale green colour larvae strip was thick and white in colour. The abdomen was turn in yellowish green and thoracic reason was remain dark green coloured, when larvae start moulting (Plate-21B). The fifth

Plate 21 (A) Plate 21 (B) Plate 21 (C)

Plate 21: (A) Fifth instar larva (B) moulting (C) and head capsule

Plate 22 (A) Plate 22 (B) Plate 22 (C)

Plate 22: (A) Sixth instar larva (B) moulting (C) and head capsule

Plate 23 (A) Plate 23 (B) Plate 23 (B)

te 23: (A) Full grown larva goes into the soil (B) pre-pupa (C) and head capsule with exuviae

instar larva was more active and aggressive as compare to previous stage but at the time of moulting larva was less active.

The length and breadth of fifth instar larva (Table-20) was ranged from 15.92 to 19.87 mm (17.71 ± 1.27 mm) and 2.12 to 3.16 mm (2.70 ± 0.31 mm), respectively. Previously, it was also reported average as length and breadth of fifth instar larva of *H.* armigera as 20.97 and 3.25, respectively on chickpea by Ali *et al.* (2009).

Head capsule was transparent light orange in colour (Plate-21C). The length and breadth of head capsule (Table-21) ranged from 1.77 to 2.14 mm with an average of 1.97 ± 0.13 mm and 1.84 to 2.38 mm with an average of 2.11 ± 0.16 mm, respectively.

Result given in Table-22 present the duration of fifth instar larva ranged from 4 to 5 days with an average of.4.55 ± 0.51 mm. The present investigation more or less similar confirmation with Patel *et al.* (2011) who recorded duration of fifth instar larva of *H. armigera* ranged from 3 to 6 days, when reared on rose.

4.4.2.7 Sixth instar

The sixth instar larva was flattened ventrally but convex dorsally. The body was pinkish brown and pale green in colour with two black longitudinal strips on dorsal side and scattered short hairy setae present all over the body (Plate-22A). The characteristics of larva during moulting were similar to the previous instar (Plate-22B). Legs were pinkish to light green in colour.

The body length and breadth of sixth instar larva (Table-20) ranged from 20.11 to 30.60 mm (25.93 ± 3.70) and 3.19 to 4.32 mm (3.72 ± 0.37 mm) respectively. Similarly, it was also reported as 30.50 to 34.50 mm in length and 3.80 to 4.25 mm in breadth when *H. armigera* was reared on chickpea, by Ali *et al.* (2009).

Head capsule of sixth instar larvae was similar in appearance as of fifth instar larvae, but differed in size (Plate-22C). After moulting, mostly a head capsule was found in excreta. The length of head capsule (Table-21) varied from 1.86 to 3.44 mm (2.69 ± 0.51 mm), while breadth varied from 2.13 to 3.73 mm (2.96 ± 0.49 mm).

The data of duration of sixth instar larva summarized in Table-22 ranged from 4 to 6 days (4.71 ± 0.72 days). In past, Patel *et al.* (2011) recorded that the duration of sixth larval instar duration ranged from 4 to 8 days when reared on rose.

4.4.2.8 Total larval instar

The perusal of data presented in Table-22 revealed that, the total larval development period of *H. armigera* varied from 21 to 25 days (21.4 ± 1.71 days). Earlier, this period of *H.* armigera was recorded as 14 to 20 days on chickpea by Ali *et al.* (2009). While, as per Patel *et al.* (2011) it was 19 to 28 days when reared on rose. The variation in the larval period may be because of different hosts.

4.4.3 Pre-pupa

4.4.3.1 Colour, shape and size

After completion of larval development, final instar larva stopped feeding and change its colour from pinkish brown to light pinkish brown and pale green to light green yellowish with less prominent strips. These was the indication of larva undergoing pre-pupal stage. The full grown larva wondering on the soil for pupation (Plate-23A) and pupated within the soil by making an earthen cocoon (Plate-24A). After preparing an earthen cocoon, the larva contracted its body while the legs remained straight (Plate-23B). During this period the larva did not exhibit any movement unless it was disturbed. Finally, larva shedding off cuticle and head capsule was attached with that inside the cocoon and goes into pupal stage (Plate-23C). Ali *et al.* (2009) and Patel *et al.* (2011) also observed that the full grown larva of sixth instar becomes sluggish and suspended feeding and movement.

The length and breadth of pre-pupa was varied from 13.02 to 17.29 mm (15.44 ± 1.38 mm) as indicated in Table-23. The length and breadth of pre-pupa of *H. armigera* was, respectively, 25.43 and 4.56 mm on chickpea (Ali *et al.*, 2009); 25.01 and 4.96 mm on rose (Patel *et al.*, 2011) and 24.12 to 3.51 mm on groundnut (Gadhiya *et al.*, 2014). The difference found in size of pre-pupa between present study and previous study may be due to different hosts.

