

**STUDIES ON PEST INCIDENCE, BIOLOGY AND
FIELD RESISTANCE OF TOBACCO CATERPILLAR
Spodoptera litura (Fabricius) ON SOYBEAN
IN MAJOR DISTRICTS OF UTTARAKHAND**

Thesis

Submitted to the



**G.B. Pant University of Agriculture & Technology,
Pantnagar – 263145, (U.S. Nagar) Uttarakhand, India**

By

Rukesh Pramod K. N.

M.Sc. Ag. (Entomology)

***IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF***

Doctor of Philosophy
(Entomology)

August, 2019

ACKNOWLEDGEMENT

I shall ever, remain thankfully indebted to all those learned souls, my present and former teachers, known and unknown hands who directly or indirectly motivated me to achieve my goal and enlightened me with the touch of their knowledge and constant encouragement. I feel this is an extremely significant and joyous opportunity bestowed upon me by the goddess of learning, to think about and thank all those persons. I thank almighty for carrying me when I could not walk and helping me safe under his company of love, care and endless blessings without which this tedious and wearisome task could not be accompanied.

*Words in my lexicon fail to elucidate my profound sense of veneration & indebtedness to my advisor **Dr. Neeta Gaur**, Associate Professor, Department of Entomology for her inspiring guidance and encouragement, constructive criticism, congenial discussion, valuable suggestions and keen interest during the course of investigation & all the assistance provided throughout the tenure of study. I deem it to be my privilege to acknowledge the indelible inspiration and constructive help received from the members of my Advisory Committee namely **Dr. A. K. Karnatak**, Vice-Chancellor UUHF Bharsar and Professor, Department of Entomology, **Dr. Ruchira Tiwari**, Associate Professor, Dept. of Entomology and **Dr. Y. Singh**, Professor, Department of Plant Pathology.*

I extend my sincere thanks to Honorable Vice Chancellor, Director Experiment Station, Dean Post-Graduate Studies, Dean College of Agriculture, Head, Department of Entomology and staff members of University Library.

I am also thankful to all the teachers of Department of Entomology, specially Dr. R. M. Srivastava, Professor, for their guidance and help. The help rendered by the staff members of the Department, Jungi Yadav ji, Subodh Sharma sir, Ram Karan bhai, Jairam bhai, Ramu, Amit, Santosh and Jagat is thankfully acknowledged. I am thankful to Dr. H. R. Jaiswal, Senior Technical Assistant, AICRP-Soybean Pantnagar for his help in conducting field trials. I specially thank my senior, Dr. Ashish Devrani, for his presence during the survey programme and also in executing the research work. I appreciate the moral support given by my beloved seniors Dr. Swati Mogallapu and Dr. Shivashankara. I acknowledge my heartfelt thanks to my respected seniors, Rakesh sir, Dr. Chavan Vikas Tukaram sir, Gaurav sir, Dr. Neha Kunjwal ma'am, Kiran ma'am, Dr. Akanksha Chand ma'am.

I would like to thank especially Sanjay Tiwari (Dr.) sir Dept. of Irrigation and Drainage Engineering, College of Technology, G. B. P. U. A & T Pantnagar for helping in preparation of map of the research study.

I fall short of words to express my sincere thanks to my dear friends B's: Ajaykumara K.M., M. S. Sai Reddy, Devanshu Dev, Nishant Chorasias, Deepak Koujalagi, Devender Sharma and Gaurav Joshi. I highly acknowledge them for

providing the warm company, love & care, encouragement, active help during the degree programme. Blissful moments shared with them will remain cherishable for life.

I also want to give a special thank to my beloved friends, Rajani Pant, , Archana, Anjali Tiwari, Sarnya, Amritlingam, Daniel, Vijay Joshi, Avinasha, Shukla ji and to Aniket, Yogesh, Parmesh, Jayram, Srinidhi, Shivu, Akhya, Santu, Rammi, Sundra and Vikki, who were there before my journey of Pantnagar was even started back in 2015.

The help rendered by my dear friends Gaurav Joshi, Shivendra Nath Tiwari Ji and Devanshu Dev will always remain in my heart.

I feel lucky to be able to form such a loving bond with my batchmates, Gaurav Joshi, Ajaykumara K.M., M. S. Sai Reddy, Jyoti Ji, Divya Sati and Anju Yadav.

My guidemates, Dr. Swati Mogallapu, Deepsikha, Priyanka, Parul Suyal, Rashmi Joshi ma'am, Mrityunjoy, Gaurav Choudhary and Sudha Mathpal are acknowledged for their joyful company in the laboratory.

I would also like to give a special mention to my friends and seniors from PKB including Guru sir, Prasanna sir, Jayram sir, Srinivash (Sinu), Dhanraj, Anand, Bharath, Abhishek, Divija Yogesh, N. Gouda and Ganur to make me feel connected to my beautiful state, Karnataka.

It was always cheerful to have loving and joyous company of profound juniors especially Ravi Biradar, Ravindra, Chenesh, Avinash, Swoyam, Samraj, Jai Hind, Hashib, Sushil, Vinayak, Gaurav Choudhary, Seenam Mishra, Shikha Rohila, Divya Rawat and Shilpi during the whole course of degree programme.

Where the emotions are involved, words cease to mean. My vocabulary fails to accentuate my profound reverence and sincere regards to my Mother, Narasamma, Father, Nagarajaiah S., and my loving sisters, Prathima and Lavanya for their ceaseless inspiration, moral and spiritual support, profound love and unending encouragement, guiding me to achieve success at every step in life.

I render my heart-felt thanks to UGC, New Delhi, for granting me 'RGNF' scholarship for the Ph. D. degree programme.

I apologize for the faux pass of the persons who have extended the help in a way or other and deserved such thanks.

August 2019
Pantnagar

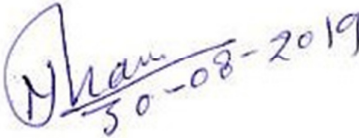

(Rukesh Pramod K. N.)
Author

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON PEST INCIDENCE, BIOLOGY AND FIELD RESISTANCE OF TOBACCO CATERPILLAR *Spodoptera litura* (Fabricius) ON SOYBEAN IN MAJOR DISTRICTS OF UTTARAKHAND**” submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** with major in **Entomology** and minor in **Plant Pathology** of the College of Post Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Rukesh Pramod K. N., Id.No. 49652** under my supervision and no part of the thesis have been submitted for any other degree or diploma.

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

Pantnagar
August, 2019


(Neeta Gaur)
Chairperson
Advisory Committee

CERTIFICATE

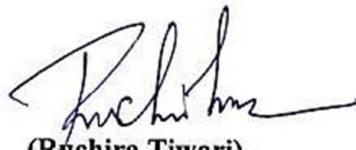
We, the undersigned, members of the Advisory Committee of **Mr. Rukesh Pramod K. N., Id.No. 49652** a candidate for the degree of **Doctor of Philosophy** with major in **Entomology** and minor in **Plant Pathology**, agree that the thesis entitled “**STUDIES ON PEST INCIDENCE, BIOLOGY AND FIELD RESISTANCE OF TOBACCO CATERPILLAR *Spodoptera litura* (Fabricius) ON SOYBEAN IN MAJOR DISTRICTS OF UTTARAKHAND**” may be submitted in partial fulfillment of the requirements for the degree.



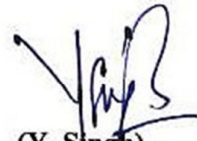
(Neeta Gaur)
Chairperson
Advisory Committee



(A.K. Karnatak)
Member



(Ruchira Tiwari)
Member



(Y. Singh)
Member



(Ex-officio member)
Head of the Department

CONTENTS

S. No.	Chapters	Page No.
1.	INTRODUCTION	
2.	REVIEW OF LITERATURE	
3.	MATERIALS AND METHODS	
4.	RESULTS AND DISCUSSION	
5.	SUMMARY AND CONCLUSION	
	LITERATURE CITED	
	VITA	
	ABSTRACT	

LIST OF TABLES

SI No.	Table No.	Description	After page No.
1.	3.1	Location selected for survey of insect pests of soybean in Uttarakhand during 2016-17	
2.	3.2.1	Chemical ingredients of Fraction-A used in artificial diets	
3.	3.2.2	Composition of artificial diets for rearing of <i>S. litura</i>	
4.	3.4.1	Details of the insecticides used to study the field-efficacy against tobacco caterpillar (<i>S. litura</i>) on soybean	
5.	4.1	Incidence of insect pests of soybean and their natural enemies in major districts of Uttarakhand	
6.	4.2.1	Growth & Survival parameters of <i>S. litura</i> (Mean±SD*) under different diet formulations	
7.	4.3.1	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Udham Singh Nagar poulation at 24, 48 and 72 HAE	
8.	4.3.2	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Nainital poulation at 24, 48 and 72 HAE	
9.	4.3.3	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Haridwar poulation at 24, 48 and 72 HAE	
10.	4.3.4	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of New Tehri poulation at 24, 48 and 72 HAE	
11.	4.3.5	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Pittoragarh population at 24, 48 and 72 HAE	

-
12. 4.3.6 Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Dehradun population at 24, 48 and 72 HAE
 13. 4.3.7 Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Champawat population at 24, 48 and 72 HAE
 14. 4.3.8 Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Almora population at 24, 48 and 72 HAE
 15. 4.3.9 Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Pauri Garhwal population at 24, 48 and 72 HAE
 16. 4.3.10 Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Uttarkashi population at 24, 48 and 72 HAE
 17. 4.3.11 Resistance ratio of different insecticides to different populations of *S. litura* in Uttarakhand at 24, 48 and 72 HAF
 18. 4.4.1 Efficacy of different insecticides against tobacco caterpillar (*S. litura*) on soybean during *kharif* 2016
 19. 4.4.2 Efficacy of different insecticides against tobacco caterpillar (*S. litura*) on soybean during *kharif* 2017
 20. 4.4.3 Effect of different insecticides on soybean seed yield during 2016 and 2017
 21. 4.4.4 Pooled data of bio-efficacy of different insecticides against *S. litura* of 2016 and 2017 *kharif* season:
-

LIST OF FIGURES

SI. No.	Fig. No.	Particulars	After page No.
1.	4.2.1	Total larval period of <i>S. litura</i> on different artificial diets	
2.	4.2.2	Total life cycle duration of <i>S. litura</i> on different artificial diets	
3.	4.3.1	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Udham Singh Nagar population at 24, 48 and 72 HAE	
4.	4.3.2	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Nainital population at 24, 48 and 72 HAE	
5.	4.3.3	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Haridwar population at 24, 48 and 72 HAE	
6.	4.3.4	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Tehri Garhwal population at 24, 48 and 72 HAE	
7.	4.3.5	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Pithoragarh population at 24, 48 and 72 HAE	
8.	4.3.6	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Dehradun population at 24, 48 and 72 HAE	
9.	4.3.7	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Champawat population at 24, 48 and 72 HAE	
10.	4.3.8	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Almora population at 24, 48 and 72 HAE	
11.	4.3.9	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Pauri Garhwal population at 24, 48 and 72 HAE	
12.	4.3.10	Dosage -mortality response of different insecticides against 3 rd instar larvae of tobacco caterpillar, <i>Spodoptera litura</i> (Fab.) of Uttarkashi population at 24, 48 and 72 HAE	

LIST OF PLATES

Plate No.	Description	After Page No.
1.	Major insect pests of soybean and their natural enemies	
2.	Glimpse of survey on soybean crop in major districts of Uttarakhand	
3.	Experimental setup of soybean and other host based artificial diets on <i>S. litura</i>	
4.	Rearing of populations of different districts and bioassay studies experimental setup	
5.	Experimental site of field -efficacy of different insecticides	



Introduction



Soybean [*Glycine max* (L.) Merrill.] is an important leguminous crop. Native of soybean is in Asia and the first known records, however, indicate that soybean emerged as a domesticated crop around the eleventh century B.C. in China (**Hymowitz, 1970**), where it was cultivated for its oil since centuries and they named it as a “yellow jewel” which feeds china’s entire population.

Soybean is one of the most important oilseed crop grown in India and throughout the world. In India, it is mainly grown in Madhya Pradesh, Rajasthan, Gujarat and Maharashtra. In India soybean is cultivated in an area of about 11.39 million hectares with a production of about 13.79 million tones and productivity is about 1.2 t/ha (**Anon., 2016**). In Uttarakhand Soybean is cultivated in an area of about 0.220 lakh hectare with a production of about 0.91 million ton with a productivity of 1103 kg/ ha.

From nutritional point of view, soybean contains 43.20 per cent protein and 20.00 per cent of edible oil. Soybean is a good source of phosphorus and lecithin. It also contains good amount of potassium, sulphur and Vit. E. Soybean protein is mainly rich in amino acids like leucine, methionine and threonine that the human body requires. For vegetarians, it is known as “poor man’s meat”. Owing to the absence of sugar content, it is considered to be very suitable diet for diabetic patients.

The national production of soybean has not been able to meet its domestic requirement due to the poor average yield. Among the various factors responsible for the poor yield, non-replacement of old cultivars with new improved ones and insect pest damage (**Lal et al., 1981**) are the major ones. Out of the various factors attributed to the low yield, one of the main factors is the economic losses caused by insect-pest to various pulses varied from 10 to 15 percent (**Bindra, 1968**).

According to Bhattacharya and Rathore (1979), 60 to 100 species of insects are found to attack the soybean at various stages in Uttar Pradesh. **Mundhe (1980)** reported about 16 insect species on soybean crop in Maharashtra. Among the various insect

pests infesting soybean crop, following are considered to be important (**Singh et al., 1989; Sojitra, 1990 and Vyas, 1996**).

1. Gram pod borer : *Helicoverpa armigera* (Hub.)
2. Pink pod borer : *Cydia ptychora* (Meyr.)
3. Leaf eating caterpillar : *Spodoptera litura* (Fabr.)
4. Green semilooper : *Chrysodeixis acuta* (Walker)
5. Grey semilooper : *Amyna octo* (Guenee)
6. Girdle beetle : *Oberopsis brevis*
7. Leaf miner : *Aproerema modicella* (Deventer)
8. Whitefly : *Bemisia tabaci* (Gennadius)
9. Stem fly : *Ophiomya phaseoli* (Tryon)
10. Thrips : *Caliothrips indicus* (Bag.)
11. Aphid : *Aphis glycine* (Koch)
12. Jassid : *Empoasca kerri* (Pruthi)

The tobacco caterpillar, *Spodoptera litura* (Fab.) is a serious and regular pest in Madhya Pradesh. It damages soybean from mid August to October in *kharif* and from November to March in *rabi*. Incidence of *S. litura* was observed in all the soybean growing parts of Uttarakhand and was confined to *kharif* season. After damaging the leaves, they also start feeding on young parts, consequently damaging 30 to 50 per cent of the pods (**Anon., 2007**). Higher population was noticed in Udham Singh Nagar and Haridwar districts. The pest was active in grand growth stage of the crop (**Patil, 2002**).

Insect pests and diseases are important limiting factors of agricultural production across the globe. The tobacco caterpillar, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) is a polyphagous insect, whose reproductive capacity and migration ability over long distances has made it an economically important pest of many agricultural crops with a wider geographic range throughout tropical and temperate Asia, Africa, North Africa and Pacific Island however it is absent in European Union (**Feakin, 1973; EPPO/CABI, 1997**). It is widely distributed in India causing serious losses when

outbreaks occur (**Tandi and Narayananan, 2002**). Outbreak of this pest occurred during 1987-88 in Andhra Pradesh and Tamil Nadu, where it caused 66% loss in the yield of seed cotton running into a loss of few hundred crores of rupees (**Dhaliwal and Arora, 2001**). In 2004, *S. litura* was seen grazing even unpreferred weeds on the roadside and drains after devouring the soybean fields of Madhya Pradesh. It challenges majority of conventional control strategies and also cry 1Ac encoded transgenic cotton and is becoming a serious pest of important commercial crops next to *Helicoverpa* spp. (**Janakiraman and Gupta, 2002**). *S. litura* has been reported to attack over 112 cultivated plant species belonging to 44 families, out of which about 60 species are known from India (**Garad et al., 1984; Chari and Patel, 1972**). It is a serious pest causing enormous losses to many economically important cultivated crops such as cotton, soybean, groundnut, tobacco and vegetables, feeding gregariously on leaves leaving midrib veins only (**Qin et al., 2004**). This defoliator is a potential pest of pulses, oil seeds and millets and now has become a major pest of cotton causing economic losses ranging from 25.8-100% (**Dhir et al., 1992**) based on crop stage and its infestation level in the field. In India, it has become a major pest and endemic particularly in southern states causing yield losses up to 71% (**Amin, 1983**).

Its control has depended mostly on application of various insecticides. This was the first lepidopteran to develop insecticide resistance in India when **Srivastava and Joshi (1965)** reported the failure of HCH to check this pest on cauliflower with seven fold resistance. Development of insecticide resistance in this pest has been faster in the last two decades (**Venkateshwarlu et al., 2006**). As a result, many field populations have developed high resistance against wide variety of insecticides including organophosphate, carbamate, pyrethroids and some selected newer chemistry insecticides with frequent field control failures (**Armes et al., 1997; Kranthi et al., 2001; Ahmad et al., 2007, 2008; Saleem et al., 2008**). Strain of *S. litura* resistant to chlorinated hydrocarbons, organophosphates and carbamates have been detected in areas where intensive control operations were carried out with these insecticides (**Srivastava and Joshi, 1965; Ingram, 1973; Ramakrishnan et al., 1984**).

Development of resistance has led to sporadic outbreaks and crop failures (**Ahmad et al., 2007**). Recently, there was an outbreak of *S. litura* on soybean in Kota

region of Rajasthan and a loss of Rs 300 crore was estimated. The pest also struck in epidemic form on soybean in Vidarbha region of Maharashtra in August 2008 and caused wide spread losses (**Dhaliwal and Koul, 2010**). In 1987-88, *S. litura* outbreak was reported from Andhra Pradesh and Tamil Nadu, where it caused 66% loss in the yield of seed cotton running into a loss of few hundred crores of rupees (**Dhaliwal and Arora, 2001**). If suitable control measures are not adopted, it is capable of defoliating entire crop (**Tandi and Narayananan, 2002**). The management of the pest has therefore become increasingly difficult all over the world and the most commonly used insecticides are ineffective in controlling it.

Currently, there are 261 pesticide molecule and 585 pesticide formulations registered for use in India (<http://www.cibrc.nic.in/>). There has been a sequential rise in the production and consumption of pesticides in India during the last three decades, the consumption pattern however, differs from rest of the world. Only one per cent of the insecticides are consumed in India as compared to 76 per cent of world consumption (**Bhattacharya et al., 2009**). It is revealed that in 2014-2015 the total chemical pesticide consumption in India was 57533 MT (<http://pib.nic.in/>). Synthetic pyrethroids representing the major invention in insecticide chemistry in recent years contribute 25 percent to the total pesticides marketed in the country (**Verma and Singh, 2000**). The per capita consumption of pesticides in India is lowest in the world, and the highest being in Taiwan (17kg/ha) followed by China (13kg/ha), Japan (12kg/ha), USA (7kg/ha), Korea (7kg/ha), France (5kg/ha), UK (5kg/ha) and India (0.6kg/ha) ([http://www.tsmg.com/download/reports/Indian AgrochemicalsIndustry 2013](http://www.tsmg.com/download/reports/IndianAgrochemicalsIndustry2013)).

The hazards and harmful effects of insecticides especially the wide application of conventional insecticides necessitate the use of new chemistry insecticides which are more effective, specific, safer for humans and much less toxic to our ecosystem (**Korrat et al., 2012**). To enhance crop productivity with multiple pest situations, several workers have advocated the use of insecticide mixture for resistance management (**Ishaaya et al., 1985; Ascher et al., 1986; Tabashnik, 1989; Dittrich et al., 1990**).

Keeping in view the aforesaid background information the present study has been conducted with following objectives:

1. To ascertain the incidence and status of insect pests of soybean and their natural enemies in major districts of Uttarakhand
2. To study the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *Spodoptera litura*.
3. To study the field resistance of tobacco caterpillar *Spodoptera litura* to insecticides in major districts of Uttarakhand
4. To study the field efficacy and economics of major insecticides against tobacco caterpillar *Spodoptera litura* on Soybean



*Review
of
Literature*



The available literature pertaining to the different areas of investigation has been reviewed and presented in chronological order under following heads:

- 2.1 To ascertain the incidence and status of insect pests of soybean and their natural enemies in major districts of Uttarakhand
- 2.2 To study the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *Spodoptera litura*.
- 2.3 To study the field resistance of tobacco caterpillar *Spodoptera litura* to insecticides in major districts of Uttarakhand
- 2.4 To study the field efficacy and economics of major insecticides against tobacco caterpillar *Spodoptera litura* on Soybean

2.1 To ascertain the incidence and status of insect pests of soybean and their natural enemies in major districts of Uttarakhand.

Suenaga (1953) investigated the seasonal variations of *Melanagromyza sojae* (Zehntner) in Kyusu Island where it is widely distributed and attacks several legumes. The insect was prevalent from May to October, soybean plant dissections during this period indicated that the larvae first started appearing and that their population was low in June. No damage was observed on soybean sown early in summer. The soybean crop sown after June started showing signs of damage by *M. sojae* and the crop sown in July and later had 100 per cent damaged stem. During this period, the population of second and third generation was very high. In west and south east part of Kyusu island 100 per cent plants showed damage even earlier than the July sown crop. *M. sojae* had four generations during May to October.

Survey carried out at Pantnagar revealed that stem fly damage was more severe during the rainy season than in the summer season. Crop suffered from severe damage at the seedling stage and caused plant mortality. However, during later stage the plant can withstand the damage (**Singh and Beri, 1973**).

Adimani (1976) reported stem fly incidence on soybean which commenced from third week after sowing and continued up to tenth week. **Singh (1982)** observed a greater infestation of stem fly in blackgram between June to September, than the other months of the year. Its infestation at legumes in sunny experimental plants averaged 14.8 per cent plants infested over the three years as against 44.9 per cent in shady plants during the same period.

Talekar and Chen (1983) studied the *M. sojae* infestation on soybean and mungbean throughout the year in Taiwan, but the infestation was more severe during relatively dry period after the rainy season that lasted from May to September. Between October to December, almost 100 per cent soybean and 60-70 per cent mungbean were damaged by these flies.

Singh and Singh (1990a) studied the seasonal incidence of *M. sojae* on soybean. The plant infestation increased abruptly in the third week of August and infestation increased from 72 to 98.90 per cent in the first week of September. The fly infested almost every plant (99.9 to 100) in the first week of October. Immediately after monsoon break, the crop was attacked by agromyzid than in case of delayed sowing (**Kundu and Srivastava, 1991**).

M. sojae generally infest soybean throughout the season, infestation was initially low, and reached its peak in the 5th to 8th weeks after planting and declined towards the end of the season (**Berg et al., 1995**).

Patil (2002) reported that stem fly incidence was high in Jamkhandi (14.80%) and Mudhol (14.45%) taluks of Bagalkot district, Gokak (16.20%), Raibag (16.30%) and Athani (14.45%) of Belgaum district.

Survey conducted during 2003-04 revealed the infestation of stemfly upto 20 per cent at Dharwad and 65 per cent at Athani and Chikkodi taluks of Belgaum districts (**Anon., 2004**).

Fletcher (1922) was the earliest worker to report the incidence of nine species of insects occurring on soybean from India. About 85 species of insects belonging to six different orders and a mite on soybean were reported from Madhya Pradesh by **Gangrade (1962)**.

Ramakrishna Ayyar (1963) reported two insects of soybean crop from south India. **Rawat et al. (1969)** recorded over two dozen different species of arthropod pests of soybean from Madhya Pradesh, India.

Approximately 380 species of insects have been collected from soybean crop from many parts of the world (**Luckmann, 1971**). **Saxena (1972)** from Madhya Pradesh recorded 32 insect pests and two non-insect pests of soybean. A total of 267 insect species were reported from soybean fields in Arkansas (**Tugwell et al., 1973**). **Singh (1973)** registered 56 insect pests and a mite on soybean crop from Pantnagar, Uttar Pradesh.

Rai et al. (1973) recorded 24 insect species feeding on soybean in Karnataka, among them maximum damage was inflicted by the larvae of *Lamprosoma indicata* F, *Stomopteryx subsecivella* Zeller, *Diacrisia obliqua* Walker and the gelechid shoot borer. **Adimani (1976)** recorded 59 insect species belonging to six orders occurring around Dharwad on soybean in Karnataka. According to **Mundhe (1980)** the semilooper, *T. orichalcea* was a pest mainly during kharif although it was observed in stray instances during summer also.

Singh et al. (1988) reported a higher larval population of the noctuid, *Rivula sp.* on DS 76-1- 29 and PK 472 (18.4-19.8 larvae/10 plants) than on MACS 75 and JS 76-259 (4.8-5.0 larvae/10 plants). PK 472 and Bragg sown on 25th June, however, gave maximum grain yield as compared to remaining cultivars and dates of sowing. Cultivars sown on 25th June recorded higher larval populations of *Rivula sp.* (20.5 larvae/10 plants).

Sontakke and Patro (1991) reported the incidence of about 20 insect pests on soybean in Western Orissa. Field studies were carried out during 1988-89 in Chiplima, Orissa, India indicated that, kharif crop of soybean suffered greater damage by insect pests than the rabi crop. Lowest pest incidence and higher yields were recorded with early sowings (20th June and 5th July; 1st and 15th November) in both the seasons. Three need-based applications of monocrotophos in kharif and two in rabi gave satisfactory control of all the insect pests, resulting in increased grain yield of 11.2 and 3.1 q/ha, respectively as compared to control as reported by **Sontakke and Mishra (1994)**. Field studies conducted in Himachal Pradesh, India, during 1993 showed that

delaying the sowing date of soybean resulted in the decrease of yields. The maximum yield (3.69 q/ha) was obtained by sowing on 28th May and the lowest yield (1.45 t/ha) was obtained by sowing on June 25th (**Chandel and Gupta, 1995**). The studies on date of sowing carried out at Dharwad also revealed the higher incidence of *S. litura* with late sown groundnut crop (**Patil, 1995**).

Occurrence of 34 species of insects was observed during kharif and summer in Bangalore. Among them, *A. modicella* (Deventer), *Liriomyza trifolii* (Burgess), *M. sojae*, *T. orichalcea*, *Monolepta* sp. and *H. armigera* were considered as major insect pests on the crop (**Venkataramanappa, 1996**). **Thippaiah (1997)** noticed 34 species of insects on soybean during kharif season and 25 species during summer season, in Bangalore, Karnataka. Among these, lepidopteran defoliators, *T. orichalcea*, *S. litura*, *Achaea janata* (Linn.) and *Achaea lactina* (L.) appeared only during kharif season where as *S. obliqua* was noticed during both summer and kharif seasons.

Chaturvedi et al. (1998) reported that during kharif of 1995, 17 insect and one mite species were recorded infesting soybean variety JS 72-44 (Gaurav) sown on 15th July 1995 in Sehore, Madhya Pradesh, India. Of these, two damaged the stems, 10 defoliated the plants, five sucked the cell sap and one damaged the roots at different growth stages of the crop, starting from immediately after the emergence of the cotyledons.

The population density of some insects associated with soybeans was estimated in a field experiment in India during kharif 1985 by following simple random sampling and two-stage sampling techniques at three stages of plant growth, 60-64, 86-89 and 98-99 days after sowing, using the ground cloth sampling method. Population densities of *S. obliqua* and *S. litura* during the crop growth period were maximum around the second half of October. However, density of *T. orichalcea* was higher during the later part of September or early October. Significant correlations were observed between population densities of some insect species as reported by **Vinod Kumar et al. (1998)**.

Populations of *Biloba subsecivella* (Zuller), *Chrysodeixis acuta* (Walker), *S. litura* and *S. obliqua* were low in early-sown (22nd June and 2nd July) soybean. Incidence of these pests was high in crops sown between 12th July and 1st August (**Mandal et al., 1998**).

Jayappa (2000) reported 40 and 21 species of insects attacking soybean during *kharif* and summer seasons, respectively in Bangalore, Karnataka. 300 species of insect pests were infesting soybean, of which blue beetle, grey semilooper, green semilooper and stem fly were major insect pests in Madhya Pradesh (**Singh et al., 2000**). The lepidopteran defoliators like *S. litura*, *T. orichalcea* and *S. obliqua* were observed on the crop from 28 days after sowing and caused severe defoliation in Bangalore as reported by **Kamala (2000)**.

Ngoyen Phi-Dieu Huyen (2001) reported that lepidopteran defoliators like *S. litura*, *T. orichalcea* and *L. indicata* were observed from 21 days after germinations (DAG), of which *H. armigera* was a major pest. *Spodoptera litura* was seen from 21 to 49 DAG with less incidence (0.12 to 0.5 / plant). *Thysanoplusia orichalcea* was observed from 21 to 77 DAG and population was more at 42 and 49 DAG.

Patil (2002) opined that soybean was attacked by 48 phytophagous insect species, among these the seedling borers, *M. sojae*, *Obereopsis brevis* Swed, leaf eating caterpillar *S. litura* and pod borer, *Cydia ptychora* Meyrick were key pests during *kharif*. Whereas, leaf miner, *A. modicella*, white fly, *Bemisia tabaci* (Genn.) and leaf hopper, *Amrasca biguttula biguttula* (Ishida) were major pests during summer.

An experiment was carried out at the experimental station of the University of Tocantins in Gurupi, Brazil to determine the population fluctuation of soybean pests. Among defoliating caterpillars, *Anticarsia gemmatalis* (Hub.) and *Cydia includes* (Fab.) were the most abundant. Among the defoliating beetle complexes, *Ceratomyia arcuata* (Oliv.) was the most abundant, with population peaks near the reproductive stage as registered by **Didonet et al. (2003)**.

Sastawa et al. (2004) reported that the number of insect defoliators and pod sucking bugs were significantly higher in soybean sown on 31st July in 2001 and on 28th August in 2002. Grain yields were higher in early sown soybean in 2001 as compared to late sown crop in 2002.

Meena and Sharma (2006) reported the minimal larval population of 1.42 larvae per meter row length in early sown crop (25th June), followed by mid sown crop and late sown crop which recorded 1.67 and 1.87 larvae per mrl, respectively at Udaipur, Rajasthan.

Madrap et al. (2007) recorded the seasonal incidence of insect pests of soybean during Kharif season at Parbhani. The studies revealed that the infestation of leaf miner and semilooper were less during the *Kharif* season. However, infestation of *S. litura* and girdle beetle was more up to 6.8 and 5.6 per cent, respectively.

Maximum larval population of *S. litura* and *T. orichalcea* (7.80, 12.00, 12.80 and 6.50, 6.20 and 8.60 larvae/mrl, respectively) were noticed on the crop sown on 08-06-06, 27-06-06 and 08-07-06 dates, respectively. Early sown crop recorded lower incidence of *S.litura*, *T. orichalcea* and *S. obliqua* defoliators as compared to that of late sown crop as reported by **Harish (2008)**. Basic information on the seasonal incidence of leaf eating caterpillars on soybean is considered most essential to manage the pest.

2.2 To study the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *Spodoptera litura*.

Abdullah et al. (2000) reported that an artificial diet and soybean leaves will be used in rearing the larvae of beet armyworm, *Spodoptera exigua* (Hubner) (Lepidoptera :Noctuidae) in laboratory condition. The artificial diet was composed of soaked mungbean, baking yeast, methyl paraben, sorbic acid, ascorbic acid, casein, choline chloride, agar, vitamin, formalin and distilled water. Survival of larvae on artificial diet (96.67%) was higher than those reared on soybean leaf (63.64%). Weight of larvae and pupae reared on artificial diet was significantly higher than those of the larvae and pupae fed with soybean leaves. The larval and pupal periods of those fed with artificial diet was found to be 15.7 ± 0.84 and 6.73 ± 0.51 days respectively, whereas, those fed with soybean leaf was 18.65 ± 0.83 and 8.5 ± 0.52 days respectively. The average number of eggs laid was 577.9, when the larvae were reared on artificial diet. However, it was 472.5 when the larvae were reared with soybean leaf. The female and male life spans were 14.6 and 11.4 days on artificial diet and 13.1 and 10.2 days with soybean leaf. Without feeding, the adult showed a life span of 6.29 ± 1.42 and 5.3 ± 0.66 days in artificial diet and soybean leaf respectively. The sex ratio was more or less similar in the first and second generations but in the third generation males number increased considerably (1:1.72).

Divakara and Doddamane Manjulakumari (2015) reported that the study of artificial diet formulation and its efficacy evaluation on development and reproduction of *S.litura* and the biological parameters based on mass rearing of eleven continuous generations showed higher pupation (89.3 ± 1.84) and survival (70.4 ± 1.21) of larvae on new modified diet formulation and the average number of eggs laid by insects reared on this diet was 3546.4 ± 10.21

Sreelakshmi and Mathew (2017) studied development of castor based oligidic diet for tobacco caterpillar, *S.litura* (Fabricius) and its comparative study with other artificial and natural diets. The results revealed that populations reared on castor based oligidic diet showed a significant reduction in total larval period (13.08 days) and total life period (32.66 days) with high development indices and survival per cent (73.26) when compared to populations reared on natural diets.

Saljoqi et al. (2015) reported Studies on rearing of *S.litura* (Fabricius) on different artificial diets i.e., bean based diet (Diet-1) and gram based diet (Diet-2) and its parasitism with *Trichogramma chilonis* (Ishii) will be conducted under controlled laboratory conditions of $27\pm 2^{\circ}\text{C}$, $65\pm 5\%$ RH and 14:10 L:D during 2013. The results showed that feeding the 1st, 2nd and 3rd generations of the immature stage of *S. litura* on diet-2 resulted in highest % survival rates among all the parameters of immature stages of *S. litura*, lower total larval duration (15.8 days as against 17.2 days of control) and total duration from egg to adult stage (29.6 days as against 31.9 days for diet-1). The mature adult stage of *S. litura* showed almost same trend of better performance of *S. litura* fed on diet-2 in terms of higher oviposition period 5.7 days and higher female fecundity (total number of eggs 1612.3) compared with the oviposition period 5.2 days and female fecundity (total number of eggs 1541.86) recorded for diet-1. No significant difference was observed among the diets in the % parasitism rate of *S. litura* by *T. chilonis*. Increased trend of parasitism coincided with the increased time of exposure. Highest parasitism rate of 91.1% and 89.5 % was observed in the egg cards exposed to *T. chilonis* for 24 h in Diet-2 and Diet-1, respectively, while after 16 h exposure, 90 and 88.6 % was recorded for Diet-2 and Diet1, respectively. Diet-2 was found to be better compared with Diet-1 for rearing of *S. litura*.

2.3 To study the field resistance of tobacco caterpillar *Spodoptera litura* to insecticides in major districts of Uttarakhand

Pramanik and Chatterjee (2003) have observed that abamectin had the lowest LC₅₀ value of 110.068 ppm for *P. xylostella* and 271.416 ppm for *S. litura*, while novaluron had the highest LC₅₀ of 1482.335 ppm for *P. xylostella* and 1976.430 ppm for *S. litura*. The order of relative toxicity was: abamectin > spinosad > acetamiprid > cartap hydrochloride > novaluron.

Gupta et al. (2004) estimated the relative susceptibility of five days old larvae of *S. litura* to certain novel insecticides. On the basis of LC₅₀ value, the order of toxicity of different insecticides was emamectin benzoate (6.93) > fenvalerate (1.82) > indoxacarb (1.62) > cypermethrin (1.00) > abamectin (0.94) > quinalphos (0.67) > bifenthrin (0.51) > spinosad (0.44) > endosulfan (0.28) > betacyfluthrin (0.23) > lambda cyhalothrin (0.19).

Munir Ahmed et al. (2005) studied effectiveness of some new chemistry insecticides against second instar larvae of leaf worm, *S. litura* under controlled laboratory conditions at three different concentrations and the results revealed that, emamectin benzoate 1.9 EC proved to be the best followed by lufenuron 5 EC, spinosad 45 SC and indoxacarb 15 SC, respectively. Abamectin 1.8 EC proved to be the least effective to control the pest.

Gupta et al. (2005) studied the toxicity of new molecules on *Earias vittella* (Fabricius) based on LC₅₀ values. The LC₅₀ values of abamectin, betacyfluthrin, emamectin benzoate, spinosad, cypermethrin, endosulfan, lambda cyhalothrin, chlorpyrifos, indoxacarb and fipronil were 0.0001, 0.0001, 0.0004, 0.0004, 0.0006, 0.0017, 0.0027, 0.0032, 0.0237 and 0.0409 per cent, respectively.

Similarly, **Venkateswarlu et al. (2005)** have determined the relative toxicity of some novel insecticides against insecticide resistant Guntur strain of *S. litura* on Cotton. Novaluron was found to be the best at 72 h after treatment with higher relative toxicity than quinalphos (x77.0) and fenvalerate (x76.9) to which the pest has developed increased levels of resistance, followed by indoxacarb which was 63.6 and 63.1 times toxic than fenvalerate and quinalphos at LD₅₀ level. At LD₉₀ level indoxacarb was the best to eliminate the resistant individuals which was 50.0 and 37.7

times toxic than fenvalerate and quinalphos followed by novaluron which was 27.1 and 33.0 times toxic than quinalphos and fenvalerate. Profenofos was third in efficacy against resistant *S. litura*. Among the novel insecticides thiodicarb and spinosad showed poor efficacy against resistant Guntur strain of *S. litura*.

Stanley et al. (2006) carried out studies on acute toxicity of emamectin benzoate and spinosad to *S. litura* for arriving at discriminating doses of resistance monitoring and reported that, the pest was highly susceptible to these insecticides. The discriminating doses were fixed at 0.40 ppm for emamectin and 125 ppm for spinosad to *S. litura*. The discriminating doses when applied to the field collected population of Coimbatore and Madurai areas, no resistance was detected, which was confirmed by very high percentage mortality.

Dhawan et al. (2007) studied the susceptibility of third instar larvae of *S. litura* to certain novel insecticides. The LC₅₀ of emamectin benzoate, novaluron, pyridalyl, flubendiamide, chlorantraniliprole, chlorpyrifos and thiodicarb were 0.0001, 0.0020, 0.0037, 0.0040, 0.0044, 0.0390 and 0.0410 per cent, respectively.

Shankarganesh et al. (2007) have observed that among the novel insecticides, indoxacarb was the best against the Bangalore and Guntur populations of *S. litura* with higher relative toxicity than cypermethrin (12.1 and 15.9), fenvalerate (10.9 and 20.6) lambda-cyhalothrin (6.1 and 26.0) and profenophos (9.2 and 20.4), respectively, followed by emamectin benzoate which was 6.0 and 4.2, 5.5 and 5.48, 3.1 and 6.92 and 4.58 and 5.44 times more toxic than cypermethrin, fenvalerate lambda-cyhalothrin and profenophos at the LC₅₀ level. The larvae of *S. litura* obtained from Guntur and Bangalore had 10.4, 4.8, 17.2 and 7.8-fold and 3.6, 1.1, 1.8 and 1.9 fold resistance to cypermethrin, fenvalerate, lambda-cyhalothrin and emamectin benzoate, respectively, compared to the Delhi population.

Kaur et al. (2007) have found indoxacarb as the most toxic against the three populations of *S. litura* in Punjab (Malerkotla, Hoshiarpur and Mansa) followed by thiodicarb, chlorpyrifos and spinosad. Cypermethrin and fenvalerate were less toxic indicating development of resistance and acephate was the least toxic. The new molecules, *i.e.* indoxacarb (LC_{0.00001-0.00003%}) and thiodicarb (LC_{0.00039-0.0010%}) proved extremely toxic and almost all the populations indicated high level of susceptibility to these insecticides.

A comparison of Punjab and Delhi population of *S. litura* indicated that the Punjab population was 2.27 and 1.36 fold resistant to chlorpyrifos and ethion, respectively than that of Delhi population. At LC₅₀, the relative resistance value for quinalphos was 1.32 by leaf dip method, indicating that Punjab population may develop faster resistance against quinalphos as compared to Delhi population (**Kodandaram and Dhingra, 2007**).

Emamectin benzoate showed the highest relative toxicity (1093.2, 986.5, 870.6, 254.3 and 160.3 times) than triazophos, cypermethrin, deltamethrin, chlorpyrifos and quinalphos to which the pest, *S. litura* has developed high level of resistance. Novaluron was the next best which showed better toxicity (134.2, 121.0, 106.8, 31.2 and 20.4 times) than triazophos, cypermethrin, deltamethrin, chlorpyrifos and quinalphos at LD₅₀ level, respectively (**Prasad et al., 2007**).

The toxicity studies by **Ahmad et al. (2008)** against various populations of *S. litura* in Pakistan indicated that for spinosad, resistance ratio compared with Lab-PK were in the range of 7–122 fold, 3–95 fold for indoxacarb, 4–186 fold for abamectin, 2–77 fold for emamectin and 13–224 fold for fipronil. The resistance ratio for insect growth regulator (IGR) tested was in the range of 2–66 fold for leufenuron, 8–56 fold for diflubenzuron and 2–153 fold for methoxyfenozide. Pair wise comparisons of the log LC_{50s} suggested a cross-resistance mechanism.

Ajanta et al. (2008) studied toxicity of emamectin benzoate in the laboratory to determine its performance on three larval stages (5, 7 and 9 days old) of tobacco caterpillar, *S. litura* using three types of assay techniques viz., leaf dip, Potter's tower and thin film method taking three different formulations of emamectin benzoate and reported that, median lethal concentrations (LC₅₀) of emamectin benzoate 1.9% EC against 5, 7 and 9 days old larvae were recorded as 0.00005, 0.00017 and 0.0007 per cent, respectively.

Dhawan et al. (2008) have found the LC values of emamectin benzoate, novaluron, pyridalyl, flubendiamide, chlorantraniliprole, chlorpyrifos and thiodicarb against *S. litura* by topical application technique as 0.0001, 0.0020, 0.0037, 0.0040, 0.0044, 0.0390 and 0.0410%, respectively. Based on the LC value, the order of toxicity of different insecticides was emamectin benzoate > novaluron > pyridalyl >

flubendiamide > chlorantraniliprole > chlorpyrifos > thiodicarb with relative toxicities of 390.0, 19.50, 10.54, 9.75, 8.86, 1.00 and 0.95, respectively.

Prasada Rao and Grace (2008) studied the susceptibility of *Spodoptera exigua* (Hubner) to different insecticides and reported that LC₅₀ of indoxacarb, novaluron, emamectin benzoate, lufenuron, spinosad, methomyl, deltamethrin, cypermethrin, profenophos, thiodicarb, quinalphos, chlorpyrifos, fenvalrate, endosulfan and acephate were 0.029, 0.037, 0.04, 0.15, 0.9, 0.208, 0.239, 1.09, 1.51, 2.23, 3.9, 6.02, 6.16, 6.30 and 35.4 µg/larva, respectively.

Kitturmath (2008) generated baseline values for indoxacarb and spinosad against the laboratory reared *S. litura* for 25 generations without exposing to insecticide by using artificial diet and found that indoxacarb (LD₅₀ of 0.19 µg a.i./g) was highly toxic to susceptible strain as compared to spinosad (LD₅₀ of 3.74 µg a.i./g). Suby et al. (2008) studied efficacy of certain newer insecticides with novel mode of action on *S. litura* using leaf dip method and the results revealed that, LC₅₀ of emamectin benzoate against 4, 7 and 10 days old larvae were recorded as 0.22, 0.25 and 0.34 ppm, respectively and recorded maximum mortality of larvae followed by indoxacarb (33 ppm), spinosad (166 ppm) and cypermethrin (408 ppm).

The experiment on contact toxicity against 9d old larvae of *S. litura* by larval dip method indicated that deltamethrin was the most toxic insecticide and dimethoate was least toxic. The LT₅₀ value of deltamethrin, cypermethrin, alphamethrin, lambda-cyhalothrin and dimethoate was 10.30, 10.93, 14.40, 22.54, and 23.80 h respectively at the concentration closer to LC₅₀ at 24h. Deltamethrin therefore was fastest acting synthetic pyrethroid. Dimethoate was 6.4 times less toxic than deltamethrin and 2.7 times less toxic than alphamethrin at LC₅₀ level (**Kumar, 2008**).

A comparative dose mortality response expressed in terms of relative toxicity indicated that indoxacarb and methomyl were almost *at par* whereas thiamethoxam, imidacloprid and fipronil were 28.54, 37.45 and 44.36 times less toxic than indoxacarb against the larvae of *S. litura*. Imidacloprid, fipronil and thiamethoxam, in particular, showed a very high RT value indicating far less stomach toxicity to *S. litura* as compared to indoxacarb and methomyl. The order of toxicity by leaf dip method 24HAE at LC₅₀ levels was: indoxacarb (2) > methomyl (296) > fipronil (816) >

thiamethoxam (1984) > imidacloprid (3719ppm) whereas in residue contact bioassay 24HAE at LC₅₀ level, the order of toxicity was: indoxacarb (15) > methomyl (19) > fipronil (571) > imidacloprid (572ppm) (**Ramangouda, 2008**).

Rao (2008) studied insecticide resistance in *S. litura* from cotton fields in Kurnool, (A.P.). The LC₅₀ (micro g per larva) values of lufenuron, emamectin benzoate, novaluron, indoxacarb, profenofos, endosulfan, chlorpyrifos, deltamethrin, quinalphos, spinosad, cypermethrin, dichlorvos, acephate and fenvalerate were 0.0068, 0.0069, 0.030, 0.21, 0.213, 0.645, 0.93, 0.95, 1.02, 1.14, 3.31, 5.12, 5.3 and 5.49 micro g per larva, respectively. The LC₉₀ (micro g per larva) values for emamectin benzoate, lufenuron, novaluron, indoxacarb, chlorpyrifos, endosulfan, spinosad, deltamethrin, cypermethrin, thiodicarb, quinalphos, profenofos, dichlorvos, fenvalerate and acephate were 0.017, 0.89, 0.89, 1.23, 2.23, 2.95, 3.89, 5.12, 11.48, 16.5, 16.9, 17.78, 18.62, 21.37 and 34.67 micro g per larva, respectively. Using the LC₅₀ value of cypermethrin as the control, dichlorvos, acephate and fenvalerate were found to be the least toxic. Based on the LC₉₀ values, emamectin benzoate was the most potent, whereas acephate was the least potent.

Lingaraj et al. (2009) studied relative toxicity of selected novel insecticides at the rate of 2 ml of each concentration against tobacco caterpillar, *S. litura* and the results revealed that, LC₅₀ values for abamectin, chlorfenapyr, indoxacarb, spinosad, thiodicarb and quinalphos were 0.0302, 0.0094, 0.0039, 0.0135, 0.0292 and 0.0321, respectively at 24 hours with relative toxicity being 1.28, 3.41, 8.23, 2.33 and 1.09 respectively as compared to quinalphos, while at 48 hours, the LC₅₀ values were 0.0204, 0.0084, 0.0029, 0.0127, 0.0248 and 0.0262 per cent, respectively, the relative toxicity being 1.27, 3.11, 9.03, 2.06 and 1.05 by topical application. Indoxacarb exhibited highest toxicity both at 24 and 48 hours while, spinosad outperformed indoxacarb.

Ramanagouda and Srivastava (2009) studied the effect of five insecticides viz., indoxacarb 14.5 SC (Avaunt), methomyl 40 SP (Lannate), fipronil 0.3 GR (Regent), thiamethoxam 25 WG (Actara) and imidacloprid 17.8 SL (Confidor) on *S. litura* for toxicity evaluation by contact and leaf dip methods and the results revealed that, indoxacarb 14.5 SC was the most toxic insecticide at 24 hr exposure at all the

three concentrations, the values being 7.0 ppm (LC30), 15 ppm (LC50) and 126 ppm (LC90) whereas imidacloprid 17.8 SL was least toxic with 281, 572 and 3313 ppm at LC30, LC50 and LC90, respectively.

Temple et al. (2009) conducted an experiment to evaluate three bioassay methods (viz., insecticide treated diet, topical application and adult vial test) for potential use in future insecticide resistance surveys and to determine the baseline toxicity of rynaxypyr to selected lepidopteran pests. The results revealed that rynaxypyr (chlorantraniliprole) was highly toxic to bollworm, *Helicoverpa zea* (Boddie), fall armyworm, *Spodoptera frugiperda* (J.F.Smith) and tobacco budworm *Heliothis virescens* (F.), in all the three laboratory bioassay procedures.

Talikoti et al. (2009) estimated the relative susceptibility of third instar larvae of *S. litura* to certain novel insecticides under laboratory conditions and reported that on the basis of LC50 value, indoxacarb 15.8 EC proved to be highly toxic to the both early and late instar larvae followed by spinosad 45 SC which was also equally effective in controlling the larvae.

Hardke et al. (2011) conducted baseline dose-mortality responses for fall armyworm, *S. frugiperda* larvae in laboratory bioassays to confirm field efficacy against natural infestations and to determine residual efficacy of selected insecticides and the results revealed that, among the newer insecticides chlorantraniliprole, cyantraniliprole, flubendiamide and spinetoram recorded LC50 value ranging from 0.066 to 0.93 µg/ml. In diet-incorporated assays, the LC50 values of chlorantraniliprole and spinetoram were significantly lower than the LC50 of all other insecticides.

Talikoti et al. (2012) conducted bioassay studies against third instar larvae of *S. litura* and indicated that among the insect growth regulators viz., buprofezin, lufenuron, novaluron and the check diflubenzuron, the highest relative toxicity was exhibited by novaluron at 76 hr and lufenuron at 96 and 120 hr of exposure by topical application. Novaluron exhibited greater toxicity irrespective of the time of exposure when sandwich method was used and lufenuron was intermediary in toxicity.

Karuppaiah and Chitra (2013) estimated the relative susceptibility of third instar larvae of *S. litura* to certain novel insecticides. On the basis of LC50 values, the

order of toxicity of different insecticides was chlorantraniliprole 18.5 SC (37.75 ppm) > emamectin benzoate 5 SG (37.75 ppm) > indoxacarb 15.8 EC (3.28 ppm) > spinosad 45 SC (1.91 ppm) > pyridalyl 10 EC (1.61 ppm) > flubendiamide 20 WG (1.24 ppm) > bifenthrin 10 EC (1.00 ppm) > koranda 505 EC (0.83 ppm) > polytrin C 44 SC (0.68 ppm) by direct spray method. The LC50 obtained by leaf-dip method revealed that chlorantraniliprole 18.5 SC (0.0001%) was most effective followed by emamectin benzoate 5 SG (0.0002%) and indoxacarb 15.8 EC (0.0012%).

Che et al. (2013), Beet armyworm, *Spodoptera exigua* (Hubner), is a serious pest of vegetables in China, and its control is heavily dependent on chemical insecticides. The current resistance status of nine insecticides was investigated in 16 field populations collected from seven provinces of China during 2009-2012. Compared with the susceptible strain WH-S, some field populations evolved various levels of resistance to eight of the nine insecticides tested: emamectin benzoate (4- to 348-fold), indoxacarb (2- to 41-fold), spinosad (5- to 38-fold), chlorantraniliprole (2- to 44-fold), tebufenozide (2- to 87-fold), chlorfluazuron (3- to 31-fold), cypermethrin (79- to 1240-fold), and chlorpyrifos (8- to 3,080-fold), but no significant resistance was detected to chlorfenapyr (0.4- to 7-fold). This indicates that chlorfenapyr has no cross-resistance with these other currently used insecticides. Four consecutive years resistance screening at two places shows that resistance patterns will be different between populations from Luhe (Jiangsu Province) and Fengxian (Shanghai). Resistance levels to chlorpyrifos will be much higher in populations from Luhe (877- to 3,080-fold) than from Fengxian (8- to 110-fold). Fengxian populations reported to be developed moderate levels of resistance to tebufenozide (13- to 87-fold), but no resistance in Luhe populations (2- to 6-fold). However, Luhe populations developed moderate levels of resistance to chlorfluazuron (21- to 31-fold), but there was no resistance in Fengxian populations (3- to 5-fold).