Plate 24 (A)

Plate 24 (B)

Plate 24 (C)

Plate 24: (A) Earthen cocoon (B) freshly formed pupa (C) and fully developed pupa

Plate 25 (A)

Plate 25 (B)

Plate 25 (C)

Plate 25: (A) Spiny posterior tip (B) abdominal segment (C) spiracles

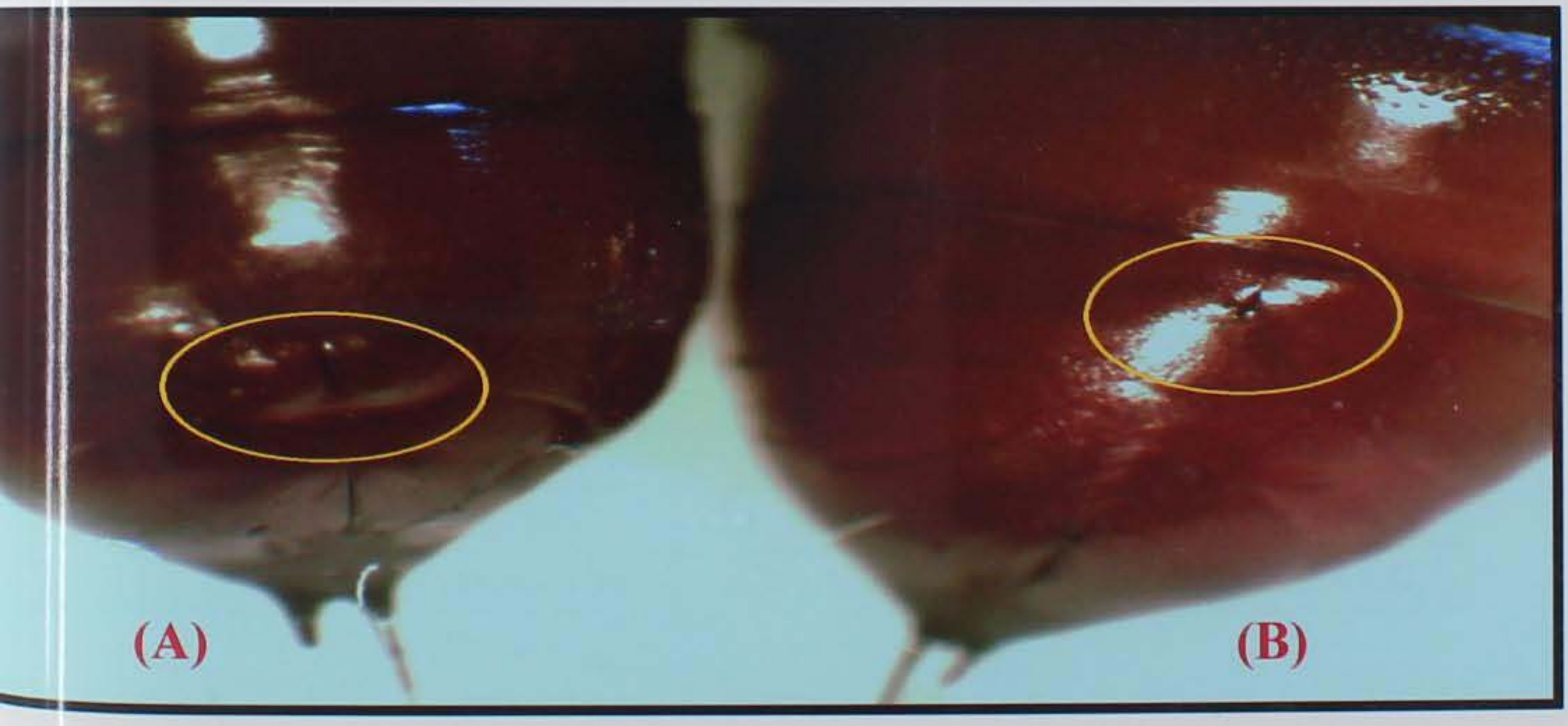


Plate 26: Morphomatric difference: (A) male (B) female

Table 23: Measurement of pre-pupa and pupa of *H. armigera*

Sr. No.	Pre-pupa		Pupa	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
1	16.01	2.82	12.25	3.68
2	17.29	3.06	11.00	3.31
3	15.20	3.13	12.48	4.12
4	16.26	3.28	13.42	4.57
5	16.06	3.15	10.98	2.76
6	14.17	2.64	12.20	3.38
7	13.02	2.64	11.40	3.52
8	17.09	3.13	13.10	4.12
9	15.78	3.35	12.88	2.91
10	13.47	2.91	11.52	3.76
11	16.90	3.73	12.78	3.80
12	14.78	3.14	13.06	4.23
13	15.39	3.25	11.24	3.30
14	13.61	3.07	13.31	4.11
15	17.15	3.69	11.93	3.45
16	16.39	3.52	13.40	4.51
17	13.90	3.24	11.16	3.21
18	13.53	2.98	12.79	3.76
19	16.78	3.84	12.36	3.72
20	15.88	3.41	12.85	4.01
21	17.11	3.58	11.66	3.31
22	13.67	3.19	12.76	3.75
23	14.37	2.89	12.90	4.07
24	16.83	3.42	13.13	4.32
25	15.42	2.98	11.67	2.59
Min.	**13.02**	**2.64**	**10.98**	**2.59**
Max.	**17.29**	**3.84**	**13.42**	**4.57**
Av. ± S.D.	**15.44 ± 1.38**	**3.20 ± 0.32**	**12.33 ± 0.80**	**3.69 ± 0.52**