Tong et al. (2013) carried out studies to evaluate resistance in the populations of *Spodopteralitura* Fab. (Lepidoptera, Noctuidae) from five districts of Hunan Province in China to various insecticides from 2010 to 2012. For organophosphates and pyrethroids, resistance ratios compared with a susceptible Lab-BJ strain will be in the range of 14–229-fold for organophosphates and 12–227-fold for pyrethroids. Similarly,

relative low levels of resistance to emamectin, indoxacarb, and chlorfenapyr will be observed in all five populations. In contrast, the resistance to carbamates (thiodicarb or methomyl) was significantly higher than that of organophosphates, pyrethroids and newer chemistry insecticides. The pairwise correlation coefficients of LC₅₀ values indicated that the newer chemistry insecticides and old generation insecticides will be not significant except abamectin, which was negatively significantly correlated with methomyl. A significant correlation was observed between thiodicarb, methomyl, and deltamethrin, whereas resistance to bifenthrin showed no correlations with resistance to other insecticides except deltamethrin. The results are discussed in relation to integrated pest management for *S. litura* with special reference to management of field evolved resistance to insecticides.

Jeughale and Bhalkare (2015) carried out studies to evaluate resistance in the population of *Spodopteralitura* Fab. (Lepidoptera, Noctuidae) from eight districts of Vidarbha region in India to indoxacarb from 2011-2013. For indoxacarb, resistance ratio compared with a susceptible strain will be in range of 2.66 to 6.14 fold. However, relatively low level of resistance to indoxacarb was observed in all eight populations.

The LC values of emamectin benzoate, novaluron, pyridalyl, flubendiamide, chlorantraniliprole, chlorpyrifos and thiodicarb against third instar larvae of *S. litura* by topical application techniques were 0.0001, 0.0020, 0.0037, 0.0040, 0.0044, 0.0390 and 0.0410%, respectively. On the basis of LC value, the order of toxicity of different insecticides was emamectin benzoate > novaluron > pyridalyl > flubendiamide > chlorantraniliprole > chlorpyrifos > thiodicarb with relative toxicity of 390.0, 19.50, 10.54, 9.75, 8.86, 1.00 and 0.95, respectively (**Dhawan et al., 2007**).

Ramanagouda and Srivastava (2009) determined the bioefficacy of five insecticides against 7d old larvae of *S. litura* by contact and leaf dip methods. Indoxacarb was the most toxic insecticide at 24h exposure, the value being 7.0ppm (LC₃₀), 15ppm (LC₅₀) and 126ppm (LC₉₀) and imidacloprid was the least toxic with 281, 572 and 3313 ppm at respective LC levels. The order of toxicity by residue contact bioassay method at LC₅₀ was indoxacarb > methomyl > thiamethoxam > fipronil > imidacloprid. In leaf dip method also at 24h after exposure, indoxacarb was the most toxic insecticide (LC₃₀ = 1.0, LC₅₀ = 2.0 and LC₉₀ = 13ppm) and imidacloprid was the least toxic (LC₃₀ = 2186,

LC₅₀ = 3719 and LC₉₀ = 10377ppm). The order of toxicity at all the three LC levels was indoxacarb > methomyl > fipronil > thiamethoxam > imidacloprid.

An investigation was undertaken to determine the toxicity of indoxacarb and imidacloprid by leaf dip method against 8d old larvae of *S. litura*. At 24h after exposure, at all the levels, indoxacarb was more toxic insecticide (LC₃₀ = 1.1, LC₅₀ = 2.2 and LC₉₀ = 10 ppm) than imidacloprid (LC₃₀ = 1825, LC₅₀ = 3643 and LC₉₀ = 19962 ppm). The order of toxicity at all the three LC levels and at different time intervals was indoxacarb > imidacloprid (**Sharma, 2011**).

The stomach toxicity of indoxacarb, cypermethrin, alphamethrin and profenophos against 8 d old larvae of *S. litura* by leaf dip bioassay method was determined by **Pal (2012)**. The order of toxicity at 48 h LC₅₀ level was: profenophos (0.025%) > alphamethrin (0.031%) > cypermethrin (0.038%).

Effectiveness of emamectin benzoate, lufenuron, chlorpyrifos and cypermethrin against field populations of 2nd instar larvae of *S. exigua* was tested by **Saeed et al (2012)** by leaf dip method. Emamectin benzoate gave the lowest LC₅₀ value, 0.005 mg/l (95% FL: 0.004-0.007 mg/l) followed by lufenuron, 0.65 mg/l (95% FL: 0.38-0.93 mg/l). While there was a non significant difference in the LC₅₀ values of cypermethrin and chlorpyrifos, 146 mg/l (95% FL: 108-188 mg/l) and 175 mg/l (95% FL: 113-256 mg/l), respectively. The order of effectiveness in terms of LT₅₀ values was; cypermethrin > chlorpyrifos > emamectin benzoate > lufenuron.

Bhatnagar et al. (2013) have reported that the relative toxicity ratio (RTR) of novel molecules at LC₅₀ value in comparison to cartap hydrochloride against *S. litura* at 24 and 48h were: spinosad (4.77, 9.9) > fipronil (1.59, 3), and at 72 h the values were spinosad (10.14) and fipronil (2.54). LC₅₀ values of cartap hydrochloride, fipronil and spinosad, were 0.44% and 0.126%; 0.0418% and 0.079%; 0.004% and 0.0264% respectively at 24 h.

The bioassay studies with alphamethrin, endosulfan, flubendiamide, indoxacarb and novaluron and biopesticides like emamectin benzoate and spinosad against third instar larvae of *S.litura* by leaf dip method and topical application using Potter's tower revealed that emamectin benzoate was highly toxic to third instar larvae with LC₅₀ of

4.23 x10⁻⁶ % by leaf dip and 2.24 x 10⁻³ % by topical application. The relative toxicity of emamectin benzoate, indoxacarb, spinosad, alphamethrin, novaluron and flubendiamide were 4554.05, 765.08, 2.99, 2.25, 1.95 and 1.83 by leaf dip method, while by topical application, emamectin benzoate, indoxacarb, alphamethrin, novaluron and spinosad, were 34.52, 11.20, 4.17, 2.29 and 1.50 times, respectively more toxic than endosulfan. The larvae were highly susceptible to emamectin benzoate and indoxacarb when tested by leaf dip and topical application methods (**Sharma and Pathania, 2015**).

The relative toxicity study of six insecticides to third instar larvae of *S. obliqua* by **Nair et al. (2007)** revealed that on the basis of LC₅₀ values (% ai), the descending order of toxicity was: emamectin benzoate 5 SG (0.00005), cypermethrin 10 AF (0.00013), indoxacarb 14.5 SC (0.00053), endosulfan 35 EC (0.00323), fenvalerate 20 EC (0.00340) and fenprothrin 30 EC (0.00513).

The order of toxicity, on the basis of LC₅₀ has been reported by **Karuppaiah and Srivastava (2013)** as chlorantraniliprole > emamectin benzoate > indoxacarb > spinosad > pyridalyl > flubendiamide > bifenthrin > koranda and > polytrinC with the relative toxicity of 37.75, 37.75, 3.28, 1.91, 1.61, 1.24, 1, 0.83, 0.68 by direct spray method; and by leaf dip method chlorantraniliprole (0.0001) was most effective followed by emamectin benzoate (0.0002) and indoxacarb (0.0012). The order of relative toxicity was 203, 101, 16.9, 2.86, 1.97, 1.83, 1.6, and 1.4 for chlorantraniliprole, emamectin benzoate, indoxacarb, spinosad, koranda, pyridalyl, polytrin C and flubendiamide, respectively.

The results of baseline susceptibility of *S. litura* by topical application method revealed that field population exhibited lower susceptibility to spinosad, emamectin benzoate, indoxacarb and lufenuron as evidenced by higher LD₅₀ values of 0.2485, 0.0425, 0.0223 and 0.0198 µg a.i./larva, respectively in comparison of susceptible population (0.0262, 0.0120, 0.0045 and 0.0031 µg a.i./larva). Field population of *S. litura* was 9.48, 6.39, 4.96 and 3.54-fold resistant to spinosad, lufenuron, indoxacarb and emamectin benzoate, respectively. Lufenuron, indoxacarb and emamectin benzoate were more toxic than spinosad (**Patil et al., 2015**).

Kuldeep and Shri Ram (2004) have observed the lowest LC₅₀ of 15.46 ppm for 0 to 24 h old larvae of *S. litura*, while for 6 day old larvae it was 42.17 ppm. LT values ranged from 341.5 to 149.0 h and 321.7 to 138.2 h for 0 to 24h old and 6 day old larvae of *S. litura*, respectively.

On the basis of LC₅₀ values against *S. obliqua*, Virat, Bulldockstar, Anaconda, Polytrin C, Ducord, Nurelle D, Spark, Nagata and Spectrum were 5.36, 5.88, 5.04, 3.40, 3.23, 2.74, 1.68, 1.62 and 1.13 times more toxic than Super D. Koranda was 0.87 times less toxic than Super D when evaluated by direct spray method. A comparison of the relative resistance based on LC₅₀ values of *S. obliqua*, *S. litura* and *Helicoverpa armigera* to various insecticide mixtures indicated that *H. armigera* was relatively resistant amongst these three pests (**Dhingra et al., 2007**).

The investigation on lethal and sub lethal effects of diflubenzuron (Diflubenzuron 25WP) and lufenuron (Match 5EC) against neonates of *S. obliqua* on artificial diet fortified with eight levels of diflubenzuron and lufenuron indicated diflubenzuron complete larval mortality in diflubenzuron at 1 and 2 ppm on sixth day and at 0.8, 0.4, 0.2 and 0.1 ppm on eighth day. All larvae failed to reach pupal stage at 0.05 ppm while only 26.7% pupation and 10% adult emergence was noticed at 0.025 ppm. All adults emerged were deformed on diflubenzuron treated diets. Lufenuron caused complete larval mortality at 0.53 to 12.5 ppm on fortified diets on eighth day. At 0.26 ppm of lufenuron, the larvae could not reach to pupal stage. Only 46.7% pupation occurred at 0.132 ppm which resulted in 20% adult emergence. LC₅₀ for diflubenzuron and lufenuron were 0.024 and 0.143 ppm, while LT₅₀ ranged from 220.9 to 544 h and 228.3 to 577.8 h, respectively (**Gupta and Bhattacharya, 2008 a**).

Chilana (2009) assayed novel molecules using 'leaf dip', Potter's spray tower, topical microapplicator and thin film methods against 7 day old larvae of *S. litura* and *S. obliqua* and reported that emamectin benzoate and indoxacarb were most effective by all assay techniques. Among all the bioassay techniques, leaf dip method was adjusted the best. Emamectin benzoate and indoxacarb depicted 124 to 7223.8 and 16 to 1911.1 fold effectiveness (relative toxicity at LC₉₀) than endosulfan. The toxicity response with synthetic pyrethroids was the best under Potter's spray tower and deltamethrin showed very low values of LC₅₀ 0.0061, 0.0032 and 0.0028 % at 24, 48 and 72 h respectively to *S. litura*, however at 48 h bifenthrin was found 147 times more toxic than endosulfan to *S. obliqua*.

2.4 To study the field efficacy and economics of major insecticides against tobacco caterpillar *Spodoptera litura* on Soybean

Tests on the control of *S. litura* (Fab.) carried out in 1975-76 and 1976-77 with 11 insecticides indicated that all the compounds were effective in reducing the pest numbers, with no significant difference between them after 72 h, but fenvalerate 0.02%, chlorpyrifos 0.04% and leptophos 0.068% gave more rapid kill of the larvae than the other compounds (**Patel and Chari, 1980**).

Relative susceptibility of lambda-cyhalothrin, decamethrin [deltamethrin], cypermethrin, bifenthrin, Bulldock [beta-cyfluthrin] and fenvalerate, and chlorpyrifos, malathion, endosulfan and lindane against 2nd instar larvae of *S. litura* was determined by **Singh and Singh (1997)**. It was concluded that lambda-cyhalothrin was the most effective and lindane was the least effective insecticide.

The toxicity of ethofenprox [etofenprox] was compared with beta-cyfluthrin, bifenthrin, alpha -cypermethrin, deltamethrin, lambda -cyhalothrin, cypermethrin, and fenvalerate against *S. litura*. Compared with cypermethrin (set at 1.0), the most toxic was beta-cyfluthrin (29.5), followed by etofenprox (10.1) while fenvalerate (0.43) was the least toxic. Comparison of LC₅₀ values showed that during 1995-2002 *S. litura* resistance to all the synthetic pyrethroids increased 5.36 (lambda -cyhalothrin) to 12.64 fold (fenvalerate) (**Kodandaram and Dhingra, 2003**).

Ahmad and Saleem (2004) reported that Chlorpyrifos, methomyl, emamectin benzoate and lufenuron proved most effective and gave 100% mortality of 2nd instar larvae of *S. litura* at recommended half and double the recommended field dose. Thiodicarb, spinosad and methoxyfenozide showed 90.8, 87.5 and 81.7% larval mortality, respectively. Minimum mortality was observed for abamectin (45.8%), indoxacarb (50%) and profenofos (36.7%).

Bioefficacy of novaluron (Rimon 10 EC) against *S. litura* attacking cotton was compared with chlorpyrifos, thiodicarb, spinosad and endosulfan by **Saini et al. (2010)**, in the laboratory and at farmers' fields. The results indicated that in the laboratory though initial mortality in novaluron at 0.005 and 0.01 per cent concentration was low, yet the larvae stopped feeding within two days and gradually all larvae were dead when observed after nine days of treatment. Spinosad (Tracer 45 SC) 0.015 per cent had no

toxicity against this pest. Under field conditions, novaluron at 37.5 and 50 g a.i./ha was as good as thiodicarb (Larvin 75 WP) at 470 g a. i./ha after seven days of spray.

Thirteen insecticides were evaluated by **Saini et al. (2005)** against *S. litura* and it was concluded that thiodicarb (Larvin 75 WP) (0.075%) was the best insecticide giving 100% kill of the larvae within 24 h when untreated larvae were offered treated leaves. When both larvae and leaves were treated, thiodicarb provided complete kill of the larvae within 48 h even at lower concentration (0.037%). The next promising insecticides were chlorpyrifos 20 EC (0.06%), endosulfan 35 EC (0.11%), indoxacarb 15 EC (0.03%) and profenofos 50 EC (0.15%) giving 90.0, 76.7, 73.3 and 73.3% larval mortality, respectively, within 72 h when treated leaves were provided to the treated larvae. Spinosad (Tracer 45 SC) (0.014 and 0.018%), cypermethrin (0.01, 0.02 and 0.03%), deltamethrin (0.003, 0.006 and 0.008%) and neem (Fortune Aza 0.15 EC) (0.00075%) had poor activity against this pest.

Reddy et al. (2005) evaluated certain newer and safer insecticides, with *Bt* against *S. litura* on sunflower as foliar sprays and reported that indoxacarb + lufenuron and indoxacarb + *Bt* recorded the highest values for overall mean efficacy (69.9 and 68.1%, respectively) and yields (1656 and 1600 kg/ha, respectively). The use of insecticides at lower doses in combination with *Bt* was more effective in controlling the pest and increasing sunflower yield compared with individual insecticide sprays at higher doses.

ShuiJin et al. (2006) proposed that for control of *S. litura* in Nanjing, Jiangsu and Hexian, Anhui, Province, China, pyrethroid insecticides should be prohibited, use of OPs and carbamates should be limited, and the other insecticides with no resistance, e.g., monosultap, abamectin, hexaflumuron and fipronil, should be used rationally and in rotation to delay resistance development.

Pineda et al. (2007) concluded that the combination of lethal and sublethal effects of methoxyfenozide and spinosad might exhibit significant effects on the population dynamics of *S. littoralis*.

Sammour et al. (2008) have reported that chlorfluazuron and lufenuron significantly decreased the pupal weight, percent pupation, longevity, mating frequency and fecundity in *S. littoralis*.

A chronic feeding experiment conducted against 8d old larvae of *S. litura* with sub lethal doses of four insecticides *viz.*, indoxacarb (0.0001%), methomyl (0.017%), imidacloprid (0.2%) and thiamethoxam (0.1%) revealed that the larvae consumed less food when leaves treated with tested insecticides were offered as food as compared to untreated. The consumption was reduced by 20.90, 19.23, 17.60 and 14.53% at LC₃₀ of indoxacarb, methomyl, imidacloprid and thiamethoxam, respectively over control. Sublethal dose of these insecticides were effective in delaying the development of *S. litura* and extended the developmental parameters significantly (**Basera, 2009**).

Various insecticides belonging to SP, OP and biorational were evaluated by two bioassay techniques (direct spray and leaf dip) against third instar larvae of *S. litura* by **Kodandaram et al. (2009)**. Betacyfluthrin was found to be most toxic and ethion least toxic to *S. litura*. Regardless of method of application relative efficacy of most of the synthetic pyrethroids was same except betacyfluthrin and alphamethrin. The effectiveness of indoxacarb followed by chlorpyrifos, acephate, quinalphos and spinosad was more by leaf dip method than direct spray.

Studies were carried out to monitor the level of esterase activity at different age intervals of *S. litura* and to determine the relative susceptibility of seven day old larvae against six different synthetic insecticides. The activity slightly increased from 2nd to 4th day *i.e.* 0.120- 0.158 moles /mg /min. and from the 5th day, there was drastic increase. Indoxacarb followed by emamectin benzoate was the most effective. The data on relative toxicity to cypermethrin showed that except fenvalerate all other insecticides *viz.*, lambda cyhalothrin, profenophos, indoxacarb and emamectin benzoate were 1.21, 2.45, 7.20 and 2.87 fold toxic to *S. litura*, respectively (**Shankarganesh et al., 2009**).

Hardke et al. (2011) evaluated 4 recently developed insecticides (chlorantraniliprole, cyantraniliprole, flubendiamide, and spinetoram) and 5 commercial standards (indoxacarb, lambda-cyhalothrin, methoxyfenozide, novaluron, and spinosad). In diet-incorporated assays, the LC₅₀ values of chlorantraniliprole and spinetoram were significantly lower than the LC_{50s} of all other insecticides against fall armyworm. The results indicate that newer insecticides are equal to or more efficacious against fall armyworm than traditional insecticides.

The bioefficacy studies conducted by **Khan et al. (2011)** against *S. litura* indicated that chlorpyrifos, profenofos, emamectin benzoate, spinosad, indoxacarb, methoxyfenozide and lufenuron proved highly toxic with extended exposure time. After 3 days of the insecticide treatment, 100% mortality was observed in emamectin benzoate @ 100 and 110 ml, followed by chlorpyrifos @ 1100 ml (96.56%), lufenuron @ 55 ml (86.67%) and methomyl @ 440 ml/acre (83.34%).

An experiment conducted by **Pandey (2011)** to examine the stomach toxicity of three insecticides against 7 d old larvae of *S. litura* by leaf dip method reflected the order of toxicity at 24h LC₅₀ level as: profenofos (1738ppm) > triazophos (2618ppm) > imidacloprid (4373 ppm). In another study, the three insecticides profenofos, deltamethrin and λ - cyhalothrin showed almost similar values of LC₅₀ (1000ppm).

Rehan et al. (2011) recorded the LC₅₀ data through diet incorporation method against *S. litura* as emamectin benzoate (1.59 ppm), spinosad (7.77 ppm), profenofos (686.5 ppm) and imidacloprid (258.75 ppm) at generation 1. The decrease in the LC₅₀ values after 11 generations as compared to the field population of *S. litura* was 4.81, 9.83, 9.3 and 13.82 folds against emamectin benzoate, spinosad, imidacloprid and profenofos, respectively. The estimated decrease in resistance was 11.36, 11.11, 16.67 and 9.61 for imidacloprid, spinosad, emamectin benzoate and profenofos, respectively.

Ragai and Sabry (2011) opined that the biorational insecticides spinosad and buprofezin can be used for the control of *S. littoralis* in a combination.

In Brazil the IGR lufenuron (Match EC - 0.3 L/ha⁻¹) showed higher efficiency on the control of fall armyworm *S. frugiperda* and lower deleterious effects on the populations of natural enemies when compared to chlorpyrifos (Fersol 480 EC - 0.6 L/ha⁻¹). Besides spiders and the predator *Doru luteipes*, the observed parasitoid species of the caterpillar were *Chelonus sp.*, *Campoletis sp.* and *Euplectrus sp.* (**Toscano et al., 2012**).

The LC₅₀ of deltamethrin, bifenthrin, emamectin benzoate, chlorfluazuron and flubendiamide against second instar larvae of *S. litura*, were 619 and 100, 74.2 and 65.8, 0.08 and 0.06, 73.4 and 52.5, and 0.37 and 0.31 ul/ml, respectively after 48 and 72 hour of exposure by leaf dip method. Pyrethroids were least effective as compared

to new chemistry insecticides, and emamectin and flubendiamide were more toxic than chlorfluazuron.

Tong et al. (2013) evaluated resistance in the populations of *S. litura* from five districts of Hunan Province in China and observed relative low levels of resistance to emamectin, indoxacarb, and chlorfenapyr. In contrast, the resistance to carbamates (thiodicarb or methomyl) was significantly higher than that of organophosphates 14–229 fold, pyrethroids 12–227 fold and newer chemistry insecticides.

Wang et al. (2013) found the LC₅₀ values of spinosad by oral exposure of late second-instar larvae to *S. exigua* at 48 and 72 h after treatment as 0.317 and 0.293 mg kg⁻¹, respectively. Spinosad at sublethal concentrations significantly extended the developmental period of survivor larvae, and reduced larval net weight. Post exposure effects were indicated by decreased pupation ratio and pupal weight, by prolonged prepupal and pupal periods and by decreased emergence ratio, fecundity and longevity of adults. The combination of lethal and sublethal effects of spinosad affected *S. exigua* population dynamics significantly by decreasing its survival and reproduction, and by delaying its development.

Narayanamma and Reddy (2014) conducted a field experiment against *Achaea janata* L., *S. litura* and *Conogethes punctiferalis* Guen and observed that chlorantraniliprole (1.64 and 1.01 larvae/plant), spinosad (1.92 and 0.92 larvae/plant) and flubendiamide (2.56 and 1.25 larvae/plant) were significantly superior for *Spodoptera* and castor semilooper, respectively at one day after spraying during the first spray. The treatments flubendiamide (1: 5.8), spinosad (1: 5.6) and chlorantraniliprole (1: 5.3) registered the highest cost benefit ratio.

Bio-efficacy studies showed that flubendiamide 480 SC @ 48 and 60 g a.i ha⁻¹ against the pod borer *S. litura* and spirotetramate 150 OD @ 60 g a.i ha⁻¹ followed by acephate 75% SP @ 468.75 g a.i ha⁻¹ and metasystox 25% EC @ 187.5 g a.i ha⁻¹ against the thrips *Scirtothrips dorsalis* were the best treatments. None of the treatments showed any phytotoxicity on chilli crop (**Reddy et al., 2014**).

The toxicity results against first and third instar larvae of *S. litura* by leaf dip method by **Sharma and Pathania (2014)** at HPKVV, Palampur indicated the LC₅₀ value of emamectin benzoate as 6.80 x 10⁻⁷ % and 4.23 x 10⁻⁶ %, respectively. The

relative toxicity to first instar indicated that emamectin benzoate, indoxacarb, spinosad, flubendiamide, alphamethrin and novaluron were 15300, 3570, 6.44, 4.16, 4.10 and 2.43 times, respectively more toxic than endosulfan. Almost similar trend was observed against third instar. The studies indicated that emamectin benzoate and indoxacarb were most toxic to *S. litura* larvae.

Bhatt et al. (2015) evaluated newer molecules against *S. litura* infesting *bidi* tobacco nursery. The results indicated that the lowest percent damage registered by flubendiamide was at par with emamectin benzoate, chlorantraniliprole and chlorpyrifos. Ninety percent mortality of *S.litura* was recorded with emamectin benzoate @ 11g a.i./ha in tobacco nursery.

The bioassay study indicated that emamectin benzoate was the most potent against 3rd and 5th larval instars of *S. littoralis* with chronic LC₉₀ values of 0.31 and 0.64 mg ml l⁻¹, respectively. The combined effect of emamectin benzoate and lufenuron or spinosad was either additive or antagonistic; suggesting that single application of these insecticides is more effective than in combination. In comparison to lufenuron and spinosad, emamectin benzoate killed both 3rd and 5th instars of *S. littoralis* significantly faster. These findings suggest that emamectin benzoate is an effective compound compared with lufenuron and spinosad for control of *S. littoralis* (**El-Sayed and EL Sheikh, 2015**).

Krishnaiah et al. (2015) evaluated imidacloprid-0.3ml/l; dimethoate-2ml/l; monocrotophos-1.6ml/l; emamectin benzoate-0.1g/l; thiodicarb-1g/l; chlorfenapyr-2ml/l and flibendiamide-0.1ml/l against *S. litura* and thrips on groundnut during *rabi* season. Chlorfenapyr toxicity was highest to *S.litura* larvae (87 to 90%) whereas thiodicarb, emamectin benzoate and flubendiamide reduced the population by >70% over control. Monocrotophos was moderately toxic and dimethoate and imidacloprid were poor in managing the pest.

Field efficacy of Alika (33, 27.5 and 22g a.i./ha), imidacloprid (20g a.i./ha), lambda-cyhalothrin (15g a.i./ha), ethion (750g a.i./ha) and thiamethoxam (25g a.i./ha) on soybean crop was evaluated against *S. obliqua* at Pantnagar by **Chand (2012)**. Ten days after spray Alika @33g a.i./ha and imidacloprid @20g a.i./ha provided cent per cent control followed by Alika @ 27.5g a.i./ha having 0.33larvae/ mrl (meter row length).



*Materials
and
Methods*



Pantnagar is situated at the foothills of Himalayas at an altitude of 243.84 meter above the mean sea level (MSL), 29°N latitude and 79.3°E longitude. The annual rainfall is about 1574.3 mm, which has a lot of variation throughout the year. The temperature variation is very large, as summer holding temperature maximum of around 40-44°C while in winter season it falls heavily to 0-9°C.