4.4.3.2 Pre-pupal period

The pre-pupal period (Table-24) found ranging from 1 to 2 days (1.48 ± 0.51 days) during present study. This stage lasted for 1 to 3 day on chickpea (Ali *et al.*, 2009) and rose (Patel *et al.*, 2011) and 1 to 4 days on groundnut (Gadhiya *et al.*, 2014).

4.4.4 Pupa

4.4.4.1 Colour, shape, size and behaviour

The newly formed pupa was transparent green to light green in colour (Plate-24B) and further, it become hard and changed into reddish brown colour with prominent black eye spot after few hours (Plate-24C). The pupa was obtect type. It was smooth, cylindrical, long and tapering towards the posterior end with two parallel spines at the posterior tip (Plate-25A). Abdomen was distinctly marked into ten segments (Plate-25B) and well defined dark brown spiracles were visible on fourth to ninth abdominal segments (Plate-25C). Male and female pupae were differentiated at pupal stage based on morphometric characters. Male pupa carries genital aperture on ninth abdominal segment, whereas, in case of female, it was present on eight abdominal segments (Plate-26). Movement of abdomen was observed when pupa was disturbed. Present observation more or less similar to earlier study of Ali *et al.* (2009) and Patel *et al.* (2011) when *H. armigera* reared on chickpea and rose, respectively.

Looking to the data in Table-23, the length of pupa measured from 10.98 to 13.42 mm (11.41 ± 1.03 mm), while that of breadth measured from 2.59

to 3.57 mm (3.21 ± 0.36 mm). Earlier, the length and breadth of pupa measured as 19.00 and 5.72 mm on chickpea by Ali *et al.* (2009) and 20.93 and 6.09 mm on rose by Patel *et al.* (2011) respectively. Thus, it is clear from this study that, host plant playing role in size of various stages of pest.

The morphometric measurements of pupa were also taken to identify the sex of pupa. Accordingly, the distance between anal and genital pores (Table-25) of male pupa was recorded as 0.45 to 0.67 mm (0.56 ± 0.45 mm), while in female, it was 1.39 to 1.72 mm (1.55 ± 0.11 mm). Thus, it was observed that the distance between anal and genital pore was more in female than male. Gadhiya *et al.* (2014) have also reported same while studying biology of pest on groundnut.

The data given in Table-24 revealed that the pupal period varied from 11 to 15 days with an average of 12.67 ± 1.28 days. In past, Ali *et al.* (2009) recorded average pupal period of 13.15 days of *H. armigera* on chickpea, while, Patel *et al.* (2011) noted it as 10.44 days on rose.

4.4.5 Adult

4.4.5.1 Colour, size, shape and behavior

Immediately after emerging from the pupa, adult took a rest for some time to stretch and harden its wings and other body parts. Once the body acquired normal structure and hardened the wings, adult looking for the food. The compound eyes were dark brown in color and were located laterally on the head. It possessed a pair of antennae of setaceous type on the dorsal side of the head between the compound eyes. Siphoning type of mouthpart was coiled and rested

Table 24: Duration of per-pupal and pupal period of *H. armigera*

Sr. No.	Pre-pupal period (Days)	Pupal period (Days)
1	1	12
2	2	12
3	1	13
4	1	14
5	1	12
6	2	11
7	2	12
8	1	13
9	1	14
10	1	11
11	2	15
12	1	13
13	2	11
14	2	12
15	2	12
16	2	14
17	1	13
18	1	15
19	2	11
20	1	12
21	2	14
Min.	**1.00**	**11.00**
Max.	**2.00**	**15.00**
Av. ± S.D.	**1.48 ± 0.51**	**12.67 ± 1.28**

Table 25: Morphometric difference of pupa of *H. armigera*

Sr. No.	Distance between anal and genital pores (mm)	
	Male	Female
1	0.65	1.66
2	0.57	1.52
3	0.45	1.39
4	0.49	1.72
5	0.61	1.48
6	0.67	1.62
7	0.58	1.66
8	0.66	1.50
9	0.50	1.50
10	0.48	1.42
11	0.66	1.71
12	0.45	1.59
13	0.47	1.70
14	0.50	1.46
15	0.61	1.41
16	0.62	1.52
17	0.66	1.43
18	0.57	1.44
19	0.49	1.39
20	0.63	1.65
21	0.54	1.69
22	0.48	1.55
23	0.58	1.51
24	0.59	1.58
25	0.53	1.59
Min.	**0.45**	**1.39**
Max.	**0.67**	**1.72**
Av. ± S.D.	**0.56 ± 0.45**	**1.55 ± 0.11**

beneath the head. The adults were of medium size with broad thorax possessing yellowish brown forewings and legs were long with dirty white scaly appearance. There was a distinguished colour pattern between male and female moths. Males were of greenish-grey in colour (Plate-27), whereas, females with orange brown and were also identified by the presence of tuft of hairs on the tip of abdomen (Plate-28). There was series of the dots on margin and black kidney shaped marked on underside of each forewing. The transparent membranous part of the forewings was covered with creamy coloured scale. Hind wings were lighter in colour and each possessed a dark coloured patch at the apical end. These observations are more or less in agreement with those reported by Ali *et al.* (2009) and Patel *et al.* (2011), when *H. armigera* was reared on chickpea and rose respectively.

The data on measurement of adult moths are given in (Table-26). The length of adult male varied from 15.94 to 18.21 mm (16.94 ± 0.83 mm) and the breadth varied from 32.18 to 34.79 mm (33.12 ± 0.82 mm). Whereas, in case of female, the length varied from 17.90 to 22.83 mm (20.31 ± 1.62 mm) and the breadth varied from 30.16 to 36.68 mm (34.23 ± 1.83 mm). These observations on length and breadth were almost similar to the observations recorded by Ali *et al.* (2009), Patel *et al.* (2011) and Gadhiya *et al.* (2014), when *H. armigera* was reared different host *viz.*, chickpea, rose and groundnut, respectively.

Plate 27: Male adult of *H. armigera*

Plate 28: Female adult of *H. armigera*

Table 26: Measurement of male and female adult of *H. armigera*

Sr. No.	Male		Female	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
1	16.03	32.29	19.34	33.39
2	15.94	32.18	17.90	30.16
3	16.89	33.15	20.32	34.85
4	18.21	34.79	19.62	33.47
5	18.08	33.56	22.50	36.58
6	16.23	32.43	18.52	32.9
7	17.50	33.68	19.63	33.45
8	16.78	33.16	18.25	32.74
9	17.21	32.47	21.98	35.91
10	16.14	32.41	17.98	30.22
11	15.96	32.22	21.42	35.77
12	17.52	32.71	19.60	33.48
13	15.95	32.22	20.59	34.92
14	18.10	34.53	22.09	36.21
15	15.98	32.34	18.78	32.93
16	16.88	33.19	21.36	35.23
17	16.28	32.45	18.74	32.86
18	15.99	32.38	22.79	36.43
19	16.71	33.14	19.20	33.26
20	17.88	33.74	20.21	34.66
21	17.62	33.69	21.87	35.64
22	18.14	34.50	22.81	36.51
23	18.08	34.47	19.00	32.96
24	16.99	33.24	20.45	34.62
25	16.38	33.11	22.83	36.68
Min.	**15.94**	**32.18**	**17.90**	**30.16**
Max.	**18.21**	**34.79**	**22.83**	**36.68**
Av. ± S.D.	**16.94 ± 0.83**	**33.12 ± 0.82**	**20.31 ± 1.62**	**34.23 ± 1.83**

4.4.6 Pre-oviposition, oviposition and post-oviposition period

Looking to the data (Table-27) it can be concluded that, the pre-oviposition period varied from 2 to 4 days (2.86 ± 0.85 days) which are close concurrence to those of Patel *et al.* (2011) and Gadhiya *et al.* (2014).

The oviposition period ranged from 7 to 9 days (8.14 ± 0.85 days) as indicated in Table-27 during present investigation. Earlier, this period reported as 4 to 7 days (Patel *et al.*, 2011) and 6 to days (Gadhiya *et al.*, 2014).

The post-oviposition period during the studies ranged from 1 to 2 days with an average of 1.52 ± 0.51 days (Table-27). Patel *et al.* (2011) and Gadhiya *et al.* (2014) also reported 0 to 2 days of post-oviposition period in *H. armigera*.

3.4.7 Fecundity

In laboratory, the egg laying capacity (Table-28) recorded during the study was varied from 742 to 1235 eggs (1048.40 ± 193.58 eggs) per female on chilli. Almost similar fecundity of 290 to 910 eggs per female on rose was recorded by Patel et al. (2011) while it was 405 to 420 on chickpea (Ali *et al.*, 2009) and 163 to 318 on groundnut (Gadhiya *et al.*, 2014).

4.4.8 Longevity of adult

The longevity (Table-27) of male ranged from 7 to 10 days (8.67 ± 1.06 days) while mated female lived for 9 to 13 days (10.90 ± 1.22 days). According to Ali *et al.* (2009), both male and female of *H. armigera* lived for about 7 to 11 and 10 to 14 days respectively. Similarly, Patel *et al.* (2011)

Table 27: Pre-oviposition, oviposition, post-oviposition period and adult longevity of *H. armigera* in/on chilli