3.1 To ascertain the status and incidence of insect pests of soybean and their natural enemies in major districts of Uttarakhand

A roving survey was undertaken to know the status of insect pests of soybean in soybean ecosystem of major districts of Uttarakhand like Udham Singh Nagar, Nainital, Almora, Champawat, Pithoragarh, Pauri, New Tehri, Uttarakashi and Roorkee as detailed in Table 1.

3.1.1 Leaf eating caterpillars

Observations on larval population of leaf eating caterpillar, *S. litura* and semiloopers were made at three randomly selected spots of one meter row in each treatment leaving border rows. Larval counts were made by shaking the plants gently over a white cloth placed between the rows. Average number of caterpillars found per meter row length (mrl) was worked out.

3.1.2 Stem fly and girdle beetle

To study the incidence of pests of soybean, roving survey was carried out in different locations of each district. In each location five fields/villages were surveyed. Survey was undertaken at flowering and harvesting stage observations were made on 10 randomly selected plants from each field during flowering and harvesting. The plants were dissected to observe the stem fly infestation, stem tunneling and extent of tunneling, later they were converted to percentage by the following formula.

Table 3.1: Location selected for survey of insect pests of soybean in Uttarakhand during 2016-17

Sl. No.	Districts	Villages	Longitude	Lattitude
01	Udham Singh Nagar	Pantnagar	29°1'15.74"N,	79°29'23.06"E
		Pantnagar	29°1'15.74"N,	79°29'23.06"E
		Sirsa	29.5336° N,	75.0177° E
		Darau	28.8720° N,	79.4451° E
		Kashipur	29.2104° N,	78.9619° E
		Gadarpur	29.0397° N,	79.2504° E
		Dineshpur	29.0462° N,	79.3212° E
02	Nainital	Haldwani	29.2183° N,	79.5130° E
		Kaladungi	29.2854° N,	79.3480° E
		Ramnagar	29.3948° N,	79.1265° E
		Bhimtal	29.3461° N,	79.5519° E
		Nawagaon	30.7227° N,	78.2804° E
03	Almora	Khairna	29.4945° N,	79.4802° E
		Majera	29.6428° N,	79.6327° E
		Hawalbagh	29.6428° N,	79.6327° E
		Matela	29.7960° N,	79.1933° E
		Dwarahat	29.7760° N,	79.4268° E
		Ranikhet	29.6434° N,	79.4322° E
04	Champawat	Majkhali	29.6792° N,	79.5133° E
		Tanakpur	29.0722° N,	80.1066° E
		Banbasa	28.9911° N,	80.0800° E
		Champawat	29.3209° N,	80.0088° E
		Lohaghat	29.4042° N,	80.0842° E
		Ghat		
05	Pittoragarh	Barakot	29.4679° N,	80.0717° E
		Gaina	29.5697° N,	80.3227° E
		Chandak	29.5965° N,	80.1917° E
		Gurna	29.5283° N,	80.1617° E
		Aicholi		
06	Pauri Gharwal	Pittoragarh	29.5829° N,	80.2182° E
		Kotdwara	29.7524° N,	78.5269° E
		Dogadda	29.8070° N,	78.6094° E
		Ghumkal	29.8925° N,	78.6701° E
		Satpuli	29.9170° N,	78.7101° E
		Pauri	30.1471° N,	78.7745° E
07	Tehri Garhwal	Srinagar	30.2247° N,	78.7986° E
		Chamba	30.3455° N,	78.3947° E
		Ranichauri	30.3111° N,	78.4097° E
		Maletha		
		Jamnikhali	30.2723° N,	78.6101° E
		Fakot	30.2273° N,	78.3508° E
08	Uttarakashi	Tipri	30.3722° N,	78.5008° E
		Chilyanisaur	30.5840° N,	78.3150° E
		Dhanpur	30.5979° N,	78.3181° E
		Nagni	30.5873° N,	78.3227° E
09	Haridwar	Dharasu	30.6101° N,	78.3202° E
		Roorkee	29.8543° N,	77.8880° E
		Podwali		
		Sultanpur	29.7561° N,	78.1055° E
		Laksar	29.7538° N,	78.0215° E

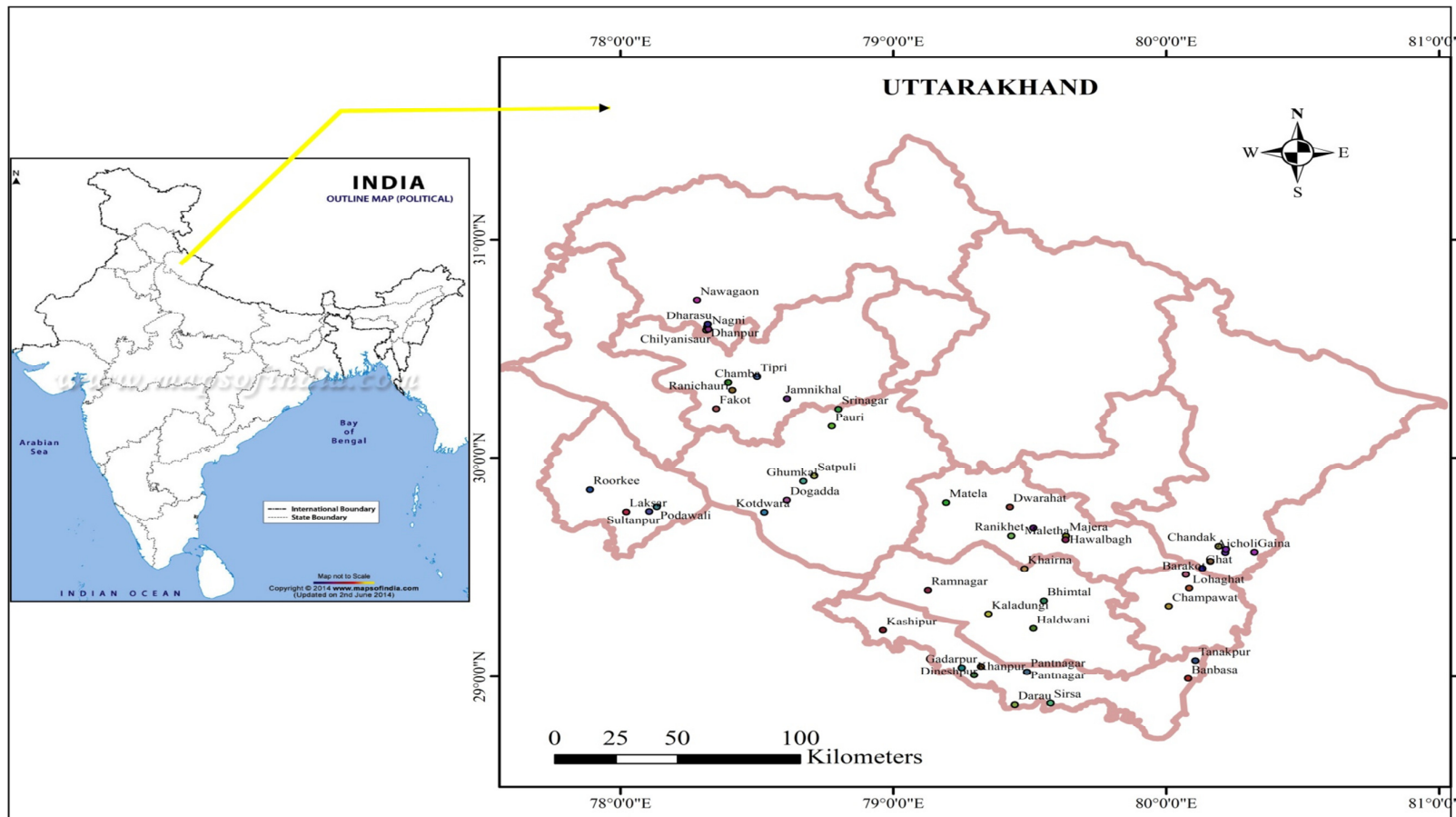


Fig. 3.1 : Sampling locations of *Spodoptera litura* (Fab.) field populations of different districts of Uttarakhand

$$\text{Per cent stem fly infestation} = \frac{\text{No. of plants affected}}{\text{Total number of observed plants}} \times 100$$

For recording the damage of the girdle beetle damage following formula was used

$$\text{Girdle beetle infestation} = \frac{\text{Number of plants with girdle beetle damage}}{\text{Total number of plants observed}} \times 100$$

3.1.3 Natural enemies

Observations on the incidence of predators (coccinellids, spiders and Eucantheaona bugs) were recorded at three randomly selected spots of one meter row in each treatment leaving border rows was taken.

3.2 Comparative study of soybean and other host based artificial diets on growth and development of *S. litura*

Present study was carried out during 2016- 2017 in the Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar.

3.2.1 Preparation of diets

The egg mass and larva of *S. litura* collected from the infested vegetable fields of various experimental locations were used for mass rearing on artificial diet. Initially, the diet recipe given by **Saljoqi et al. (2015)** was followed with few modifications (Diet 1). An up gradation for this diet has been made by adding dried soybean, castor, blackgram leaf powders and agar (diet-2, 3, 4, 5) to increase the similarity in composition to natural diet and to increase the palatability for *S. litura*. Ingredients include chickpea flour, yeast powder, ascorbic acid, sorbic acid, formaldehyde solution, agar and other chemicals listed in Table-2 and 1000ml distilled water. All the dry and wet ingredients of the diet were weighed/ measured carefully, and kept in separate containers. Half of the total water was taken in a steel vessel, brought to boil and agar was added. The total quantity of gram flour was added to the boiling agar. Remaining water was poured and stirred continuously to reduce the clump formation. Then, all the dry and wet ingredients were added to the mixture and thoroughly homogenized using

blender. The prepared diets were then poured into the sterilized plastic boxes (Plate 1a), and allowed for solidification. Diet was left over for whole night and used next day for feeding to *S. litura*. The diet was cut into small pieces of size 2 x 2 cm (Plate 1b) and introduced to the plastic rearing troughs. The *S. litura* larvae were introduced to the diet piece in the trough. The same procedure was used to rear the larvae using diet-2, 3, 4 and 5 also (Plate-2). Based on good palatability and reduced duration of life stages, the best diet was selected for further rearing of *S. litura*.

Table 3.2: Chemical ingredients of Fraction-A used in artificial diets.

Sl. No	Composition	Quantity
1.	Baking Yeast powder	10g
2.	Methyl Paraben	2.5g
3.	Sorbic acid	1.5g
4.	Ascorbic acid	3.0g
5.	Casein	3.0g
6.	Choline chloride	0.5g
7.	Agar	14g
8.	Niacin	6.0g
9.	Calcium Pantothenate	6.0g
10.	Thiamine	3.0g
11.	Riboflavin	3.0g
12.	Pyridoxin monohydrochloride	1.5g
13.	Folic acid	1.5g
14.	Biotin	120g
15.	Inositol	10g

Table 3.3: Composition of artificial diets for rearing of *S. litura*

Chickpea flour based artificial diet (Diet-I)	Soybean leaves based artificial diet (Diet-II)	Castor leaves based artificial diet (Diet-III)	Black gram leaves based artificial diet (Diet-IV)	Agar based artificial diet (Diet-V)
Chickpea flour-150g	Soybean leaves-150g	Castor leaves-150g	Black gram leaves-150g	Agar-150g
Fraction A	Fraction A	Fraction A	Fraction A	Fraction A
1litre distilled water	1litre distilled water	1litre distilled water	1litre distilled water	1litre distilled water

3.2.2 Rearing procedure of *S. litura*

A colony of *S. litura* was raised from two pairs of adults collected from field at Norman Borlaugh Crop Research Center Pantnagar, and was transferred to the laboratory. Each pair was kept in a separate glass jars with a nappy liners pasted at the walls of jars for egg laying. The mouth of jar was kept closed with a muslin cloth. The adults were fed on a piece of cotton soaked in honey solution. The eggs laid were collected and kept in Petri dishes for hatching. As the larvae emerged, they were reared on the 5 diets (Table 3) *i.e.*, chickpea based diet (Diet-1), soybean based diet (Diet-2), Castor based diet (Diet-3), black gram based diet (Diet-4) and agar based diet (Diet-5) for testing the effectiveness of the diets.

3.2.3 Culture maintenance of *S. litura*

To maintain the culture the larvae of *S. litura* were regularly fed on the prepared diets and the adult stages were fed with honey solution for the timely availability for studying its different biological parameters.

The data on time taken to complete different life stages of *S. litura* reared on artificial and natural diet were compared and documented. Larval growth index and total developmental index were calculated based on per cent pupation and per cent survival respectively using the formulae (Gupta *et al.*, 2005) mentioned below to evaluate the effect of diet on growth and development of *S. litura*. Larval growth index = % Pupation / Larval Period (days). Total developmental index = % Survival / Total Developmental Period (days).

3.2.4 Statistical analysis

Design followed was completely randomized design (factorial). Pooled data obtained from three generations was subjected data analysis by using OP Stats software.

3.3 Study of field resistance of tobacco caterpillar *Spodoptera litura* to collected from different districts of Uttarakhand state

3.3.1 Collection of *S. litura*

A roving survey was undertaken to collect the tobacco caterpillar *S. litura* of soybean in soybean ecosystem of major districts of Uttarakhand like Udham Singh Nagar, Nainital, Almora, Champawat, Pithoragarh, Pauri, New Tehri, Uttarakashi and Roorkee as detailed in Table 1

3.3.2 Culturing of the *S. litura*

A laboratory susceptible strain of *S. litura* obtained by single pair crosses of a field – collected population of *S. litura* and reared in the laboratory for 3-4 generations without exposure to insecticides. For bioassay different populations of *S. litura* at fourth or fifth- instar larvae were collected from the field crops grown in different locations of Uttarakhand state from 2017. The details of locations have been presented in Table A and depicted in Fig. A. The larvae collected were reared on semi-synthetic diet (**Ahmad et al., 2008**) in the laboratory at (Temp: 25± 2°C, RH: 75 ± 5 % and photo period of 13 hrs light: 11 hrs darkness), in glass jars for two generations before the bioassay was carried out. Diet was replaced after 24 h and pupae were collected on alternate days. Moths were also be shifted to glass cages with mesh sides for ventilation and fed on a solution containing 10 per cent honey soaked onto cotton wool ball (**Ahmad et al., 2007b**). The neonate larvae were fed with semi-synthetic diet. The field collected populations were reared in the laboratory to accommodate to laboratory conditions and to obtain sufficient insect numbers for bioassay.

3.3.3 Test insecticides

The insecticides viz., Chlorotrilineprole, indoxacarb, lambda cyhalothrin, spinosad, dichloroas, emamectin benzoate, imidachlopride, flubendiamide and lufenuron were purchased from the open market.

3.3.4 Preparation of insecticide solution

The insecticide solutions were prepared using the above commercial formulation which was diluted with distilled water. Fresh solution was prepared as and when required.

3.3.5 Bioassays

Bioassay was conducted with newly third-instar larvae of *S. litura* using a standard leaf disk method (Ahmad *et al.*, 2007b). Serial dilutions of the test compounds were prepared. Soybean leaves were cut into small 5 sq. cm. leaf disc and dipped into the insecticide solution for 10 s. These leaves were air dried at ambient temperature for 5-10 min by spreading on a towel paper. Leaves were dipped in sterile distilled water only to use as controls. Leaves treated with insecticides were then transferred to each Petri dish lined with moistened filter paper. At least five concentrations and three replications (10 larvae per replication) will be used to estimate each concentration mortality line thus total numbers of tested larvae per concentration will be 30. The bioassays will be kept at a temperature of $25 \pm 2^\circ\text{C}$ and 75 ± 5 per cent relative humidity, and photoperiod of 13:11 (light:dark). Mortality data will be scored 24 hours till 76 hours after exposure for insecticides. Larvae will be considered dead if they failed to make a co-ordinated movement when prodded with a brush.

3.3.6 Statistical analysis

- (i) The observations recorded on mortality were corrected using Abbott's formula (Abbott, 1925) as given under-

$$\text{Abbott's corrected mortality (\%)} = \frac{T - C}{100 - C} \times 100$$

Where, T = mortality in Treatments (%)

C = mortality in Control (%)

- (ii) The data so obtained was subjected to probit analysis for obtaining regression equation and computing LC/ LD values following Finney (1971). LC values were computed using probit analysis based computer programme STPR718 at the Computer Center, College of Basic Science and Humanities of this University.
- (iii) Resistance ratios (RRs) will be determined as LC50 values of field strain/ LC50 values of susceptible strain.

3.4 To study the field efficacy and economics major insecticides against tobacco caterpillar *S. litura* on soybean.

The details of the experiment are as under...

- 1) **Location** : Crop Research Centre College of Agriculture, GBPUA & T, Pantnagar
- 2) **Design** : Randomized Block Design
- 3) **Replication** : Three (3)
- 4) **Treatments** : Ten (10)
- 5) **Crop, Variety** : JS-335
- 6) **Plot size**
 - a. **(a) Gross (area)** : 5m x 5m
 - b. **(b) Net (area)** : 3.5m x 3.5m
- 7) **Spacing** : 75cm x 45cm
- 8) **Seasons** : *Kharif*, 2016 and 2017.
- 9) **Details of treatments** : As per table 4.

3.4.1 Methodology

The spraying of all insecticides was carried out with the help of knapsack sprayer. The spray solution required for uniform coverage was estimated by spraying known quantity of water before spray and then insecticides were mixed thoroughly in water. The care was taken to obtain uniform coverage of insecticides on each plant. First spray of insecticides was applied at initiation of pest infestation and second spray was repeated after of 15 day of first spray. Observations on number of larvae was recorded prior and first, third and fifth days after spraying from 5 randomly selected plants from each quadrat (1 m x 1 m). In case of dead larvae eating is stopped and larvae become darkish in colour is considered as dead. The data recorded on population was converted to per cent mortality by using the formula of **Henderson and Tilton (1955)**.

$$\text{Corrected per cent mortality} = 100 \times \left(1 - \frac{Ta \times Cb}{Tb \times Ca} \right)$$

Where,

T_a = Number of insect pest recorded after treatment

T_b = Number of insect pest recorded before treatment

C_a = Number of insect pest recorded from check plot after treatment

C_b = Number of insect pest recorded from check plot before treatment

The fruit yield obtained from each net plot of treatments was converted on hectare basis and subjected to statistical analysis. The per cent increase in yield over control was calculated by using following formula:

$$\text{Yield increase over control} = \frac{T-C}{C} \times 100$$

Where, T = Yield of respective treatment (kg/ha)

C = Yield of control (kg/ha)

3.4.2 Yield and economics

Soybean was harvested from the plot area completely in a single day. Healthy and damaged or under developed seeds was recorded and weighed separately during each harvesting. The yield per hectare was calculated for each treatment and data was subjected to statistical analysis.

Economics of all the treatments were worked out by considering the price of soybean, cost of insecticides to be used and labour charges for spraying of insecticides. Cost: benefit ratio (CBR) was also worked out to compare the economics of various insecticidal treatments.

$$\text{CBR} = \frac{\text{Net realization over control (Rs/ha)}}{\text{Total cost of insecticide + Labour charges (Rs/ha)}}$$

Table 3.4: Details of the insecticides used to study the field-efficacy against tobacco caterpillar (*S. litura*) on soybean

Tr. No.	Treatment	Dosage	Trade Name	Insecticide Group	Manufacturing Company
T ₁	Chlorantraniliprole 18.5SC	0.20 ml/l	Ranaxypyr	Diamide	Du-Pont, India, Ltd. Gurgaon
T ₂	Indoxacarb 15.8 EC	0.40 ml/l	Avaunt	Oxidiazines	Syngenta Crop Science Ltd, Mumbai
T ₃	Lambda cyhalothrin 5 EC	0.30ml/l	Karate	Synthetic Pyrethroids	Syngenta Crop Science Ltd, Mumbai
T ₄	Spinosad 45SC	0.25 ml/l	Tracer	Spynosyns	De-Nocil Crop Protection Ltd., Mumbai
T ₅	Dichlorvos 46SC	1.5ml/l	Nuvan	Organophosphate	Insecticide India Ltd, New Delhi
T ₆	Emamectin benzoate 5G	0.30 g/l	Proclaim	Semi synthetic analogue of abamectin	Syngenta Crop Science Ltd, Mumbai
T ₇	Imidacloprid 17.5 SC	0.5ml/l	Confidor	Synthetic Pyrethroids	Bayer Crop Science Ltd, Mumbai
T ₈	Flubendiamide 480SC	0.20 ml/l	Fame	Diamides	Bayer Crop Science Ltd, Mumbai
T ₉	Lufenuron 5EC	0.5ml/l	Match	Acylurea Insect Growth Regulators	Syngenta Crop Science Ltd, Mumbai
T ₁₀	Control (Untreated)	-	-	-	-



Defoliation by *S. obliqua*



Defoliation by *S. litura*



Defoliation by *Hispinae spp.*



Ash weevil



Infestation of *O. brevis*



Infestation of *M. sojae*



Natural enemy of *S. litura* (*Eucanthacona spp.*)



Natural enemy of sucking pests
(*Coccinella spp.*)



Natural enemy of sucking pest
(Spiders)

Plate 01. Major insect pests of soybean and their natural enemies



Plate 02. Glimpse of survey on soybean crop in major districts of Uttarakhand

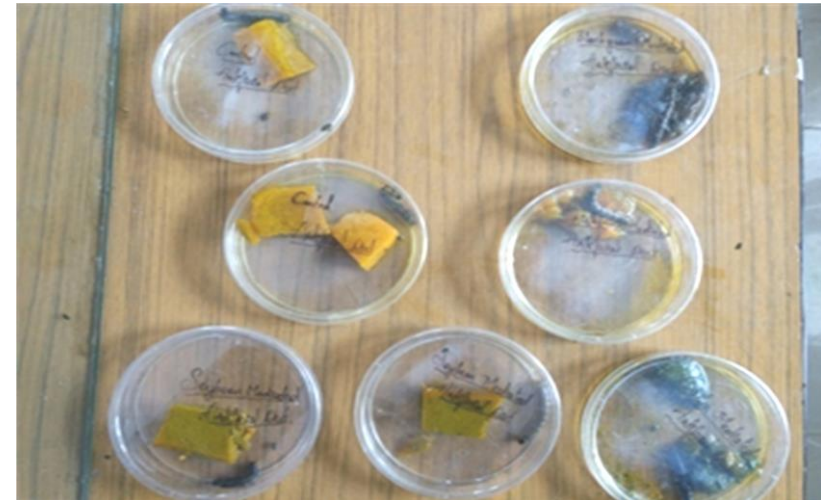
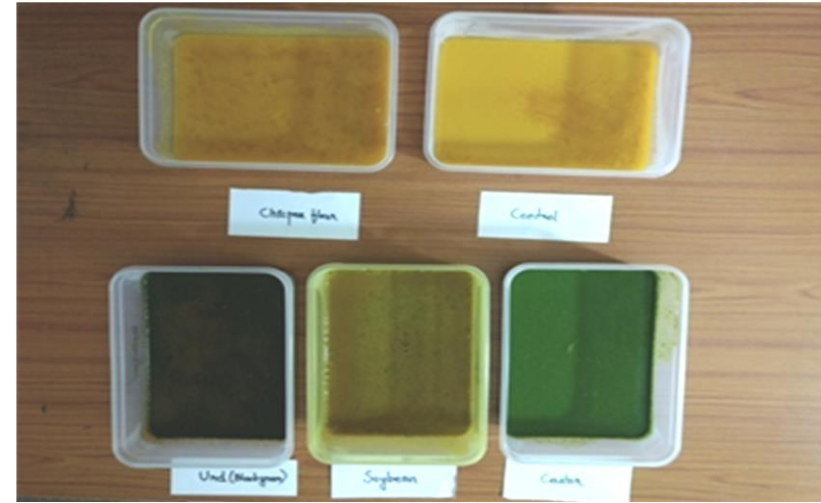


Plate 03. Experimental setup of soybean and other host based artificial diets on *S. litura*



Plate 04. Rearing of populations of different districts and bioassay studies experimental setup



Plate 05. Experimental site of field -efficacy of different insecticides



The present investigation was undertaken to study on pest incidence, biology and field resistance of tobacco caterpillar *Spodoptera litura* (Fabricius) to newer insecticides collected from major districts of Uttarakhand. The observations recorded in the present investigation have been presented and discussed under the following headings:

- 4.1 To ascertain the incidence of major insect pests and their natural enemies on soybean in major districts of Uttarakhand
 - 4.2 To study the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *Spodoptera litura*
 - 4.3 To study the field resistance of tobacco caterpillar *Spodoptera litura* to insecticides in major districts of Uttarakhand
 - 4.4 To study the field efficacy and economics of major insecticides against tobacco caterpillar *Spodoptera litura* on Soybean
- 4.1 To ascertain the incidence of major insect pests and their natural enemies on soybean in major districts of Uttarakhand**

The survey was conducted in different locations of U.S. Nagar, Almora, Nainital, Pauri Gharwal, Uttarakashi, New Tehri, Haridwar, Pithoragarh and Champawat districts during *kharif*, 2017 for assessment of incidence and severity of leaf eating caterpillars and stem fly in soybean and also recorded insecticides used during the crop and natural enemies/mrl. The data pertaining to survey was presented under.

4.1.1 Roving survey of soybean insect pests and their natural enemies

The detailed survey results of soybean insect pests of each district are presented in following paragraphs (Table no. 4.1).

4.1.1.1 U. S. Nagar District

Survey was carried out in different locations viz., Pantnagar, Sirsa, Darau, Kashipur, Gadarpur and Dineshpur during 2017 and the results indicated that the

incidence of the defoliators/mrl was ranged from 1.0 (chrysomelid beetle, Dineshpur) to 6.4 (*Spodoptera oblique*, Pantnagar). *S. litura* incidence was highest in pantnagar (6.2) and lowest in kashipur and sirsa (2.5). The incidence of *T. acuta* was found to be maximal at Pantnagar and Dineshpur (4.2) and it was minimal at Darau (2.0). The mean values of *S. litura*, *S. oblique*, *T. acuta* and *Chrysomelid* beetles was 3.8, 4.7, 3.2 and 2.0, respectively.