Sr. No.	Pre-oviposition (Days)	Oviposition (Days)	Post-oviposition (Days)	Adult longevity (Days)	
				Male	Female
1	2	9	2	8	11
2	3	8	2	8	11
3	2	9	1	7	11
4	4	9	1	10	13
5	3	7	2	8	10
6	2	9	1	9	11
7	2	9	2	10	11
8	4	8	1	7	12
9	3	8	2	8	11
10	2	7	1	9	9
11	4	7	1	10	11
12	4	9	2	8	9
13	3	8	1	9	11
14	2	8	2	10	13
15	3	7	2	10	9
16	3	9	2	8	10
17	2	9	1	9	11
18	4	7	1	9	10
19	2	9	2	7	13
20	4	8	1	8	12
21	2	7	2	10	10
Min.	**2.00**	**7.00**	**1.00**	**7.00**	**9.00**
Max.	**4.00**	**9.00**	**2.00**	**10.00**	**13.00**
Av. ± S.D.	**2.86 ± 0.85**	**8.14 ± 0.85**	**1.52 ± 0.51**	**8.67 ± 1.06**	**10.90 ± 1.22**

Table 28: Fecundity of *H. armigera*

Sr. No.	No. of eggs laid by individual female
1	1205
2	1235
3	851
4	1212
5	1200
6	852
7	1198
8	1114
9	875
10	742
Min.	**742**
Max.	**1235**
Av. ± S.D.	**1048.40 ± 193.58**

recorded the longevity of male and female adults as 4 to 8 and 5 to 11 days, respectively. While, Gadhiya *et al.* (2014) reported this duration of male and female adults as 7 t0 8 days and 8 to 10 days respectively.

4.4.9 Sex ratio

Based on morphological characters mentioned earlier, the adult were differentiated into their sexes. Out of 100 adults emerged from laboratory mass culture during period of study, 34 were males and 66 were females, which indicated the preponderance of female. The sex ratio of male to female was 1: 2.08 (Table-29). According to Gadhiya *et al.* (2014), the sex ratio of *H. armigera* was 1: 1.12 when reared on groundnut.

4.4.10 Total life cycle

The total life span (Table-30) (Plate-29) from eggs to the death of adult occupied by male was 40 to 59 days (48.43 ± 2.44 days). While, female occupied 47 to 57 days (51.72 ± 2.72 days). Thus, a total life period of male was shorter than female recorded during present investigation. The present findings are more or less in agreement with those of Gadhiya *et al.* (2014).

4.4.11 Larval-pupal parasite of *H. armigera*

A tachinid fly, *Juriniopsis adusta* larval-pupal parasite was found to parasitize *H. armigera*, when the larvae were collected from chickpea field during the present studies. Mostly, the third and fourth instar larvae were found parasitized by this parasite in field condition. The parasitized larvae showed its normal developmental activity until pupation. But the infected pupae were turned

Adult

Egg

Pupa

1st instar

Pre-pupa

Total life cycle of
H. armigera

Male
40 to 50 days

Female
47 to 57 days

2nd instar

6th instar

3rd instar

5th instar

4th instar

Plate 29: Life cycle of *H. armigera* on chilli

Table 29: Sex ratio of *H. armigera*

Sr. No.	Adult observed	Numbers of adult		Sex ratio (Male: Female)
		Male	Female	
1	10	4	6	1: 1.49
2	10	3	7	1: 2.33
3	10	3	7	1: 2.33
4	10	4	6	1: 1.49
5	10	4	6	1: 1.49
6	10	3	7	1: 2.33
7	10	4	6	1: 1.49
8	10	3	7	1: 2.33
9	10	4	6	1: 1.49
10	10	2	8	1: 4.00
Total	**100**	**34**	**66**	-
Min.		**2.00**	**6.00**	**1: 1.49**
Max.		**4.00**	**8.00**	**1: 4.00**
Av. ± S.D.		**3.40**	**6.60**	**1: 2.08**

Table 30:Detail of life cycle of *H. armigera*

Sr. No.	Particulars	No. obs.	Period (Days)		Avg. ± S.D.
			Min.	Max.	
1	Incubation period (Days)	25	2	5	3.9 ± 0.74
2	Hatching percentage	10484	5577		53.20 %
3	Larval period (Days)				
	I instar	25	2	4	2.88 ± 0.73
	II instar	24	3	4	3.46 ± 0.51
	III instar	23	3	5	3.91 ± 0.79
	IV instar	22	3	5	3.73 ± 0.70
	V instar	22	4	5	4.55 ± 0.51
	VI instar	21	4	6	4.71 ± 0.72
	Total larval period (Days)	21	21	25	23.14 ± 1.28
4	Pre-pupal (Days)	21	1	2	1.48 ± 0.51
5	Pupal period (Days)	21	10	14	11.86 ± 1.56
6	Pre-oviposition period (Days)	21	2	4	2.86 ± 0.85
7	Oviposition period (Days)	21	7	9	8.14 ± 0.85
8	Post-oviposition periods (Days)	21	1	2	1.52 ± 0.51
9	Sex ratio (Male: Female)	100	34	66	1: 2.08
10	Adult longevity (Days)				
	Male	21	7	10	8.67 ± 1.06
	Female	21	9	13	10.90 ± 1.22
11	Total life cycle (Days)				
	Male	21	40	59	48.43 ± 2.44
	Female	21	42	62	50.67 ± 2.13
12	Fecundity	10	742	1235	1048.40 ± 193.58

dark brown to black in colour after 2 to 3 days of pupation and that indicated the parasitization. After 3 to 4 days, a maggot of tachinid fly came out from pupae by making hole and pupates outside (Plate-30A and B). Adult of *H. armigera* did not emerged from infected pupae. The pupal period of tachinid fly was recorded as 2 to 3 days. The adult tachinid fly closely resembled to house fly (Plate-31). It was grayish in colour and hairy setae were observed on thoracic and anal region having brown coloured compound eyes, pair of aristate antenna, sponging mouthparts, sticking legs and single pair of membranous wings.