Stem fly incidence ranged from 14.6 per cent (Gadarpur) to 60.2 per cent (Pantnagar) and mean was 29.6 per cent. The white fly/ 3 leaves incidence on soybean ranged from 2.4 (Gadarpur) to 10.8 (Pantnagar) and mean was 5.7. Jassid/ 3 leaves were recorded highest in Gadarpur (3.6) and lowest in Sirsa (2.1) and the mean recorded was 2.8. The girdle beetle per cent infestation was ranged between 1.4 (Kashipur) to 8.9 (Patnagar) and mean was 3.9.

The natural enemies per meter row length was recorded highest at Pantnagar (6.5, Lady bird beetle) and lowest at Dineshpur (1.5, Spiders). The mean values of lady bird beetle, *Eucanthacona* bug and spiders was 3.6, 3.3 and 2.9, respectively.

4.1.1.2 Nainital

Survey was carried out in different locations viz., Haldwani, Kaladungi, Ramnagar, Bhimtal, Navagaon and Khairna during 2017 and the results indicated that the incidence of the The defoliators/mrl was ranged from 2.3 (*T. acuta*, Bhimtal and Khairna) to 6.4 (*S.litura*, Nayagaon). The incidence of *S. obliqua* was found to be maximum at Haldwani (5.5) and was minimal at Khairna (3.4). The incidence of chrysomelid beetle was highest in Kaladhungi (6.0) and lowest in Haldwani (2.6). The mean values of *S. litura*, *S. oblique*, *T. acuta* and chrysomelid beetles was 5.1, 4.3, 3.2 and 4.4, respectively.

Stem fly incidence ranged from 13.4 per cent (Bhimtal) to 18.9 per cent (Haldwani and Kaladhungi) and mean was 16.3 per cent. The white fly/ 3 leaves incidence on soybean ranged from 3.1 (Khairna) to 13.1 (Kaladhungi) and mean was 6.5. Jassid/ 3 leaves were recorded highest in Kaladhungi (6.1) and lowest in Ramnagar (2.1) and the mean recorded was 3.5. The girdle beetle per cent infestation was ranged between 2.1 (Bhimtal) to 8.8 (Kaladhungi) and mean was 5.5.

The natural enemies per meter row length was recorded highest at Kaladhungi (6.9, Lady bird beetle) and lowest at Khairna (1.6, Spiders). The mean values of lady bird beetle, *Eucanthacona* bug and spiders was 5.3, 4.0 and 2.4 respectively.

4.1.1.3 Almora

Survey was carried out in different locations viz., Majera, Hawalbagh, Matela, Dwarahat, Ranikhet and Majkhali during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 2.4 (*T. acuta*, Matela and Dwarahat) to 6.7 (Chrysomelid beetle, Majera). *S. litura* incidence was highest in Majera (6.4) and lowest in Matela (3.4). The incidence of *S. oblique* was found to be maximum at Hawalbagh (6.4) and was minimal at Ranikhet (2.9). The mean values of *S. litura*, *S. oblique*, *T. acuta* and chrysomelid beetles was 4.3, 4.4, 3.1 and 4.9, respectively.

The incidence of stem fly ranged from 12.1 per cent (Matela) to 14.3 per cent (Ranikhet) and mean was 13.2 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.2 (Matela) to 6.4 (Ranikhet) and mean was 3.7. Jassid/ 3 leaves were recorded highest in Hawalbagh (6.1) and lowest in Matela (2.3) and the mean recorded was 3.8. The girdle beetle per cent infestation was ranged between 2.3 (Matela) to 4.1 (Dwarahat) and mean was 3.2.

The natural enemies per meter row length was recorded highest at Dwarahat and Ranikhet (6.1, *Eucantha* bug) and lowest at Majkhali (1.6, Spiders). The mean values of lady bird beetle, *Eucanthacona* bug and spiders was 3.8, 4.2 and 3.1, respectively.

4.1.1.4 Champawat

Survey was carried out in different locations viz., Tanakpur, Banbasa, Champawat, Lohaghat, Ghat and Barakot during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 0.0 (*S. obliqua*, Banbasa) to 4.6 {*S. litura* (Lohaghat) and Chrysomelid beetle (Tanakpur)}. *T. acuta* incidence was highest in Barakot (3.2) and lowest in Tanakpur (2.1). The incidence of chrysomelid beetles was found to be maximum at Tanakpur and Champawat (4.6) and was minimal at Bambasa and Lohaghat (2.1). The mean values of *S. litura*, *S. obliqua*, *T. acuta* and chrysomelid beetles was 3.6, 3.2, 2.6 and 3.2, respectively.

Stem fly ranged from 2.6 per cent (Barakot) to 6.5 per cent (Tanakpur) and mean was 3.9 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.1 (Lohaghat) to 5.6 (Banbasa) and mean was 3.5. Jassid/ 3 leaves were recorded highest in Tanakpur and Lohaghat (3.4) and lowest in Banbasa (2.1) and the mean recorded was 2.9. The girdle beetle per cent infestation was ranged between 2.1 (Lohaghat) to 5.3 (Tanakpur) and mean was 3.3.

The natural enemies per meter row length was recorded highest at Tanakpur (3.9 Lady bird beetle) and lowest at Barakot (1.1, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders was 3.2, 2.5 and 2.1, respectively.

4.1.1.5 Pithoragarh

Survey was carried out in different locations viz., Gaina, Chandak, Gurna, Aicholi and Pithoragarh during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 0.0 (*S. oblique*, Bambasa) to 4.6 {*S. litura* (Lohaghat) and Chrysomelid beetle (Tanakpur)}. *T. acuta* incidence was highest in Barakot (3.2) and lowest in Tanakpur (2.1). The incidence of chrysomelid beetle was found to be maximum at Tanakpur and Champawat (4.6) and was minimal at Banbasa and Lohaghat (2.1). The mean values of *S. litura*, *S. oblique*, *T. acuta* and chrysomelid beetles was 3.6, 3.2, 2.6 and 3.2, respectively

Stem fly incidence ranged from 2.4 per cent (Aicholi) to 3.9 per cent (Gaina) and mean was 3.34 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.1 (Pithoragarh) to 4.1 (Gaina) and mean was 3.00. Jassid/ 3 leaves were recorded highest in Pithoragarh (4.6) and lowest in Gaina and Chandak (2.4) and the mean recorded was 2.88. The girdle beetle per cent infestation was ranged between 2.4 (Gaina) to 3.7 (Pithoragarh) and mean was 3.34.

The natural enemies per meter row length was recorded highest at Pithoragarh (3.8 Lady bird beetle) and lowest at Aicholi (1.9, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders was 3.2, 2.36 and 2.12 respectively.

4.1.1.6 Pauri Gharwal

Survey was carried out in different locations viz., Kotdwara, Dogadda, Ghumkal, Satpuli, Pauri and Srinagar during 2017 and the results indicated that the incidence of the

defoliators/mrl was ranged from 2.1 (*T. acuta*, Kotdwara) to 4.6 (Chrysomelid beetle, Ghumkal). *S. litura* incidence was highest in Ghumkal (3.0) and lowest in Dogadda and Satpuli (2.4). The incidence of *S. olique* was found to be maximum at Srinagar (3.8) and was minimal at Ghumkal (2.1). The mean values of *S. litura*, *S. oblique*, *T. acuta* and chrysomelid beetles was 2.6, 3.1, 2.5 and 4.1 respectively.

Stem fly incidence ranged from 4.9 per cent (Srinagar) to 18.70 per cent (Dogadda) and mean was 12.0 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.1 (Dogadda) to 3.1 (Satpuli) and mean was 2.50. Jassid/ 3 leaves were recorded highest in Pauri (3.9) and lowest in Ghumkal (2.5) and the mean recorded was 3.20. The girdle beetle per cent infestation was ranged between 2.4 (Kotdwara) to 7.5 (Srinagar) and mean was 4.30.

The natural enemies per meter row length was recorded highest at Srinagar (4.4 Lady bird beetle) and lowest at Ghumkal (1.4, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders was 3.0, 3.1 and 2.4, respectively.

4.1.1.7 New Tehri

Survey was carried out in different locations viz., Chamba, Ranichauri, Maletha, Jamnikhal, Farkot and Tipri during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 1.2 (*S. litura*, Tipri) to 6.4 (Chrysomelid beetle, Chamba). *T. acuta* incidence was highest in Ranichauri (3.2) and lowest in Tipri (2.1). The incidence of *S. olique* was found to be maximum at Ranichauri (4.3) and was minimal at Chamba (2.4). The mean values of *S. litura*, *S. oblique*, *T. acuta* and chrysomelid beetles was 2.9, 3.4, 2.6 and 5.1, respectively.

Stem fly incidence ranged from 6.4 per cent (Farkot) to 15.60 per cent (Chamba) and mean was 11.4 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.3 (Maletha and Jamnikhal) to 3.5 (Tipri) and mean was 2.9. Jassid/ 3 leaves were recorded highest in Jamnikhal (3.8) and lowest in Tipri (2.3) and the mean recorded was 3.1. The girdle beetle per cent infestation was ranged between 2.7 (Farkot) to 11.3 (Chamba) and mean was 6.20.

The natural enemies per meter row length was recorded highest at Chamba (4.2, Lady bird beetle) and lowest at Ranichauri (2.0, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders were 3.4, 3.0 and 2.4, respectively.

4.1.1.8 Uttarakashi

Survey was carried out in different locations viz., Chilyanisaur, Dhanpur, Nagni and Dharasu during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 1.1 (*S. litura*, Dharasu) to 6.4 (Chrysomelid beetle, Nagni). *T. acuta* incidence was highest in Nagni (3.1) and lowest in Dharasu (1.4). The incidence of *S. obliqua* was found to be maximum at Dhanpur (3.5) and was minimal at Nagni (2.1). The mean values of *S. litura*, *S. obliqua*, *T. acuta* and chrysomelid beetles was 2.9, 2.9, 2.3 and 4.5, respectively.

Stem fly incidence ranged from 2.4 per cent (Chilyanisaur) to 13.60 per cent (Dhanpur) and mean was 5.7 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 2.3 (Dharasu) to 4.3 (Dhanpur) and mean was 3.1. Jassid/ 3 leaves were recorded highest in Dharasu (3.7) and lowest in Chilyanisaur (2.2) and the mean recorded was 2.7. The girdle beetle per cent infestation was ranged between 2.3(Nagni) to 10.7 (Dhanpur) and mean was 5.1.

The natural enemies per meter row length was recorded highest at Dharasu (4.6 Lady bird beetle) and lowest at Nagni (1.9, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders was 3.6, 2.9 and 2.3, respectively.

4.1.1.9 Haridwar

Survey was carried out in different locations viz., Roorkee, Laksar, Sultanpur, Podawali and Khanpur during 2017 and the results indicated that the incidence of the defoliators/mrl was ranged from 2.1 (*T. acuta*, Laksar) to 4.6 (Chrysomelid beetle, Khanpur). *S. litura* incidence was highest in Laksar (3.5) and lowest in Roorkee and Podwali (2.6). The incidence of *S. oblique* was found to be maximum at Podwali (4.6) and was minimal at Sultanpur (2.1). The mean values of *S. litura*, *S. obliqua*, *T. acuta* and chrysomelid beetles was 3.02, 3.5, 2.68 and 3.22, respectively.

Stem fly incidence ranged from 13.2 per cent (Roorkee) to 23.4 per cent (Khanpur) and mean was 19.04 per cent. The white fly/ 3 leaves incidence on soybean was ranged from 3.1 (Laksar and Podawali) to 4.5 (Khanpur) and mean was 4.08. Jassid/ 3 leaves were recorded highest in Sultanpur (2.9) and lowest in Podwali (1.2) and the mean recorded was 2.24. The girdle beetle per cent infestation was ranged between 1.4 (Podwali) to 5.6 (Khanpur) and mean was 2.92.

Table No. 4.1: Incidence of insect pests of soybean and their natural enemies in major districts of Uttarakhand

District	Location	Host	Previous crop	Insecticide used	Insecticide Majorly used	Defoliators/mrl				White fly/3 leaves	Jassid/3 leaves	Stem fly (%infestation)	Girdle beetle (%infestation)	Naturalenemies/mrl		
						S. litura	S. obliqua	T. acuta	Chrysomelid beetle					Lady bird beetle	Eucanthacona bug	Spiders
U. S. Nagar	Pantnagar	Soybean	Wheat	Coragen	Many	5.4	6.4	4.2	3.1	10.8	3.4	60.2	8.9	4.2	5.9	4.1
	Pantnagar	Soybean	Peas	Indoxacarb	Many	6.2	5.8	3.4	2.4	5.6	2.4	30.2	5.6	6.5	4.5	3.7
	Sirsa	Soybean	Wheat	-	-	4.1	5.1	2.6	1.0	8.5	2.1	40.4	4.1	4.8	3.5	3.4
	Darau	Urd	Mustard	-	Imidachloprid	3.1	2.6	2.0	2.4	4.8	3.2	25.4	2.3	2.4	2.4	3.1
	Kashipur		Wheat	Coragen	Nuvan	2.5	7.1	2.4	3.1	4.6	2.5	16.8	1.4	2.8	2.9	2.1
	Gadarpur	Urd	Wheat	Monocrotophos	-	2.8	2.0	3.7	1.2	2.4	3.6	14.6	2.6	2.1	2.1	2.2
	Dineshpur	Soybean	Wheat	-	-	2.5	3.6	4.2	1.0	3.5	2.4	19.7	2.3	2.1	2.0	1.5
	Mean					3.8	4.7	3.2	2.0	5.7	2.8	29.6	3.9	3.6	3.3	2.9
Nainital	Haldwani	Soybean	Wheat	Coragen	Many	4.6	5.5	4.1	2.6	7.1	3.8	18.9	6.4	5.5	6.4	2.1
	Kaladungi	Soybean	-	Indoxacarb	Many	5.9	4.1	3.5	6.0	13.1	6.1	18.9	8.8	6.9	4.6	3.4
	Ramnagar	Soybean	Potato	-	-	6.1	4.1	3.6	5.1	9.1	2.1	16.4	7.4	5.4	3.1	2.1
	Bhimal	Urd	Mustard	-	Imidachloprid	4.6	4.6	2.3	4.1	2.6	3.1	14.1	2.1	6.2	3.8	2.3
	Nayagaon		Wheat	Coragen	Nuvan	6.4	4.2	3.1	4.9	3.8	3.4	13.4	3.6	4.6	3.6	2.4
	Khairna					3.2	3.4	2.3	3.5	3.1	2.4	16.2	4.5	3.2	2.4	2.3
	Mean					5.1	4.3	3.2	4.4	6.5	3.5	16.3	5.5	5.3	4.0	2.4
Almora	Majera	Soybean	Wheat	Coragen	Many	6.4	4.3	3.1	6.7	3.6	4.1	13.6	2.4	2.4	3.6	3.4
	Hawalbagh	Soybean	-	Indoxacarb	Many	4.6	6.4	3.4	4.1	3.4	6.1	12.4	3.4	5.6	4.1	3.4
	Matela	Soybean	Wheat	-	-	3.4	3.4	2.4	2.4	2.2	2.3	12.1	2.3	3.1	2.6	3.6
	Dwarahat	Soybean	Mustard	-	-	3.7	5.2	2.4	3.1	4.3	3.6	13.6	4.1	3.5	6.1	3.1
	Ranikhet	Urd	Wheat	-	-	4.1	2.9	3.6	6.4	6.4	3.4	13.1	3.6	5.1	6.1	3.2
	Majkhali	Urd	Wheat	Nuvan	Nuvan	3.6	4.1	3.4	6.4	2.4	3.1	14.3	3.2	3.2	2.6	1.6
	Mean					4.3	4.4	3.1	4.9	3.7	3.8	13.2	3.2	3.8	4.2	3.1
Champawat	Tanakpur	Soybean	Wheat	Coragen	-	3.1	3.5	2.1	4.6	3.8	3.4	6.5	5.3	3.9	2.3	2.1
	Banbasa	Soybean	Cabbage	Imidachloprid	Imidachloprid	3.6	0.0	2.2	2.1	5.6	2.1	4.0	2.4	2.7	3.4	2.1
	Champawat	Bhatt	Cabbage	Nuvan	Nuvan	3.8	4.5	2.8	4.6	3.6	3.1	2.8	3.4	3.4	2.9	3.0
	Lohaghat	Urd	Wheat	-	Many	4.6	3.8	2.7	2.1	2.1	3.4	4.1	2.1	3.4	2.0	2.2
	Ghat	Soybean	Wheat	Nuvan	Nuvan	3.4	4.3	2.3	3.4	3.4	2.4	3.4	4.1	3.1	2.4	2.1
	Barakot	Soybean	Potato	Nuvan	Nuvan	3.2	2.8	3.2	2.4	2.4	3.1	2.6	2.3	2.4	2.1	1.1
		Mean					3.6	3.2	2.6	3.2	3.5	2.9	3.9	3.3	3.2	2.5
Pittoragarh	Gaina	Soybean	Wheat	Imidachloprid Thiomethoxam	Imidachloprid	4.1	3.2	3.4	4.1	4.1	2.1	3.9	4.1	2.1	2.4	1.8
	Chandak	Urd	Wheat	Nuvan	Nuvan	2.3	3.1	2.4	4.6	3.1	2.4	3.1	2.4	3.6	2.1	2.4
	Gurna	Soybean	Wheat	Nuvan	Nuvan	3.3	2.6	2.7	3.8	3.4	2.4	4.6	3.1	3.1	2.4	2.0
	Aicholi	Soybean	Wheat	-	-	2.7	3.3	2.9	3.9	2.3	2.9	2.4	3.4	3.4	2.1	1.9
	Pittoragarh	Soybean	Cabbage			3.4	2.9	3.4	2.4	2.1	4.6	2.7	3.7	3.8	2.8	2.5
	Mean					3.16	3.02	2.96	3.76	3	2.88	3.34	3.34	3.2	2.36	2.12

Table No. 4.1: Contd...

District	Location	Host	Previous crop	Insecticide used	Insecticide Majorly used	Defoliators/mrl				White fly/3 leaves	Jassid/3 leaves	Stem fly (%infestation)	Girdle beetle (%infestation)	Naturalenemies/mrl		
						<i>S. litura</i>	<i>S. obliqua</i>	<i>T. acuta</i>	Chrysomelid beetle					Lady bird beetle	Eucanthacona bug	Spiders
Pauri Gharwal	Kotdwara	Soybean	Wheat	Coragen	Many	2.8	2.9	2.1	3.4	2.7	3.4	12.9	2.4	3.4	2.6	2.1
	Dogadda	Soybean	Peas	Indoxacarb	Many	2.4	3.3	2.6	4.3	2.1	3.3	18.7	3.8	2.9	2.6	1.6
	Ghumkal	Soybean	Wheat	-	-	3.0	2.1	2.7	4.6	2.4	2.5	12.8	3.6	2.7	3.4	1.4
	Satpuli	Urd	Mustard	-	Imidachloprid	2.4	3.5	2.4	2.8	3.1	2.8	12.1	2.3	3.1	2.4	2.9
	Pauri		Wheat	Coragen	Nuvan	2.6	2.9	2.6	3.9	2.4	3.9	10.3	5.9	2.8	4.1	2.4
	Srinagar	Urd	Wheat	Monocrotophos	-	2.7	3.8	2.4	5.3	2.4	3.5	4.9	7.5	4.4	3.5	3.8
	Mean						2.6	3.1	2.5	4.1	2.5	3.2	12.0	4.3	3.0	3.1
Tehri Garhwal	Chamba	Soybean	Wheat	Coragen	Many	2.5	2.4	2.9	6.4	3.4	2.6	15.6	11.3	4.2	2.3	2.9
	Ranichauri	Soybean	-	Indoxacarb	Many	1.4	4.3	3.2	5.3	3.2	2.6	12.3	8.6	3.2	2.1	2.0
	Maletha	Soybean	Potato	-	-	2.6	3.2	2.4	5.6	2.3	3.4	9.2	6.3	2.6	4.3	2.8
	Jamnikhali	Urd	Mustard	-	Imidachloprid	2.3	3.2	2.6	4.1	2.3	3.8	12.3	2.9	3.6	4.1	2.3
	Farkot		Wheat	Coragen	Nuvan	2.6	3.5	2.4	4.6	2.8	3.6	6.4	2.7	3.5	2.4	2.3
	Tipri	Soybean	Wheat	Nuvan	Nuvan	1.2	3.6	2.1	4.5	3.5	2.3	12.3	5.1	3.2	2.8	2.1
	Mean						2.9	3.4	2.6	5.1	2.9	3.1	11.4	6.2	3.4	3.0
Uttarakashi	Chilyanisaur	Soybean	Wheat	Coragen	Many	3.6	2.5	2.4	5.1	2.6	2.2	2.4	3.9	3.4	2.6	2.4
	Dhanpur	Soybean	-	Indoxacarb	Many	4.0	3.5	2.4	2.6	4.3	2.4	13.6	10.7	2.9	3.4	2.6
	Nagni	Soybean	Wheat	-	-	3.1	2.1	3.1	6.4	3.1	2.6	4.1	2.3	3.4	2.3	1.9
	Dharasu	Soybean	Mustard	-	-	1.1	3.4	1.4	3.9	2.3	3.7	2.6	3.5	4.6	3.3	2.4
	Mean						2.9	2.9	2.3	4.5	3.1	2.7	5.7	5.1	3.6	2.9
Haridwar	Roorkee	Soybean	Wheat	Coragen	-	2.6	3.2	2.4	3.4	6.1	2.3	13.2	2.4	3.4	2.3	1.2
	Laksar	Soybean	Cabbage		Imidachloprid	3.5	3.1	2.1	3.4	3.1	2.4	16.6	2.6	3.1	2.3	2.4
	Sultanpur	Bhatt	Cabbage		Nuvan	3.2	2.1	3.5	2.4	3.6	2.9	21.4	2.6	3.2	2.1	2.1
	Podawali	Urd	Wheat		Many	2.6	4.6	2.5	2.3	3.1	1.2	20.6	1.4	2.6	2.7	2.1
	Khanpur	Soybean	Wheat		Nuvan	3.2	4.5	2.9	4.6	4.5	2.4	23.4	5.6	3.4	2.3	2.6
	Mean						3.02	3.5	2.68	3.22	4.08	2.24	19.04	2.92	3.14	2.34

The natural enemies per meter row length was recorded highest at Roorkee and Khanpur (3.4, Lady bird beetle) and lowest at Roorkee (1.2, Spiders). The mean values of lady bird beetle, Eucanthacona bug and spiders was 3.14, 2.34 and 2.08 respectively.

4.2 To study the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *Spodoptera litura*

The present investigation was carried out in Soybean Laboratory, Department of Entomology, G. B. P. U. A. & T Pantnagar. The data was recorded on the biological parameters, including both immature and mature adult stage of *S. litura* fed on the said diets (Table no. 3.2.2). Almost same trend of the collected data was observed in 1st, 2nd and 3rd replication of *S. litura*. Therefore, only the average mean data regarding the overall 3 replications have been presented.

4.2.1 Effect of diet-1 diet-2, diet-3, diet-4 and diet-5 on *S. litura*

The results of the present study on duration of life stages of *S. litura* are given in Table no. 4.2.1. Mean number of days taken by the first instar larva was 2.16 days on diet 2 and it was significantly on par with *S. litura* raised on diet 1 with duration of 2.4 days. However, duration of 1st instar larvae taken on diet 3, 4 and 5 were 3.28, 3.2 and 3.43 days and was significantly different with other two natural diets. The larva raised on artificial diet-2 showed a duration of 2.16 days which was significantly varied with all other diets tested except artificial diet-1. Second instar larvae showed duration of 2.39, 2.16 and 3.2 days on chickpea, soybean and castor leaves respectively and are significantly different. Whereas, larvae reared on artificial diet-5 showed duration of 3.8 days and it was on par with castor (3.28). However, diet-2 showed a reduced duration of 2.16 days and found to be effective when compared to other diets.

Third instar larvae reared on soybean leaf registered duration of 2.2 days and is found to be significantly different. Larval duration of 3.93, 3.23 and 4.06 were documented with black gram, chickpea and diet-5 and were statistically on par with each other. Larva reared on artificial diet-2 showed duration of 2.2 days and was on par with diet-2 (2.23days). Larval duration of 4th instar *S. litura* was significantly higher on diet-5 and black gram leaves with 4.7 and 3.73 days respectively. Whereas, larvae raised on chickpea, soybean, and castor showed duration of 3.43, 3.33 and 3.03 respectively and

Table No. 4.2.1: Growth & Survival parameters of *S. litura* (Mean \pm SD*) under different diet formulations

Biological Parameters	Diet I	Diet II	Diet III	Diet IV	Diet V	CD
Egg period	2.13 \pm 0.55	2.8 \pm 0.61	3.23 \pm 0.25	2.8 \pm 0.15	2.5 \pm 0.26	NS
1st instar	2.4 \pm 0.85	2.17 \pm 0.15	3.28 \pm 0.30	3.2 \pm 0.1	3.43 \pm 0.21	0.749
2nd instar	2.39 \pm 0.25	3.2 \pm 0.26	3.63 \pm 0.57	2.5 \pm 0.15	3.83 \pm 0.25	0.600
3rd instar	3.23 \pm 0.25	2.2 \pm 0.26	2.33 \pm 0.29	3.9 \pm 0.25	4.07 \pm 0.38	0.529
4th instar	3.43 \pm 0.21	3.33 \pm 0.15	3.03 \pm 0.35	3.7 \pm 0.21	4.7 \pm 0.26	0.448
5th instar	3.3 \pm 0.44	3.03 \pm 0.06	3.53 \pm 0.45	3.5 \pm 0.15	5.0 \pm 0.15	0.542
6th instar	2.83 \pm 0.29	2.37 \pm 0.23	3.43 \pm 0.50	4.0 \pm 0.47	4.6 \pm 0.15	0.649
Pre-Pupal period	3.21 \pm 0.27	3.1 \pm 0.1	2.53 \pm 0.55	3.7 \pm 0.21	3.3 \pm 0.68	NS
Pupal period	10.7 \pm 0.53	8.95 \pm 0.93	10.74 \pm 0.71	12.5 \pm 1.0	14.1 \pm 1.18	1.635
Adult life span	3.5 \pm 0.5	4.5 \pm 0.5	3.25 \pm 0.25	4.1 \pm 0.36	5.6 \pm 0.81	0.944
% Pupation	83.35	89.15	82.34	75.23	89.36	-
% Survival	74.32	81.23	85.32	64.31	55.21	-
Larval growth index	4.74	5.47	4.28	3.61	3.49	
Total Development Index	2.00	2.28	2.19	1.46	1.08	

were statistically on par. Mean number of days taken for 5th instar *S. litura* was 3.00 and 3.3 days respectively on soybean and chickpea and were on par with each other. Whereas, larva reared on castor and black gram leaf showed a duration of 3.53 days which was statistically on par with diet-5 (4.96). Agar (diet-5) registered highest larval duration for 6th instar *S. litura* with 4.63 days and was on par with black gram (3.96 days). Duration registered on soybean leaf was 2.36 days and was on par with diet-1 (2.83 days). Lowest duration was documented for diet-2 (2.36) and is significantly different with other diets tested. Total mean larval duration was found to be highest in larvae raised on Agar (diet-5) (25.63) followed by black gram (20.83) and were significantly different. Whereas, duration documented for diet-1 and castor leaf raised larvae are 17.59 and 19.25 respectively and were statistically on par. Lowest mean larval duration was recorded for diet-2 with 16.3 days and was statistically significant.