Fourty two larvae of *H. armigera* were collected from chickpea field during leafy stage of the crop, of which three larvae were found parasitized by tachinid fly. Thus, 7.14 per cent parasitization was noted during present studies (Tabel-15). The parasite was sent to NBII, Bangalore for identification.

Plate 30(A)

Plate 30 (B)

Plate 30: (A) Parasitized pupa of *H. armigera* (B) tachinid fly pupa

Plate 31: Adult of tachinid fly

Summary & Conclusion

V. SUMMARY AND CONCLUSION

Chilli, *Capsicum annum* L. is one of the prominent spice and vegetable crop of India. From a social equity point of view, this vegetable is especially important, as it is liked by rich and poor, urban and rural, upper and lower classes and is a social leveler in the class-conscious society of this part of the world. Besides income, chilli is an important source of nutrition, which is primarily consumed as spices and cooked vegetable in various ways. The biggest threat to chilli cultivation is the vulnerable and wide spread attack by several insect pests. Among them, chilli thrips, *Scritothrips dorsalis* Hood is considered as the most serious and important pest in south Gujarat region. To minimize the economic losses caused by these chilli thrips, various insecticides are being used over this crop on massive scale from transplanting to fruit harvesting, which leads to accumulation of insecticides residues in chilli fruits and dried chilli powder and pose significant health hazards to human. Moreover, insecticide residue problems are one of the most important debating issues for human health. Considering the above points in view, investigations on **"Persistence and Dissipation of Insecticides against Chilli Thrips and Biology of Fruit Borer (*Helicoverpa armigera* Hubner)** were carried out at Farmers field, Village Kesali, Ta. Gandevi, Dist. Navsari and Food Quality Testing Laboratory as well as well as Post Graduate Research Laboratory of Entomology Department, Navsari Agricultural University, Navsari, Gujarat during *Rabi* 2015-16. The important findings of the present investigation are summarized here under.

5.1 Bioefficacy of various insecticides against chilli thrips (*S. dorsalis*)

It is evident from the studies that, a treatment of fipronil 0.005 per cent (25 mL a.i./ha) and fenpropathrin 0.03 per cent (150 mL a.i./ha) found significantly superior in controlling the chilli thrips. A treatment of ethion + cypermethrin 0.1 per cent (499.5 mL a.i./ha) proved as the second best treatment, though, it was equally effective to fenpropathrin 0.03 per cent and lambda-cyhalothrin 0.005 per cent (25 mL a.i./ha). Fenazaquin 0.005 per cent (50 mL a.i./ha) remained least effective among all during present investigation.

The treatment of fipronil 0.005 per cent also resulted in significantly higher fruit yield (421.95 q/ha), which was at par with fenpropathrin 0.03 per cent (403.26 q/ ha), followed by lambda-cyhalothrin 0.005 per cent (375.04 q/ha), ethion + cypermethrin 0.1 per cent (328.43 q/h) and fenazaquin 0.005 per cent (304.19 q/h). The lowest yield was observed in untreated control plot with 172.84 q/ha.

5.1 Persistence of different insecticides in chilli.

QuEChERS method was used to validate various parameters like linearity, accuracy (% recovery), precision (% RSD) and detection limits (LOD and LOQ).

5.2.2 Persistence of Fipronil

Recommended treatment of fipronil in/on chilli fruits showed 0.27 $\mu g\ g^{-1}$ as initial deposits, which reduced to 0.09 $\mu g\ g^{-1}$ 15^{th} day after the application

reflect loss of 0.25 per cent initial deposits. The regression equation worked out was $y = -0.0258x + 1.4119$ (R^2, 0.98) and half life was 11.67 days.

5.2.3 Persistence of Lambda-cyhalothrin

The initial deposition of 0.33 µg g^{-1} of lambda-cyhalothrin was detected in/on chilli fruits, when sampled from recommended dose were analyzed. The regression equation of lambda-cyhalothrin at 0.005 per cent was fitted as $y = -0.0431x + 1.5401$ by giving 0.92 as R^2 value. Moreover, the half life period for this molecule was 6.98 days.

5.2.4 Persistence of Ethion

Data on recommended dose of ethion residues in/on chilli fruits recorded as 0.20 ± 0.05 µg g^{-1} at 0 day (2 hours of exposure). The regression equation of ethion was calculated as $y = -0.0642x + 1.2774$ ($R^2 = 0.96$) and half life period was calculated as 4.68 days.