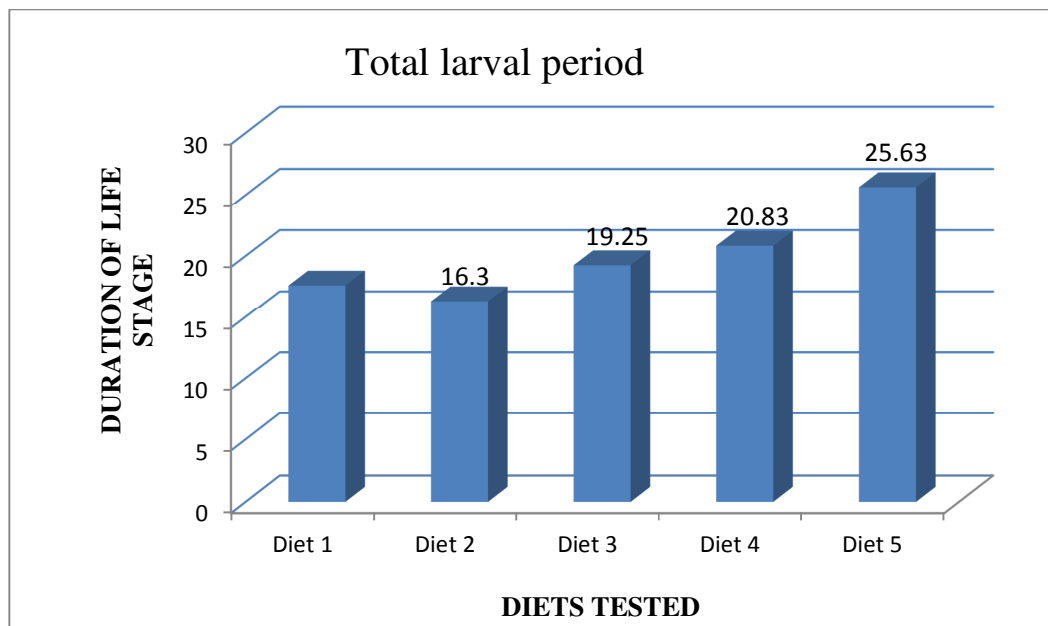


Fig. No. 4.2.1 Total larval period of *S. litura* on different artificial diets

Highest pre-pupal duration was recorded under black gram leaf with 3.73 days followed by diet-5 which was found to be 3.26 days and is on par with chickpea (3.21) and soybean (3.1). Whereas, diet-3 documented pre-pupal duration of 2.58 days and they were statistically different. Pupal duration was highest in larva raised on agar with 14.13 days followed by blackgram with 12.5 days and diet-2 with 8.95 days. Pupal

duration of *S. litura* raised on chickpea was significantly on par with both castor and diet-3. Highest adult period of 7.44days was recorded in *S. litura* raised on diet-2 followed by castor with 6.16 days and diet-1 with 5.83 days and were statistically on par with diet-2. Adult period recorded on diet-5 was 5.60 days and was on par with diet-2 (4.5). Incubation period was found to be higher in *S. litura* raised on castor (3.23) followed by soybean with 2.8 days and diet-4 with 2.7 days and is statistically equal with diet-5. Incubation period recorded with diet-2 and castor was 3.25 days and 3.16 days respectively and was statistically equal. Total life cycle period was highest for *S. litura* raised on agar with 51.1 days. Black gram and castor recorded next highest duration of 43.93 days and 39.03 days. Total life cycle period of 37.13 and 35.65 was recorded for *S. litura* raised on diet-1 and diet-2 and were statistically on par.

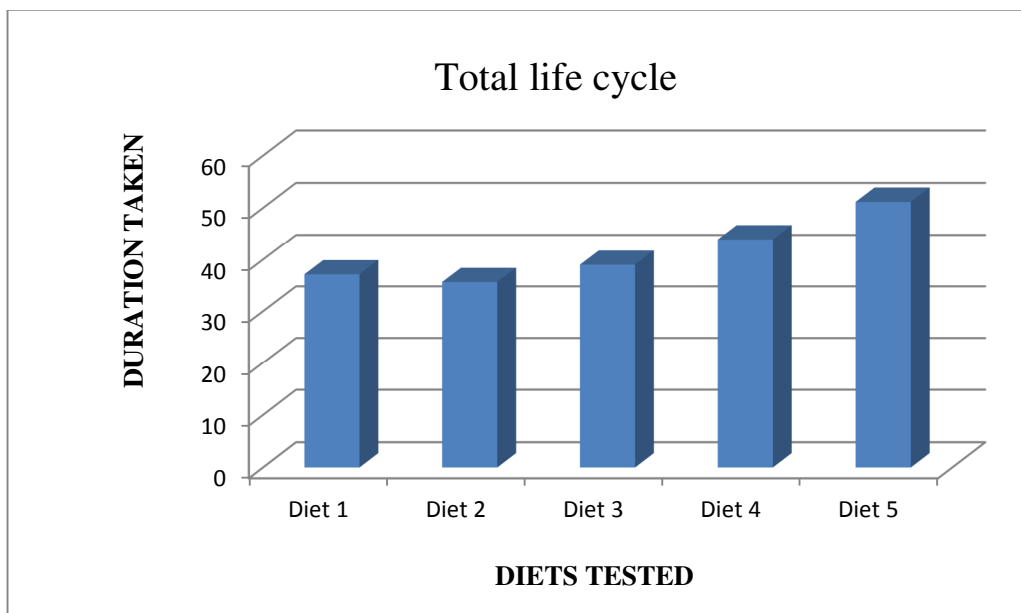


Fig No. 4.2.2: Total life cycle duration of *S. litura* on different artificial diets

4.2.2 Growth and Development indices

The larval growth index was 5.46 for diet-2 followed by 4.73, 4.27, 3.61 and 3.48 respectively for *S. litura* raised on diet-1, castor, black gram and agar based artificial diets. The developmental index was also higher in diet-2 (2.27) followed by castor based artificial diet (2.18), diet-1 (2.00), black gram based artificial diet (1.46) and diet-5 (1.07).

The development of artificial diets, pioneered by **Vanderzant et al. (1962)** facilitated the continuous production of insects. Since then, several species of dipterans, lepidopterous and coleopterans have been successfully reared under controlled laboratory conditions. In the present study, in order to guarantee a continuous and adequate supply of larvae, an effort was made to standardize a viable rearing technique. Initially, the artificial diet (Diet-1) was prepared based on the procedure described by **Saljoqi et al. (2015)**. Further, diet-2, 3, 4 and 5 were standardized by slightly modifying the procedure and composition of diet-1 to increase its palatability (Table 2). Total larval period documented for *S. litura* reared on modified diet was 16.3 days and is comparatively lower with 17.2 days and 15.08 days reported by **Saljoqi et al (2015)** on bean based and gram based artificial diets. Present study is in coordination with **Sorour et al., 2011** who reported a total larval duration of *S. littoralis* (13.78) days on bean based artificial diet. Total developmental index reported by **Gupta et al. (2005)** and **Diwakara and Manjulakumari, (2015)** were 2.84 and 1.95 which were in accordance with the present soybean based oligidic diet where total developmental index recorded was 2.28. Soybean is one of the most favorite foods of *S. litura* next to the castor, whose composition is very essential especially for skeleton build-up process of its early instars.

However, large scale mass rearing on any natural diet is very laborious process with high risk of infections. Hence, in the present study an attempt was made by mixing dried soybean leaf powder with traditional artificial diet ingredients. The effectiveness of artificial diets was assayed in terms of palatability and time taken for completion of various life stages of *S. litura*. Rearing of larvae of *S. litura* in artificial diet was successful and the number of days taken to complete the total larval period (Fig. no. 4.2.1) is lower in larvae raised in diet-2 followed by diet-1. However, total life cycle was significantly lesser in both the diets tested than populations reared on other artificial diets viz., castor, black gram and agar (Fig. No.4.2.2). Survival percentage and total growth index were also highest in *S. litura* raised on diet-3 followed by larvae raised on diet-1 and soybean based artificial diet (diet-2).

4.3 Field resistance of tobacco caterpillar *Spodoptera litura* to insecticides in major districts of Uttarakhand state are presented and discussed as below

The present investigation aimed to monitor level of different insecticidal toxicity against third instar larvae of *S. litura* (Fab.). The larvae were collected from different locations of Uttarakhand state during 2016-17 and 2017-18 and leaf dip method of bioassay was carried out to know median lethal concentration (LC₅₀) of insecticides. For different insecticides malformed larvae and shrunked larvae were considered as dead ones and results were presented in Table 4.3.1-4.3.10.

4.3.1. Udham Singh Nagar

After **24 HAF** with various insecticides tested against third instar larvae, Emamectin benzoate 5G was found to be more toxic (Table No. 4.3.1), with LC₅₀ value of 0.000252% followed by Chlorantraniliprole (Coragen) (0.000428%), Chlorantraniliprole (Coragen) (0.000428%) Indoxacarb 15.8 EC (0.000434%), Spinosad 45EC (0.000514%) dichlorvos 45SC (0.001202%), Lambda cyhalothrin 5 EC (0.001289% Flubendiamide 480 SC (0.003353%) and Lufenuron 5 EC (0.010174%). The least toxicity was recorded by Imidacloprid 17.5 SC (0.034620%).

In other quarters, order of toxicity of various insecticides against third instar larvae is as follows Emamectin benzoate 5G > Chlorantraniliprole 18.5 SC > Indoxacarb 15.8 EC > spinosad 45 SC > Dichlorvos 45SC > Lambda cyhalothrin 5 EC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

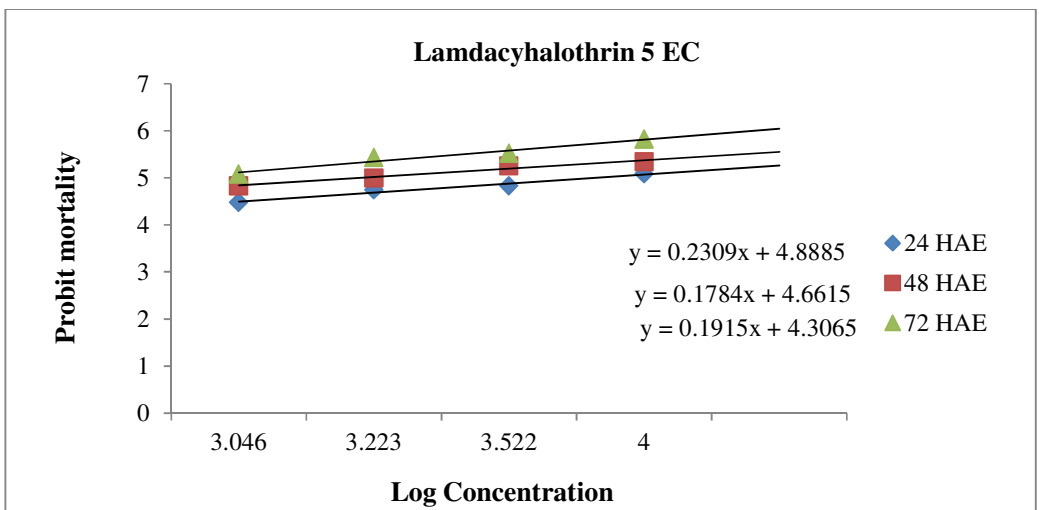
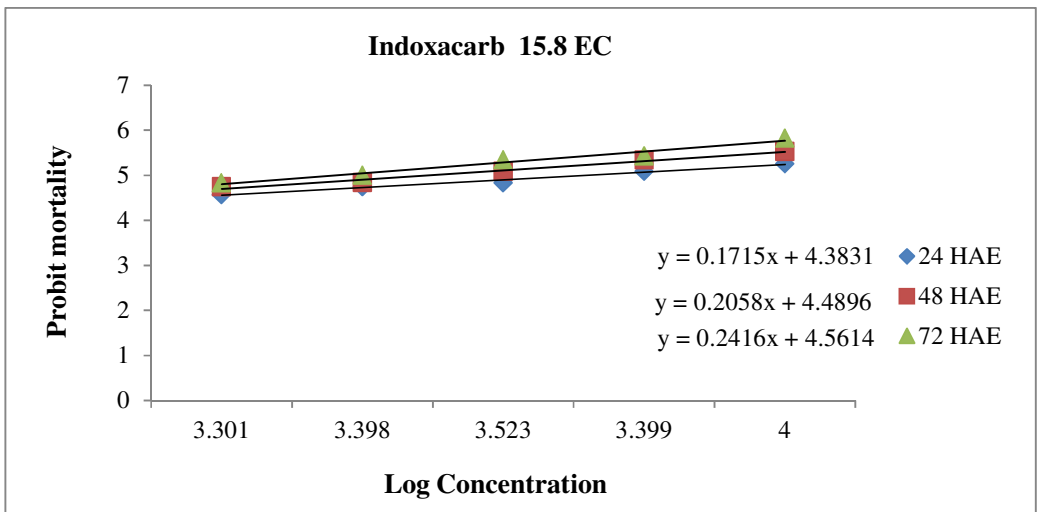
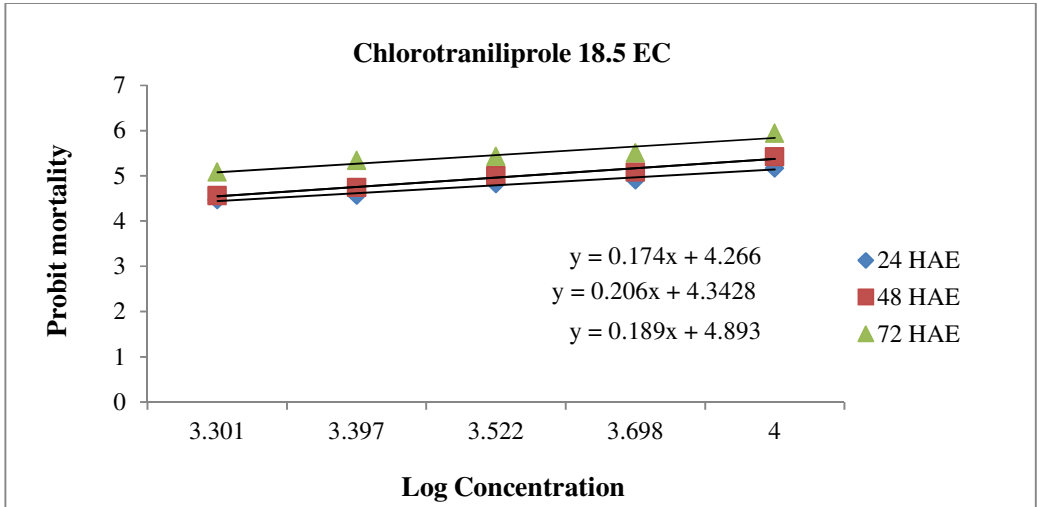
At **48 HAF**, Emamectin benzoate 5G was found to be most toxic with LC₅₀ value of 0.000118%, followed by Spinosad 45EC (0.000168%), Indoxacarb 15.8 EC (0.000210%) Chlorantraniliprole (Coragen) (0.00028031%) Lambda cyhalothrin 5 EC (0.000414%), Dichlorvos 45SC (0.000641%), Flubendiamide 480 SC (0.002063%) and Imidacloprid 17.5 SC (0.002571%). Lufenuron 5 EC (0.005986%) was found to be least toxic against the larvae.

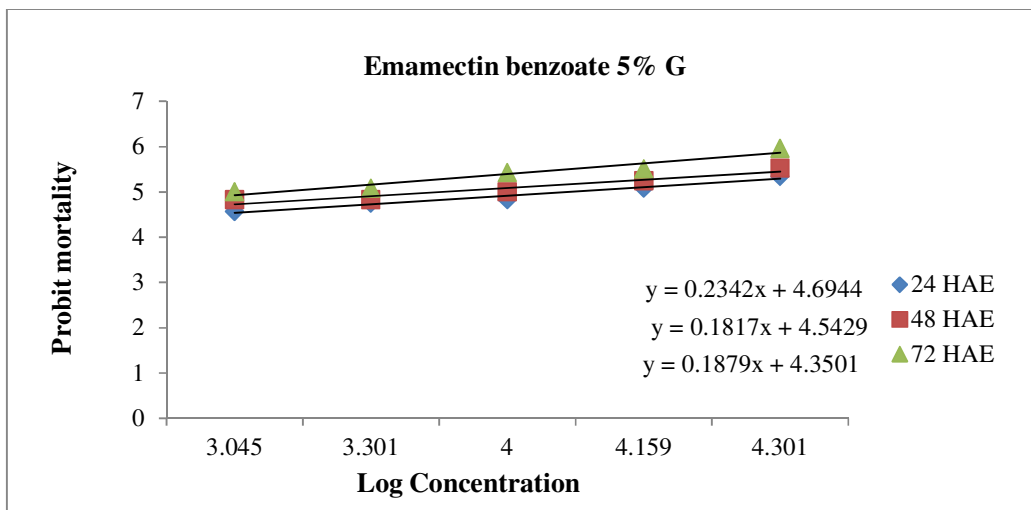
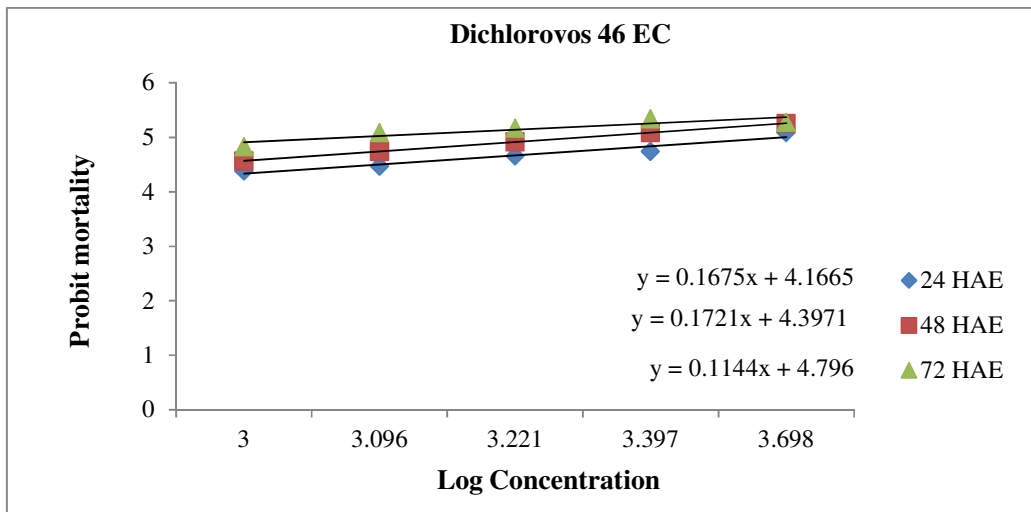
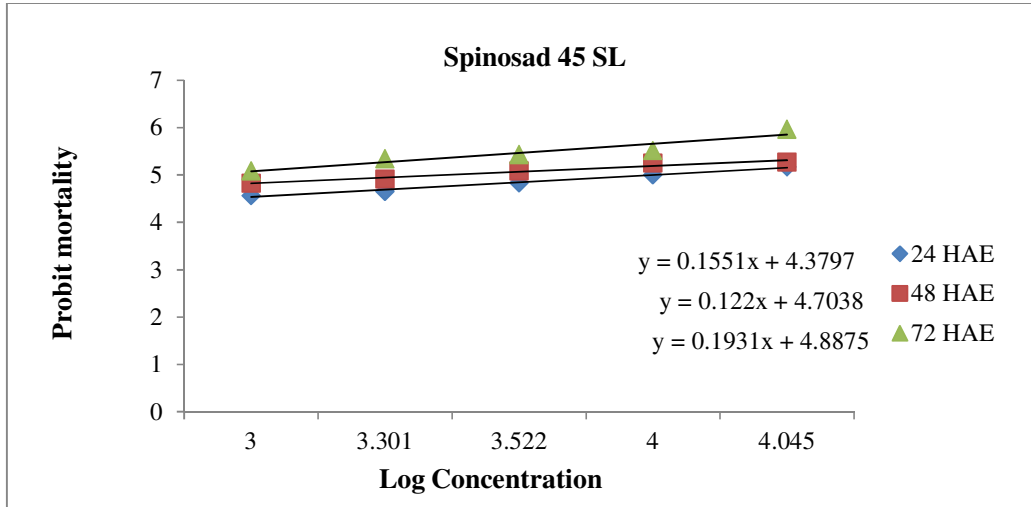
In other quarters, the order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > spinosad 45 SC > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Lambda cyhalothrin 5 EC > Dichlorvos 45SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

Table 4.3.1: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Udham Singh Nagar population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.000123	0.000428	0.009254	0.622776	Y=4.266+0.174x	0.000262	0.017936
	48	0.000098	0.000282	0.00369842	0.789473	Y=4.342+0.20x	0.000163	0.000554
	72	0.000026	0.000091	0.001673	1.115516	Y=4.893+0.189x	0.000232	0.000165
Indoxacarb 15.8 EC	24	0.000120	0.000434	0.010286	0.379314	Y=4.383+0.171x	0.000262	0.596434
	48	0.000072	0.000210	0.002924	0.940034	Y=4.489+0.205x	0.000079	0.000332
	72	0.000064	0.000159	0.001500	1.159289	Y=4.561+0.241x	0.000057	0.000230
Lamdacyhalothrin 5 EC	24	0.000195	0.001289	0.134357	0.978875	Y=4.177+0.176x	0.000592	27.544730
	48	0.000068	0.000414	0.036034	0.564598	Y=4.480+0.179x	0.000095	0.001315
	72	0.000026	0.000136	0.007870	1.439873	Y=4.746+0.208x	0.000003	0.000281
Spinosad 45EC	24	0.000057	0.000514	0.116636	0.078701	Y=4.379+0.155x	0.000210	5.451344
	48	0.000023	0.000168	0.021807	0.2195106	Y=4.703+0.122x	0.000009	0.000391
	72	0.000008	0.000050	0.005040	1.095299	Y=4.887+0.193x	0.000000	0.000127
Dichlorovas 45SC	24	0.000325	0.001202	0.030141	1.006745	Y=4.166+0.167x	0.000684	0.002500
	48	0.000186	0.000641	0.013511	0.2571047	Y=4.397+0.172x	0.000354	0.003558
	72	0.000090	0.000326	0.007749	0.2324760	Y=4.796+0.114x	0.000006	0.000540
Emamectin benzoate 5G	24	0.000027	0.000252	0.063770	0.274241	Y=4.350+0.187x	0.000092	0.002036
	48	0.000012	0.000118	0.031007	0.274934	Y=4.542+0.181x	0.000014	0.000331
	72	0.000006	0.000041	0.004254	1.430205	Y=4.694+0.234x	0.000013	0.000134
Imidachloprid 17.5 SC	24	0.000351	0.034620	0.04231	0.2471538	Y=4.222+0.160x	0.001829	0.6554429
	48	0.000035	0.002571	0.006213	1.469490	Y=4.437+0.187x	0.000104	0.069415
	72	0.000026	0.001318	0.003124	0.6151048	Y=4.516+0.190x	0.000263	0.006598
Flubendiamide 480SC	24	0.000646	0.003353	0.1928799	0.093920	Y=4.344+0.094x	0.001755	0.4467327
	48	0.000368	0.002063	0.1436385	0.9951012	Y=4.420+0.170x	0.000815	0.030210
	72	0.000100	0.000620	0.055156	0.3995481	Y=4.800+0.159x	0.000796	0.001305
Lufenuron 5EC	24	0.003159	0.010174	0.1810637	0.791570	Y=4.149+0.184x	0.006293	0.3269547
	48	0.002144	0.005986	0.074953	1.478450	Y=4.292+0.213x	0.003715	0.012556
	72	0.000957	0.002746	0.036753	0.4337042	Y=4.701+0.205x	0.000414	0.004260

Mean larval wt.=0.0232g/larva (23.2 mg)





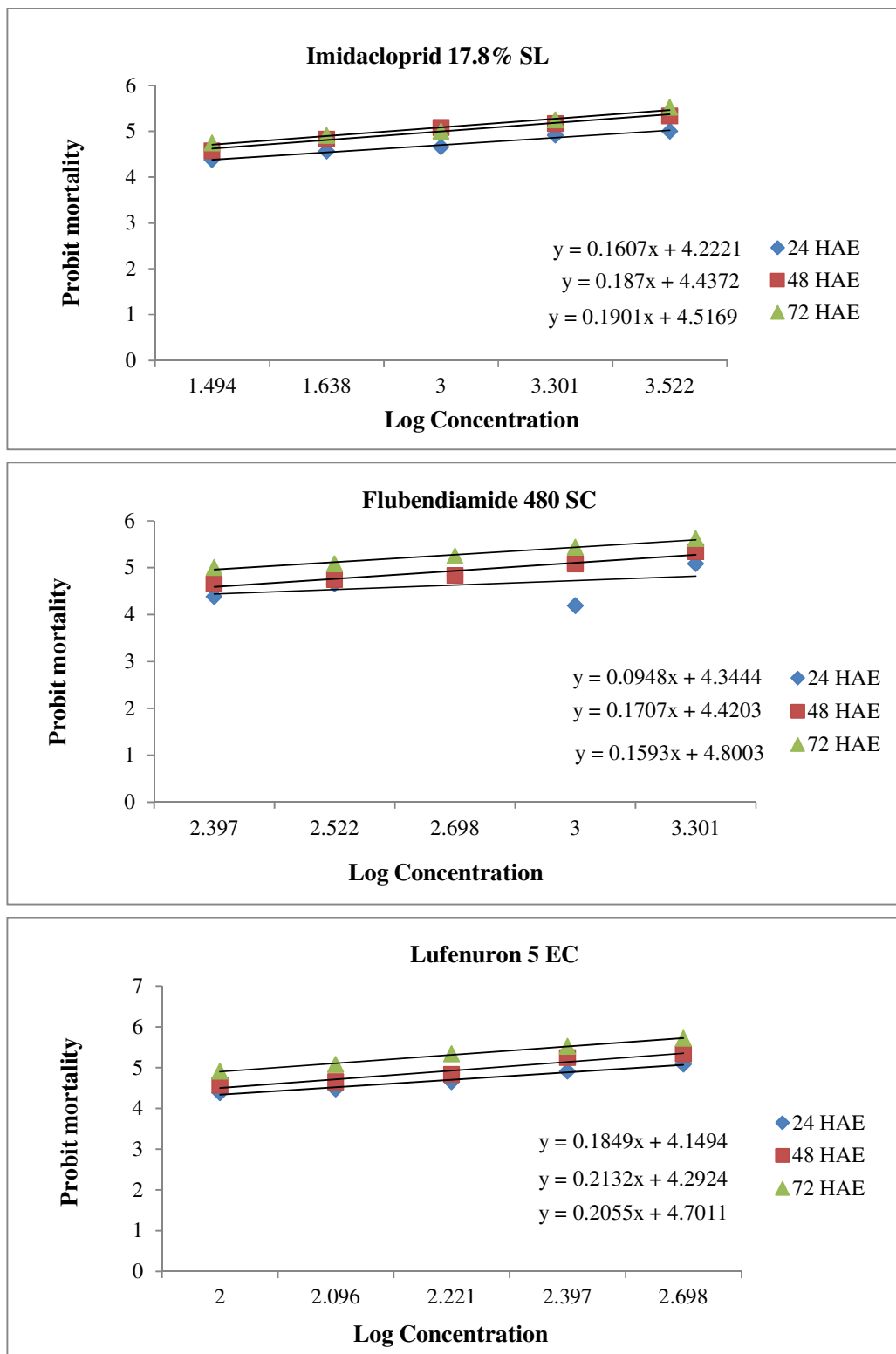


Fig. 4.3.1 Dosage-mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of U. S. Nagar population by leaf dip bioassay method

At 72 HAF, the most toxic insecticide was Emamectin benzoate 5G with LC₅₀ value of 0.000041% followed by Spinosad 45EC (0.000050%), Chlorantraniliprole (Coragen) (0.000091%) Lambda cyhalothrin 5 EC (0.000136%), Indoxacarb 15.8 EC (0.000159%), Dichlorvos 45SC (0.000326%) Flubendiamide 480 SC (0.000620%) and Imidacloprid 17.5 SC (0.001318%). The least toxicity was recorded by Lufenuron 5 EC (0.002746%).