5.2.5 Persistence of cypermethrin

The spray concentration of 0.011 per cent resulted in 0.55 µg g^{-1} of initial deposition, which gradually dissipated and were BDL (< LOQ = 0.04 µg/g) on 7th day. The regression equation obtained was $y = -0.1162x + 1.7591$ (R^2, 0.98) with a half life period of 2.6 days.

5.2.6 Fenpropathrin

The initial deposition of fenpropathrin at 0.03 per cent was 1.58 µg g^{-1} at 0 days (2 hours of exposure) were 77.33 per cent on 15th day during the

present investigations. The regression equation for fenpropathrin was fitted as $y = -0.0397x + 2.2241$ ($R^2 = 0.9772$) with a half life period of 8.14 days.

5.2.7 Persistence of Fenazaquin

The initial deposition of 2.33 µg g^{-1} at 0 days (2 hours of exposure) of fenazaquin 0.005 per cent was detected in/on chilli fruits. The regression equation of fenazaquin was fitted as $y = -0.0397x + 2.2241$ by giving $R^2 = 0.97$. Moreover, the half life period for this molecule was 8.14 days.

Conclusion

The persistence of different insecticides were poor to moderate in the chilli crop as 65.81 to 91.80 per cent of initial deposit were lost within 15th days after the spraying.

The half-life values worked out for different insecticides were as follows: fipronil (11.67 days) > fenpropathrin (8.14 days) > lambda-cyhalothrin (6.98 days) > fenazaquin (6.57 days) > ethion (4.68 days) > cypermethrin (2.6 days).

5.3 Processing factor of different insecticides in chilli.

The processing factor worked out for fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin was 8.57, 9.13, 6.19, 5.02, 6.87 and 5.38, respectively. The study of processing factor reveals that the residues of all the insecticide concentrated by 5 to 9 times due to drying followed by powdering process. The result showed that initial deposits of fipronil, lambda-cyhalothrin, ethion, cypermethrin, fenpropathrin and fenazaquin in the fresh chilli

fruits were 0.27, 0.07, 0.20, 0.55, 0.11 and 0.11 µg/ g recorded on zero day (2 hrs after last spray), while these were 2.33, 0.62, 1.25, 2.77, 0.74 and 0.60 µg/ g when subjected to processing (drying followed by powdering), respectively.

Conclusion

The chilli fruit samples sprayed with different insecticides at their recommended dose collected on zero day after the application were subjected to sun drying and powdering and the processing factor (ratio of the residues in processed to fresh products) were worked out for each insecticide. The processing factor worked out for fipronil (0.005), lambda-cyhalothrin (0.005), ethion (0.088), cypermethrin (0.012), fenpropathrin (0.03) and fenazaquin (0.005) which reveals that the residues were 5 to 9 times, when fresh chillies are subjected to sun drying and powdering.

5.4.1 Biology of fruit borer (*H. armigera*) in chilli.

Biology of chilli fruit borer, *H. armigera* indicated that the female laid eggs singly or in batches of 2 to 3 on tender leaf and shoots of chilli plant. Occasionally the eggs were found on pot, piece of black colour muslin cloth and platform. The freshly laid eggs were yellowish white in colour which changed to deep yellow after one day and become dark brown prior to hatching. Eggs were hemispherical with flat base and prominently sculptured with numerous ridges running from one polar end to another. The length and breadth of freshly laid eggs were ranging from 0.42 to 0.56 mm and 0.44 to 0.57 mm respectively. The egg laying capacity of the female varied from 742 to 1235 eggs with an average

1048.40 ± 193.58. The hatching percentage was 53.20. The incubation period ranged from 2 to 5 days.

The larvae passed through six distinct instars when fed on chilli leaves and fresh green chilli fruits. The body colour of freshly emerged larva was semi-translucent, dirty white in colour with whitish longitudinal lines on the dorsal surface of the body. The second instar larva was yellowish to light brown in colour having transparent brown spotted head capsule. The third instar larva was similar in general appearance but differed in size. At the time of moulting, cuticle turn to black in colour. Head capsule was more compact and transparent with light brown spots. In fourth instar, larvae appeared in various colours of green, reddish brown, brown, greenish brown and covered with setae all over the body. The fifth instar larvae were showed pinkish brown and pale green colour pattern with broken dorsal strips and continues lateral strips. Head capsule was transparent and light orange in colour. The sixth instar larva was flattened ventrally but convex dorsally. The body was pinkish brown and pale green in colour with two black longitudinal strips on dorsal side and scattered short hairy setae were present on all over the body. Mostly, a head capsule was found in excreta after moulting. The average length of first, second, third, fourth fifth and sixth instar larvae were 1.60 ± 0.22, 4.57 ± 0.59, 9.55 ± 1.32, 11.98 ± 2.33, 17.71 ± 1.27 and 25.93 ± 3.70 mm, while that the average breadth were 0.26 ± 0.05, 0.68 ± 0.13, 1.16 ± 0.26, 1.83 ± 0.29, 2.70 ± 0.31 and 3.72 ± 0.37 mm, respectively. The average larval duration of first, second, third, fourth fifth and sixth instar larvae were recorded as 2.88 ±

0.73, 3.46 ± 0.51, 3.91 ± 0.79, 3.73 ± 0.70, 4.55 ± 0.51 and 4.71 ± 0.72 days, respectively. The total larval period was completed in 23.14 ± 1.28 days, when reared on chilli. .