In other quarters, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > spinosad 45 SC. > Chlorantraniliprole (Coragen) > Lambda cyhalothrin 5 EC > Indoxacarb 15.8 EC > Dichlorvos 45SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

Resistance ratio of *S. litura* population found in this district against chlorantraniliprole 20 SC was found to be 2.06, 8.58 and 1.10 folds resistant compared to the susceptible population at 24, 48 and 72 HAF respectively. The same for indoxacarb 15.8 EC was 2.54, 2.09 and 2.28, lambda cyhalothrin 5 EC 4.29, 3.26 and 2.10, for spinosad 45 SC 4.06, 2.15 and 1.05, for dichlorvos 46 SC, 4.27, 2.71 and 1.77 folds, for emamectin benzoate 5 G 4.20, 5.23 and 2.19, for imidacloprid 17.5 SC it was 32.43, 22.26 and 17.97, for flubendiamide 480 SC it was 3.42, 3.92 and 2.10 folds and for lufenuron 5 EC the resistance ratio was found to be 2.94, 2.54 and 2.07 folds at 24, 48 and 72 HAF, respectively.

4.3.2. Nainital

Among the various insecticides tested against third instar larvae, at 24 HAF, Spinosad 45EC recorded highest toxicity with LC₅₀ value of 0.000420% followed by Indoxacarb 15.8 EC (0.000505%), Chlorantraniliprole (Coragen) (0.000604%), Emamectin benzoate 5 G (0.000759%), Lambda cyhalothrin 5 EC (0.000816%), Dichlorvos 45SC (0.001163%), Flubendiamide 480 SC (0.003419%) and Lufenuron 5 EC (0.010892%). Imidacloprid 17.5 SC (0.012870%) was recorded as least lethal insecticide (Table No. 4.3.2).

The order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as follows, spinosad 45 SC > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Emamectin

benzoate 5 G > Lambda cyhalothrin 5 EC > Dichlorvos 45SC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

Among the various insecticides tested against third instar larvae, **at 48 hr HAF**, Spinosad 45 EC recorded highest toxicity with LC₅₀ value of 0.000145% followed by Indoxacarb 15.8 EC (0.000294%), Emamectin benzoate 5G (0.000318%), Lambda cyhalothrin 5 EC (0.000529%), Dichlorvos 45SC (0.000562%), Chlorantraniliprole (Coragen) (0.000624%) and Flubendiamide 480 SC (0.002533%). Lufenuron 5 EC was found to be least lethal with LC₅₀ value of 0.006410%.

The order of toxicity of various insecticides to the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as follows, Spinosad 45 SC > Indoxacarb 15.8 EC > Emamectin benzoate 5G > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Chlorantraniliprole (Coragen) > Flubendiamide 480 SC > Lufenuron 5 EC.

Among the various insecticides tested against third instar larvae, **at 72 hr HAF**, Emamectin benzoate 5G recorded highest toxicity with LC₅₀ value of 0.000095% followed by Spinosad 45EC (0.000106%), Indoxacarb 15.8 EC (0.000206%), Lambda cyhalothrin 5 EC (0.000251%), Chlorantraniliprole (Coragen) (0.000255%), Dichlorvos 45SC (0.000369%) and Flubendiamide 480 SC (0.001080%). Lufenuron 5 EC was found to be least lethal with LC₅₀ value of 0.004119%.

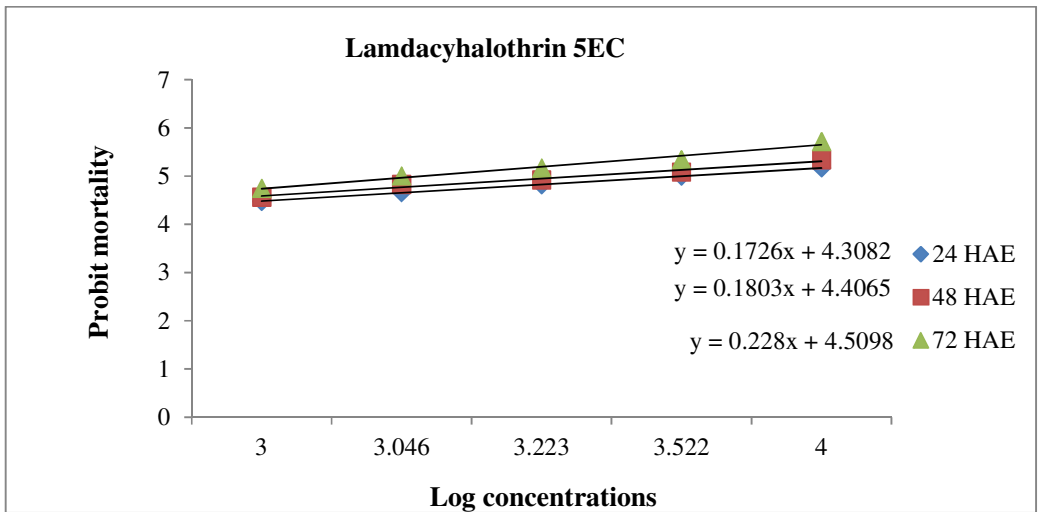
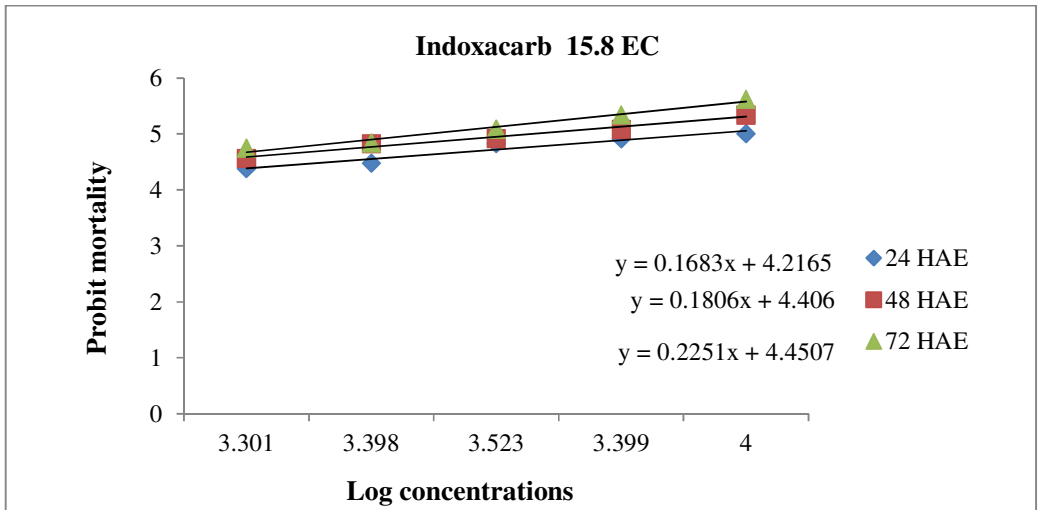
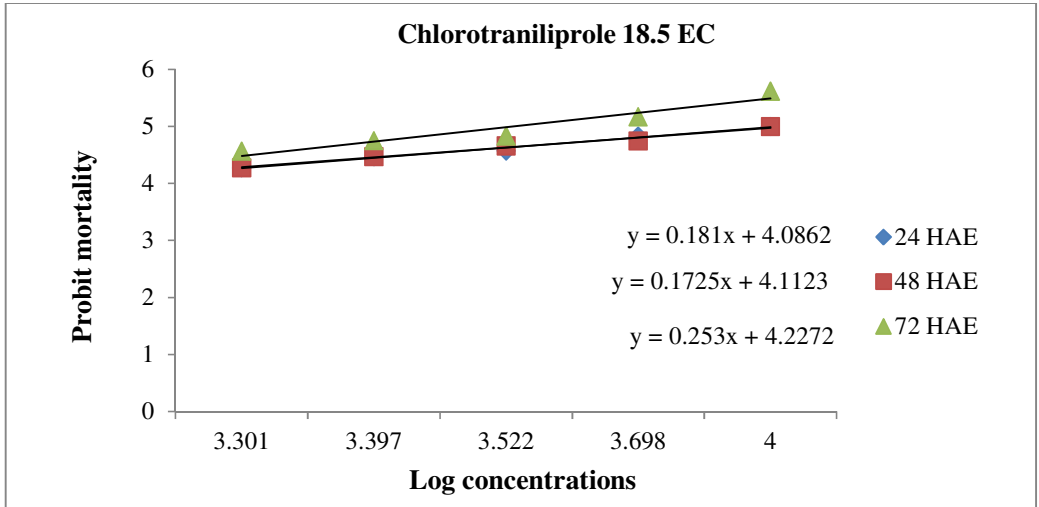
The order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as follows, Emamectin benzoate 5G > spinosad 45 SC > Indoxacarb 15.8 EC > Lambda cyhalothrin 5 EC > Chlorantraniliprole (Coragen) > Dichlorvos 45SC > Flubendiamide 480 SC > Lufenuron 5 EC.

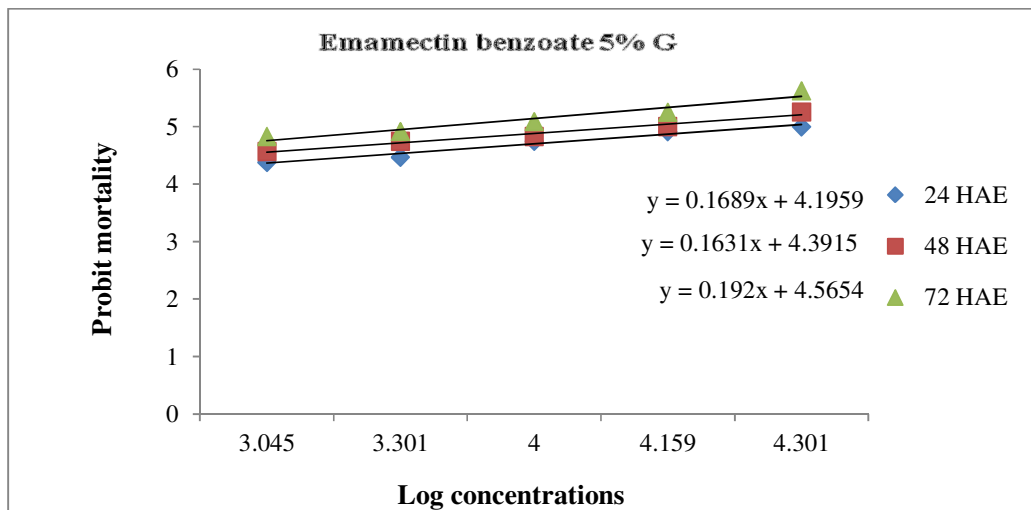
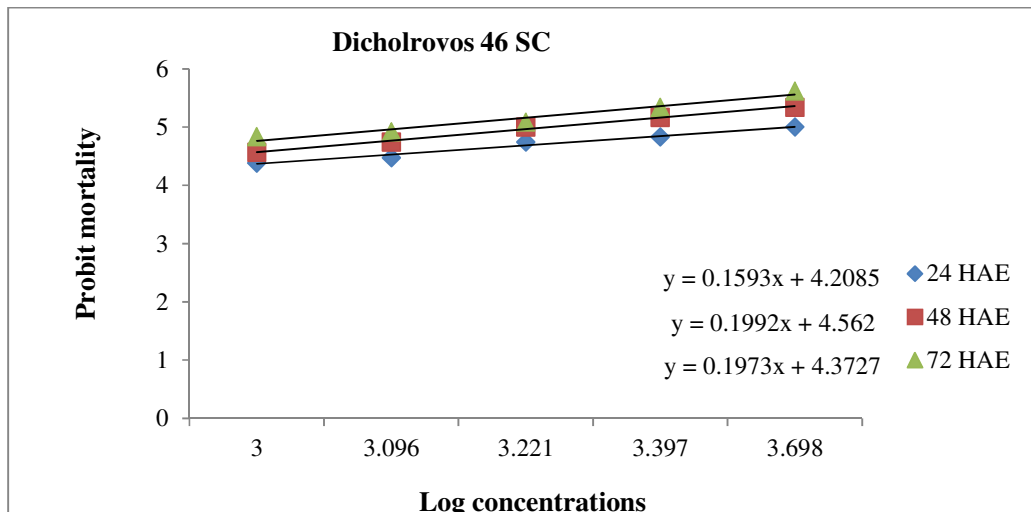
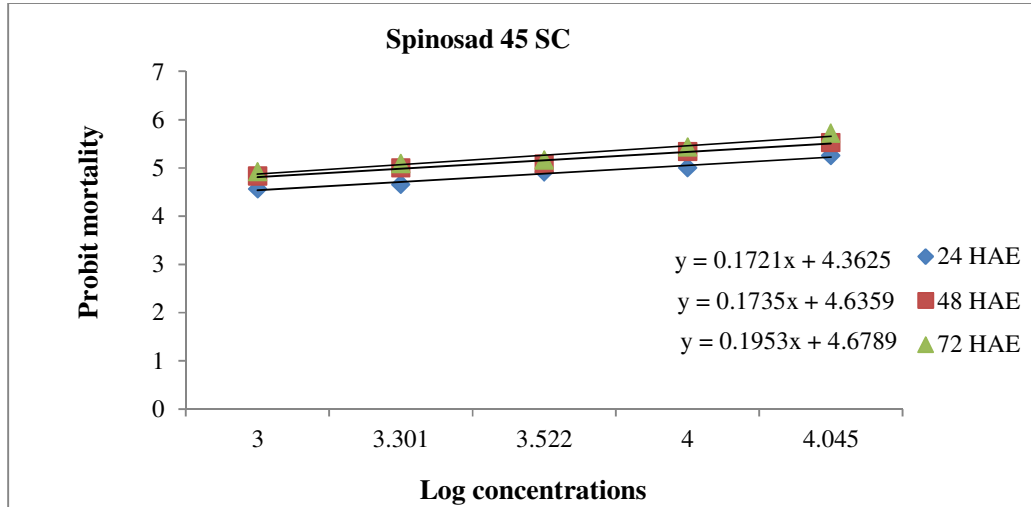
The resistance ratio for *S. litura* population of this district when compared to susceptible population for chlorantraniliprole 20 SC was found 2.90 at 24, 5.44 at 48 and 3.08 folds at 72 HAF. This ratio for indoxacarb 15.8 EC was 2.96, 2.93 and 2.95 folds, for lambda cyhalothrin 5 EC 2.71, 4.16 and 3.87 folds, spinosad 45 SC it was 3.31, 1.86 and 2.23 folds, for dichlorvos 46 SC it was 4.13, 2.38 and 2.00, emamectin benzoate 5 G it was 12.65, 14.10 and 5.07, for imidacloprid 17.5 SC 12.06, **0.00** and **0.00**, for flubendiamide 480 SC it was 3.49, 4.81 and 3.66 folds, whereas, for lufenuron 5 EC it was found to be 3.14, 2.72 and 3.11 folds at 24, 48 and 72 HAF, respectively.

Table 4.3.2: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Nainital population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAF (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraniliprole (Coragen)	24	0.000186	0.000604	0.010923	0.4938715	Y=4.086+0.181x	0.000357	0.075888
	48	0.000183	0.000624	0.012693	0.3457071	Y=4.112+0.172x	0.000360	0.4979291
	72	0.000566	0.000255	0.000036	0.1093492	Y=4.227+0.253x	0.000368	0.000171
Indoxacarb 15.8 EC	24	0.000147	0.000505	0.010562	0.4379930	Y=4.216+0.168x	0.000306	0.063691
	48	0.000090	0.000294	0.005391	0.441748	Y=4.406+0.180x	0.000156	0.000868
	72	0.000076	0.000206	0.002371	1.371490	Y=4.450+0.255x	0.000090	0.000310
Lamdacyhalothrin 5 EC	24	0.000124	0.000816	0.083603	0.5192323	Y=4.308+0.172x	0.000385	0.1142634
	48	0.000084	0.000529	0.048605	0.8426778	Y=4.406+0.180x	0.000190	0.003616
	72	0.000056	0.000251	0.010165	1.663018	Y=4.509+0.228x	0.000050	0.000455
Spinosad 45EC	24	0.000059	0.000420	0.053044	0.085605	Y=4.362+0.172x	0.000182	0.006952
	48	0.000019	0.000145	0.021444	0.4371341	Y=4.635+0.173x	0.000002	0.000329
	72	0.000017	0.000106	0.009162	0.6626536	Y=4.678+0.195x	0.000003	0.000220
Dichlorovas 45SC	24	0.000307	0.001163	0.030771	0.3730946	Y=4.208+0.159x	0.000663	0.00132
	48	0.000192	0.000562	0.007902	0.3165635	y=4.372+0.197x	0.000320	0.001160
	72	0.000118	0.000369	0.006080	1.341079	y=4.562+0.199x	0.000077	0.000582
Emamectin benzoate 5G	24	0.000057	0.000759	0.4524737	0.5923066	Y=4.195+0.168x	0.000259	0.000822
	48	0.000023	0.000318	0.2149569	0.3816079	Y=4.391+0.163x	0.000101	0.2202692
	72	0.000010	0.000095	0.022506	0.6215048	Y=4.565+0.192x	0.000072	0.000236
Imidachloprid 17.5 SC	24	0.000231	0.012873	3.032521	2.972737	Y=4.155+0.170x	0.001719	0.096351
	48	0.000382	0.023871	1.23541	1.75321	Y=4.241+0.182x	0.000232	
	72	0.000071	0.000736	0.23145	0.23546	Y=4.531+0.161x		
Flubendiamide 480SC	24	0.000717	0.003419	0.159962	0.069017	Y=4.226+0.196x	0.001841	0.1363166
	48	0.000495	0.002533	0.140882	1.357451	Y=4.323+0.179x	0.001285	0.046517
	72	0.000227	0.001080	0.050332	1.217053	Y=4.750+0.100x	0.000117	0.002047
Lufenuron 5EC	24	0.003473	0.010892	0.181593	0.1798751	Y=4.120+0.181x	0.006696	0.3563894
	48	0.001858	0.006410	0.135113	0.2568368	Y=4.397+0.172x	0.003537	0.035587
	72	0.001527	0.004119	0.047424	1.372103	Y=4.450+0.225x	0.001790	0.006203

Mean larval wt.=0.0232g/larva (23.2 mg)





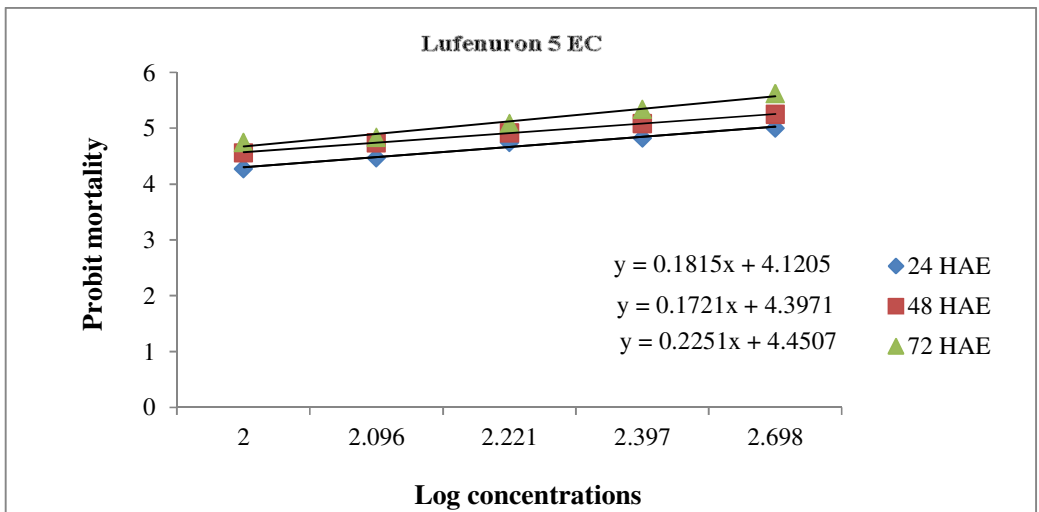
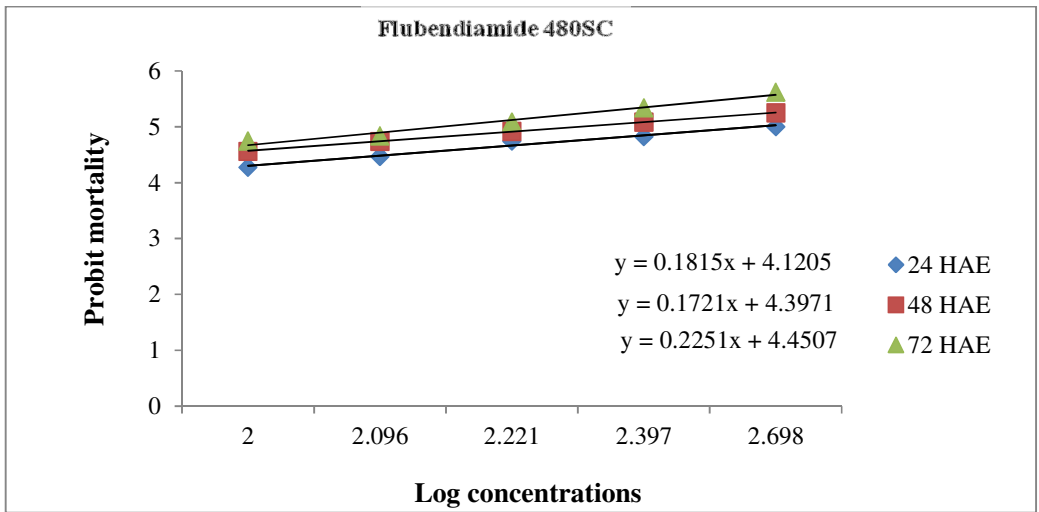
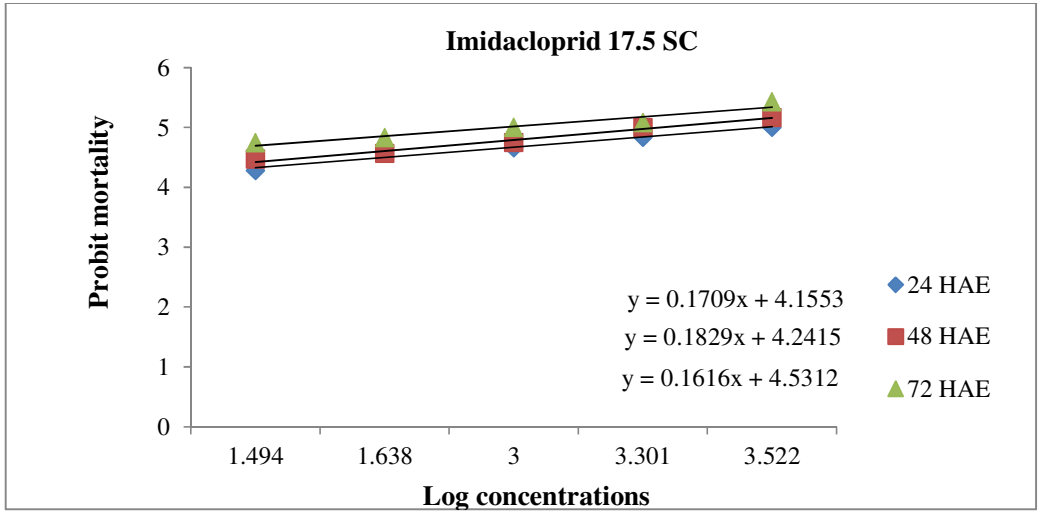


Fig. 4.3.2. Dosage-mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Nainital population by leaf dip bioassay method

4.3.3. Haridwar

At **24 HAF** (Table No. 4.3.3), the resistance level of larvae was found to be least when treated with Chlorantraniliprole (Coragen) with LC₅₀ value of 0.00037% followed by Emamectin benzoate 5 G (0.00041%), Indoxacarb 15.8 EC (0.00050%), Spinosad 45 EC (0.00068%). Dichlorvos 45 SC (0.00113%), Lambda cyhalothrin 5 EC (0.00161%), Flubendiamide 480 SC (0.00375%) and Imidacloprid 17.5 SC (0.01217%). But, the larvae was found to be least mortal with Lufenuron 5 EC (0.01320%).