The larva undergoes pupation in soil by preparing an earthen cocoon and the pre-pupal period recorded as 1.48 ± 0.51 days. The newly formed pupa was transparent green to light green in colour and further it became hard and changed into reddish brown colour with prominent black eye spot. The pupa was of obtect type. The average length and breadth of pupa measured as12.33 ± 0.80 and 3.69 ± 0.52 mm, respectively. The average pupal period was 12.67 ± 1.28 days.

The male moth was of greenish-grey while female was of orange brown. Presence of tuft of hairs on the tip of abdomen of female is the identification character. The average length of male and female measured from 16.94 ± 0.83 and 20.31 ± 1.62, while breadth with expanded wingspan measured as 33.12 ± 0.82 and 34.23 ± 1.83 mm, respectively. The sex ratio (Male: female) was 1:2.08. The average pre-oviposition, oviposition and post- oviposition periods were 2.86 ± 0.85, 8.14 ± 0.85 and 1.52 ± 0.51 days, respectively. The male and female moth lived for 8.56 ± 1.04 and 10.80 ± 1.32 days, respectively. The average longevity of male recorded as 8.67 ± 1.06 days while that of female was 10.90 ± 1.22 days. The average fecundity of the female recorded as 1048.40 ± 193.58 eggs. The total life cycle of male was completed in 40 to 59 days (48.43 ±

2.44 days), while it was completed in 42 to 62 days (50.67 ± 2.13 days) during the present investigation.

5.4.2 Larval-pupal parasite of *H. armigera*

Field collected larvae of H. armigera were found to parasitize by a tachinid fly *Juriniopsis adusta* and the parasitization recorded was 7.14 per cent.

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*Original not seen

Appendices

Appendix 1: Weekly meteorological data recorded at Meteorological Observatory, Navsari Agricultural University, Navsari (2014-15)

Standard Week	Bright Sun shine (hr/day)	Temperature (°C)			Relative Humidity (%)			Vapour pressure (mm of Hg)			Wind Speed (km/hr)	Evaporation
		MaxT	MinT	MeT	MoRH	EvRH	MeRH	MoVP	EvVP	MeVP		
1	2	3	4	5	6	7	8	9	10	11	12	13
49	8.77	32.56	15.74	40.43	69.38	36.97	87.86	11.22	13.37	17.91	2.99	3.69
50	6.63	30.16	14.00	37.16	81.86	47.92	105.82	11.65	14.68	19.00	2.19	3.07
51	7.64	29.29	13.23	35.90	70.48	47.81	94.39	9.65	14.44	16.87	4.95	3.17
52	7.69	29.04	12.98	35.53	68.73	33.19	85.33	9.09	9.55	13.86	3.85	3.18
1	7.47	28.11	13.89	35.06	85.55	38.39	104.75	11.31	10.97	16.79	3.46	2.87
2	8.99	30.11	9.77	35.00	72.10	32.40	88.29	8.30	10.24	13.42	3.01	3.33
3	8.46	29.64	12.66	35.97	82.40	33.19	98.99	10.74	10.22	15.84	3.30	3.09
4	7.00	28.01	14.51	35.27	82.98	45.90	105.93	11.46	12.66	17.79	4.45	3.10
5	8.94	29.84	14.03	36.86	78.45	36.58	96.74	10.58	12.07	16.61	5.08	3.76
6	8.77	31.97	14.93	39.44	85.12	37.05	103.64	12.14	12.80	18.54	3.82	4.60
7	9.79	32.43	13.76	39.31	86.17	40.53	106.44	11.84	14.53	19.11	2.81	4.61
8	9.61	34.39	16.06	42.41	90.49	37.88	109.43	13.71	15.02	21.22	3.05	4.70
9	7.64	23.70	12.94	30.17	74.96	44.61	97.27	11.29	12.33	17.45	4.07	4.04
10	8.93	32.71	15.24	40.34	81.46	41.58	102.25	13.27	16.18	21.36	3.81	4.90
11	8.77	32.51	18.51	41.77	84.92	48.85	109.35	15.68	17.55	24.46	5.06	5.73
12	9.09	33.14	19.04	42.66	82.79	39.50	102.54	16.65	19.58	26.44	3.78	5.71

CERTIFICATE

This is to certify that I have no objection for supplying only one copy or any part of this thesis to any scientist at a time through reprographic process if necessary for rendering reference service in a library or documentation centre.

Place : **Navsari**

Date : **10 / 08 /2016**

Patil V M

(Patil. V. M.)