In particular, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Chlorantraniliprole (Coragen) > Emamectin benzoate 5G > Indoxacarb 15.8 EC > spinosad 45 SC > Dichlorvos 45 SC > Lambda cyhalothrin 5 EC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

At **48 HAF**, the resistance level of larvae was found to be least when treated with Emamectin benzoate 5 G with LC₅₀ value of 0.00017% Spinosad 45 EC (0.00044%), followed by Chlorantraniliprole (Coragen) (0.00027%). Indoxacarb 15.8 EC (0.00033%) Dichlorvos 45 SC (0.00071%), Lambda cyhalothrin 5 EC (0.00085%), Imidacloprid 17.5 SC (0.00180%) and Flubendiamide 480 SC (0.00183%). But, the larvae was found to be least mortal with Lufenuron 5 EC (0.00563%)

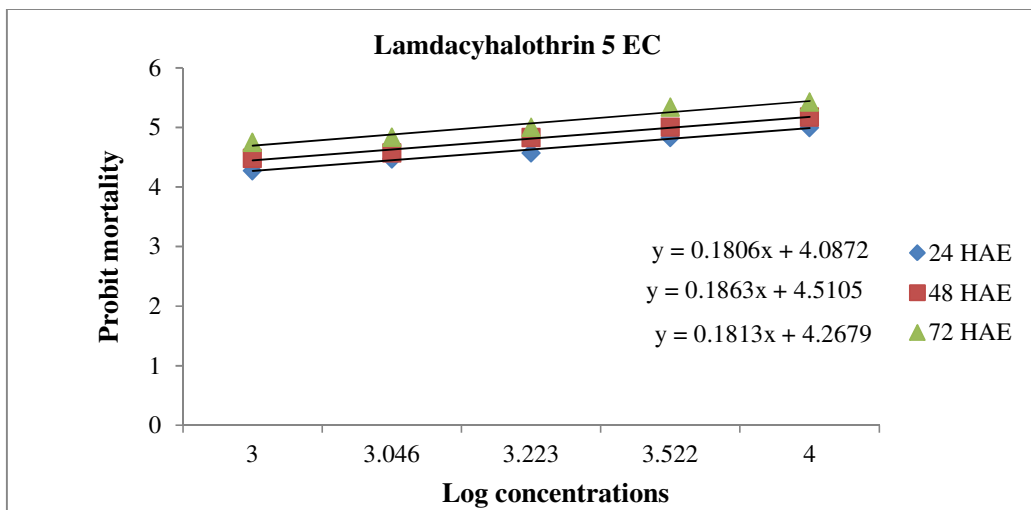
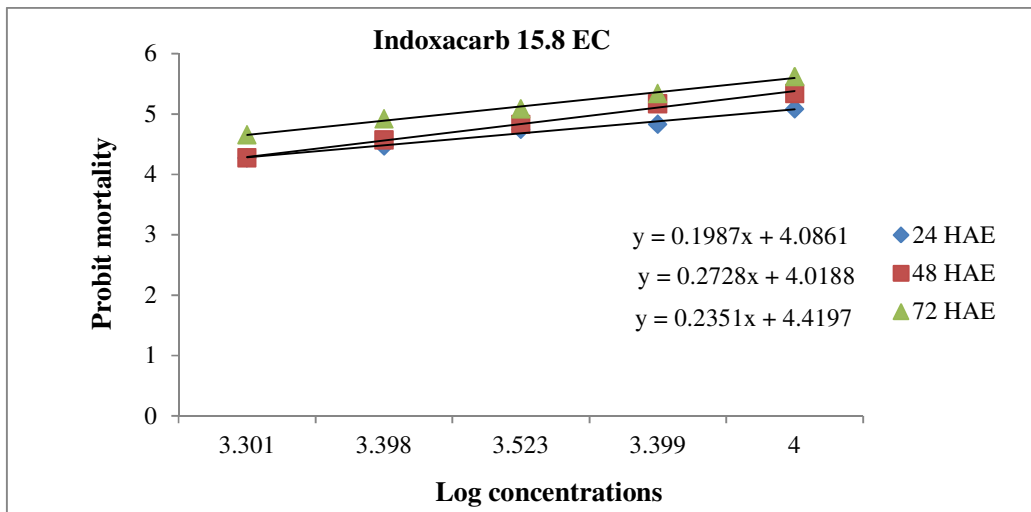
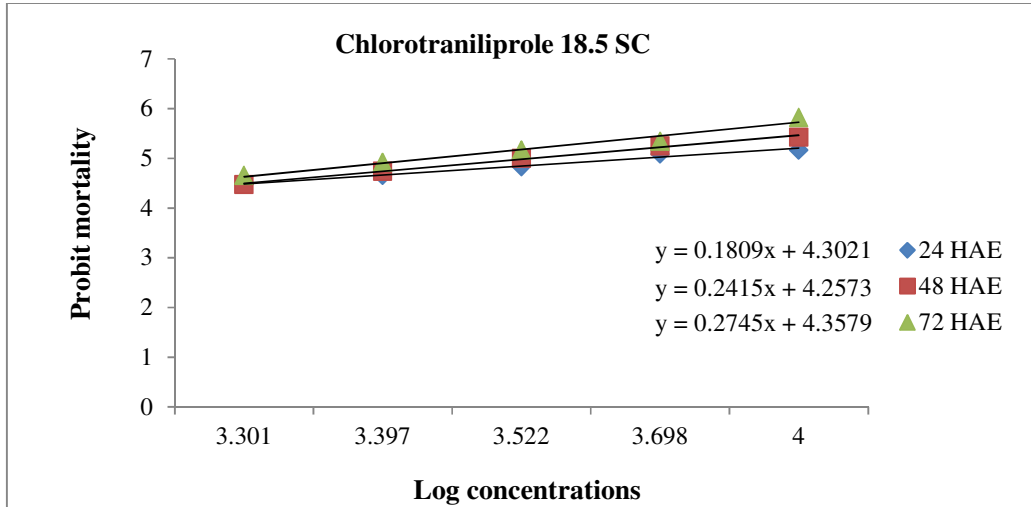
In particular, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > Chlorantraniliprole (Coragen) > Indoxacarb 15.8 EC > spinosad 45 SC > Dichlorvos 45 SC > Lambda cyhalothrin 5 EC > Imidacloprid 17.5 SC > Flubendiamide 480 SC > Lufenuron 5 EC.

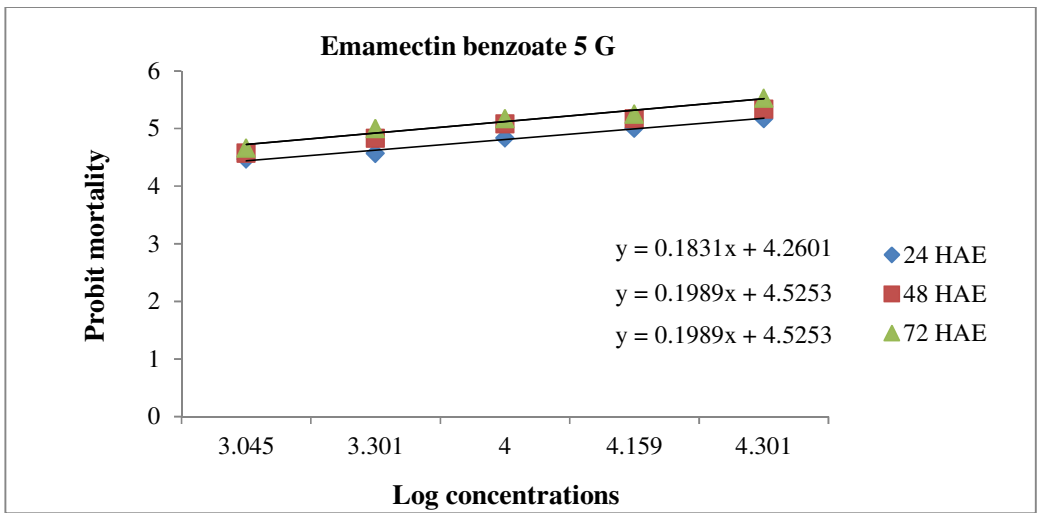
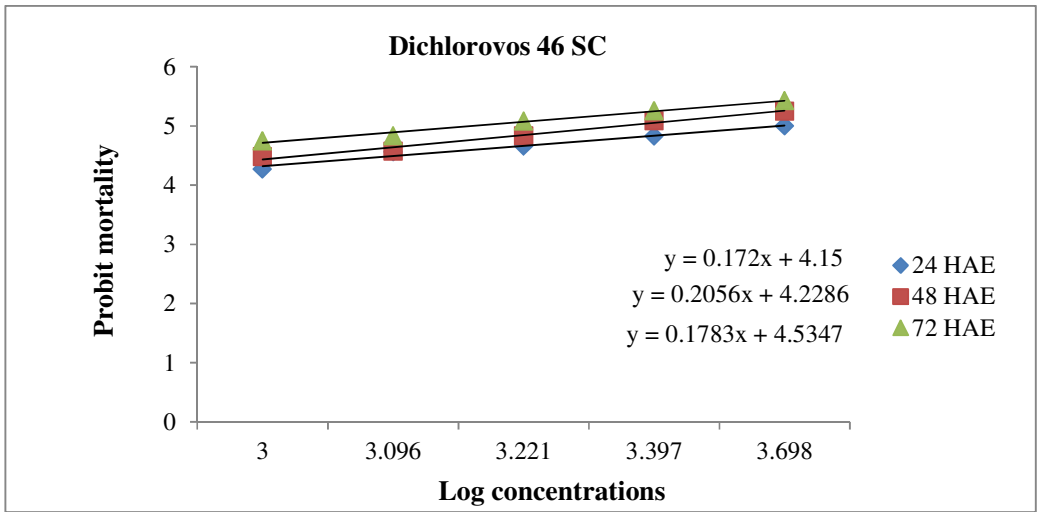
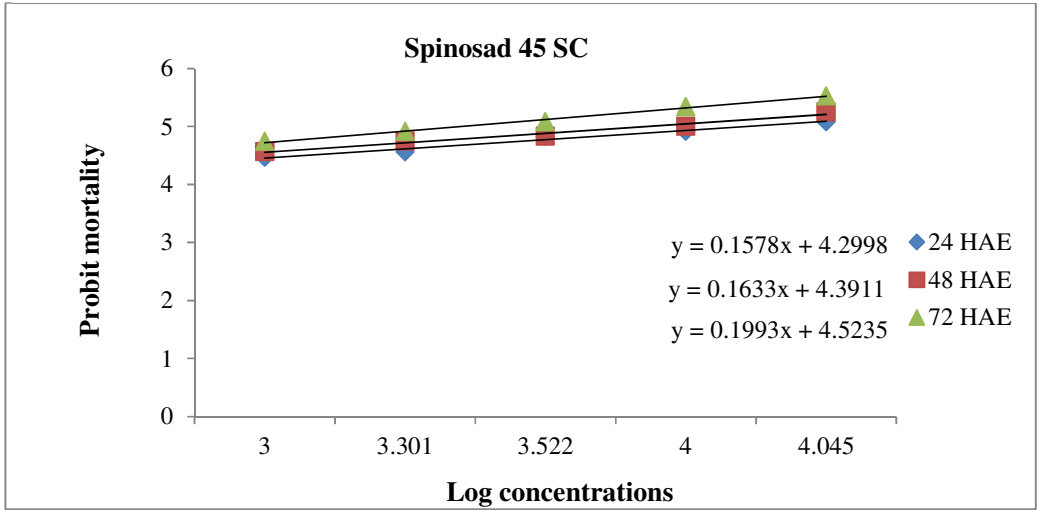
At **72 HAF**, the resistance level of larvae was found to be least when treated with Emamectin benzoate 5 G with LC₅₀ value of 0.00010% followed by Spinosad 45 EC (0.00018%), Chlorantraniliprole (Coragen) (0.00020%), Indoxacarb 15.8 EC (0.00021%), Lambda cyhalothrin 5 EC (0.00035%) Dichlorvos 45 SC (0.00044%), Imidacloprid 17.5 SC (0.00050%) and Flubendiamide 480 SC (0.00110%). But, the larvae were found to be least mortal with Lufenuron 5 EC (0.00355%).

Table 4.3.3: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Haridwar population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.00011	0.00037	0.00654	0.32188	Y=4.302+0.180x	0.00023	0.00230
	48	0.00011	0.00027	0.00230	0.34505	Y=4.257+0.241x	0.00018	0.00042
	72	0.00009	0.00020	0.00164	0.9023608	Y=4.357+0.274x	0.00011	0.00028
Indoxacarb 15.8 EC	24	0.00017	0.00050	0.00671	0.3861240	Y=4.086+0.198x	0.00032	0.00428
	48	0.00015	0.00033	0.00220	0.5425525	Y=4.018+0.272x	0.00024	0.00055
	72	0.00008	0.00021	0.00203	0.7261568	Y=4.419+0.235x	0.00011	0.00031
Lamdaacyhalothrin 5 EC	24	0.00026	0.00161	0.1426475	0.8425751	Y=4.087+0.180x	0.00071	33.82686
	48	0.00014	0.00085	0.07420	0.8390970	Y=4.267+0.181x	0.00041	0.05452
	72	0.00006	0.00035	0.03062	1.31763	Y=4.510+0.186x	0.00004	0.00085
Spinosad 45EC	24	0.00008	0.00068	0.1356267	0.05776	Y=4.299+0.157x	0.00029	15.90431
	48	0.00005	0.00044	0.08704	0.4286012	Y=4.391+0.163x	0.00017	0.1014692
	72	0.00003	0.00018	0.01300	0.3087889	Y=4.523+0.199x	0.00003	0.00037
Dichlorovas 45SC	24	0.00034	0.00113	0.02229	0.1586293	Y=4.15+0.172x	0.00068	0.2067218
	48	0.00025	0.00071	0.00946	0.8550527	Y=4.228+0.205x	0.00047	0.00223
	72	0.00013	0.00044	0.00900	0.5787230	Y=4.534+0.178x	0.00011	0.00081
Emamectin benzoate 5G	24	0.00004	0.00041	0.1473600	0.5315066	Y=4.260+0.183x	0.00016	0.03331
	48	0.00001	0.00017	0.07339	1.31795	Y=4.525+0.198x	0.00003	0.00105
	72	0.00001	0.00010	0.02992	1.57510	Y=4.525+0.198x	0.00001	0.00027
Imidachloprid 17.5 SC	24	0.00035	0.01217	76.03965	2.13131	Y=4.082+0.229x	0.00210	0.07040
	48	0.00006	0.00180	7.09899	1.49413	Y=4.354+0.232x	0.00047	0.00686
	72	0.00002	0.00050	1.25539	2.14522	Y=4.519+0.248x	0.00010	0.00246
Flubendiamide 480SC	24	0.00114	0.00375	0.07085	0.22990	Y=3.949+0.230x	0.00226	0.01956
	48	0.00039	0.00183	0.08354	0.27160	Y=4.422+0.180x	0.00076	0.00629
	72	0.00030	0.00110	0.02802	0.45719	Y=4.507+0.217x	0.00032	0.00186
Lufenuron 5EC	24	0.00381	0.01320	0.28118	0.54894	Y=4.094+0.172x	0.00745	56.54604
	48	0.00183	0.00563	0.08979	0.36859	Y=4.397+0.189x	0.00304	0.01288
	72	0.00099	0.00355	0.08232	0.62497	Y=4.639+0.172x	0.00016	0.00594

Mean larval wt.=0.0232g/larva (23.2 mg)





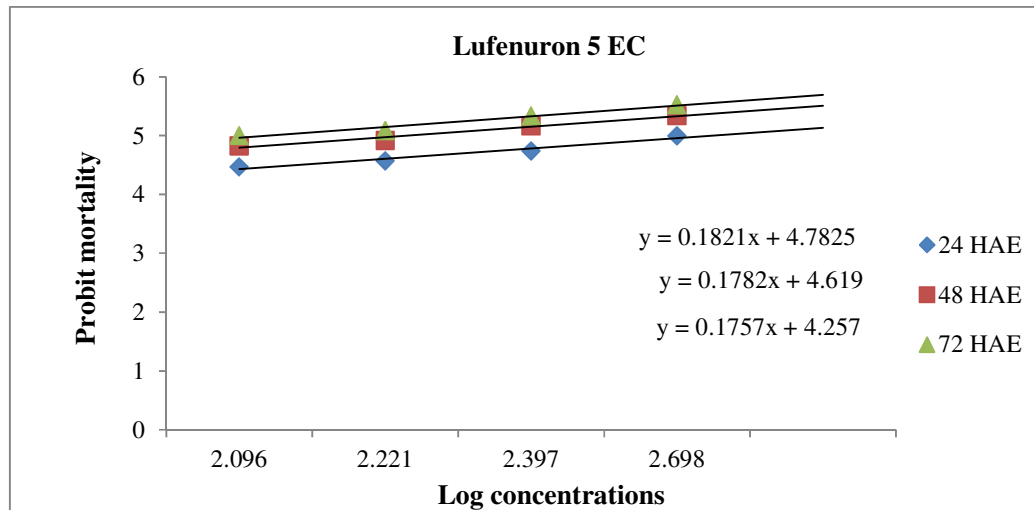
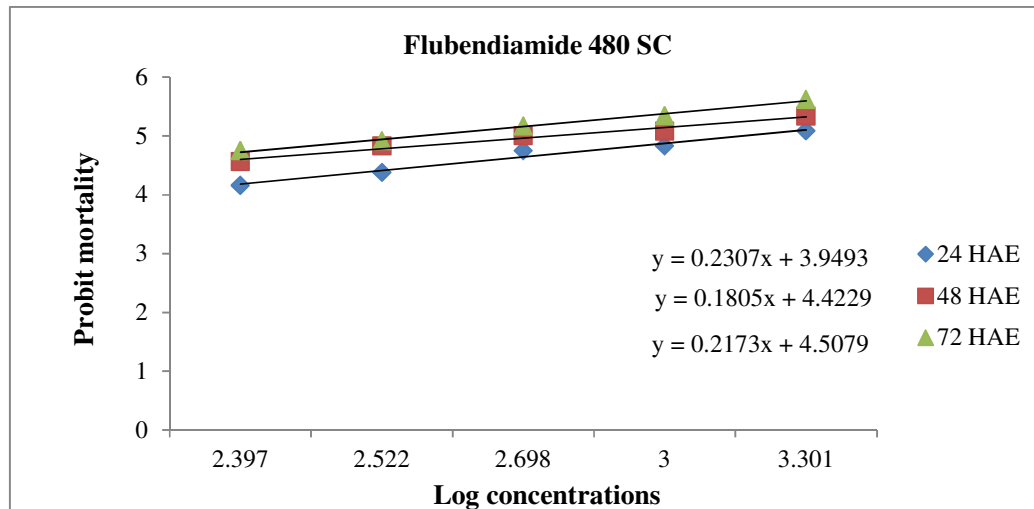
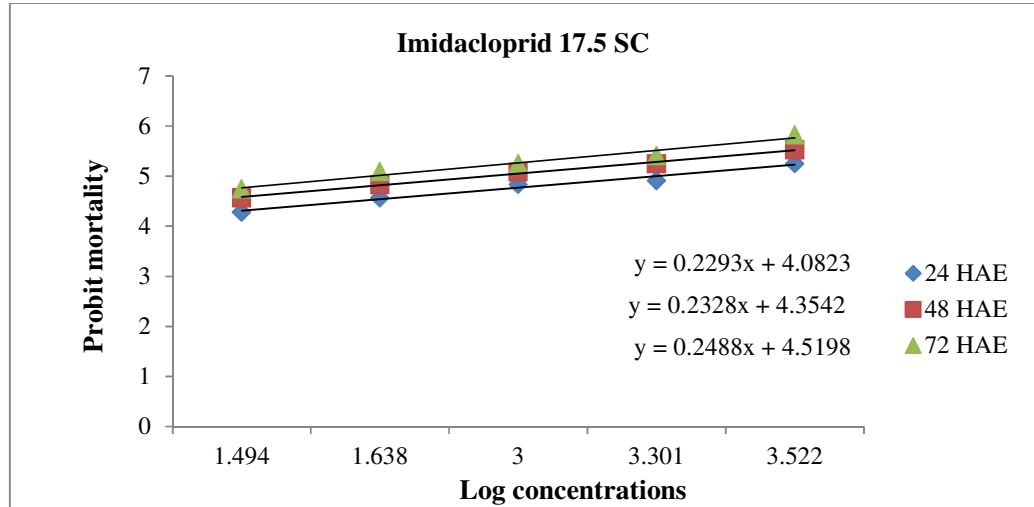


Fig. 4.3.3. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Haridwar population by leaf dip bioassay method

In particular, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC50) is as follows, Emamectin benzoate 5G > Spinosad 45 SC> Chlorantraniliprole (Coragen) > Indoxacarb 15.8 EC > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Imidacloprid 17.5 SC > Flubendiamide 480 SC >Lufenuron 5 EC.

S. litura population collected from this district exhibited 1.78, 2.36 and 2.42 folds resistance to chlorantraniliprole 20 SC at 24, 48 and 72 HAF respectively. The same population showed resistance against indoxacarb 15.8 EC 2.94, 3.29 and 3.01 times, for lambda cyhalothrin 5 EC, 5.36, 6.69 and 5.39 times, for spinosad 45 SC, 5.37, 5.63 and 3.79 times, for dichlorvos 46 SC, 4.01, 3.00 and 2.38 times, for emamectin benzoate 5 G, 6.83, 7.54 and 5.34, for imidacloprid 17.5 SC 11.40, 16.29 and 6.82 times, for flubendiamide 480 SC, 3.83, 3.47 and 3.73 and for lufenuron 5 EC, 3.81, 2.39 and 2.68 times more resistance against susceptible population at 24, 48 and 72 HAF, respectively.

4.3.4. Tehri Garhwal

At 24 hr HAF, Indoxacarb 15.8 EC reported highest larval mortality rate with LC₅₀ value of 0.000390% followed by Spinosad 45 EC (0.000450%), Emamectin benzoate 5 G (0.000472%), Chlorantraniliprole (Coragen) (0.000499%), Dichlorvos 45 SC (0.000981%), Lambda cyhalothrin 5 EC (0.001125%), Flubendiamide 480 SC (0.003146%) and Lufenuron 5 EC (0.012079%). Imidacloprid 17.5 SC (0.043679%) reported lowest larval mortality (Table No. 4.3.4).

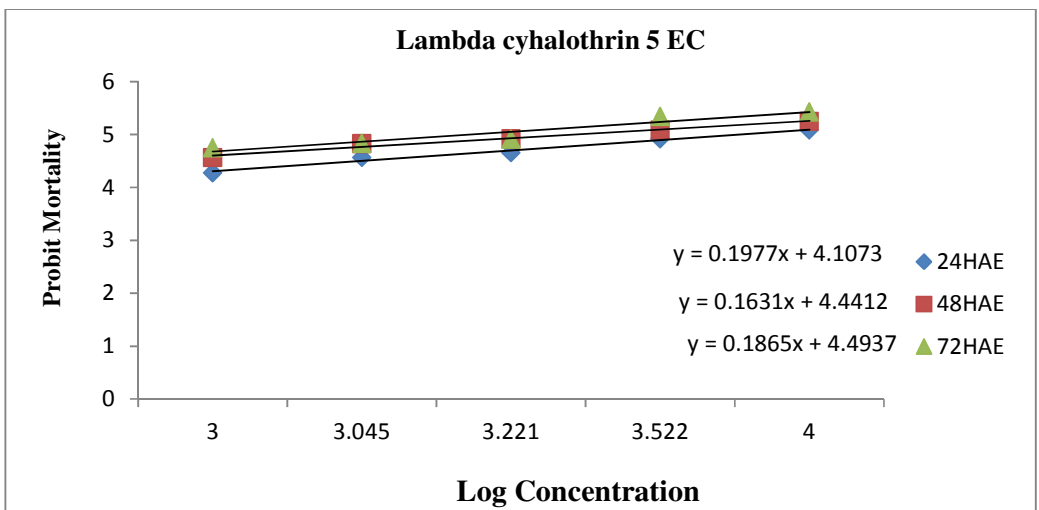
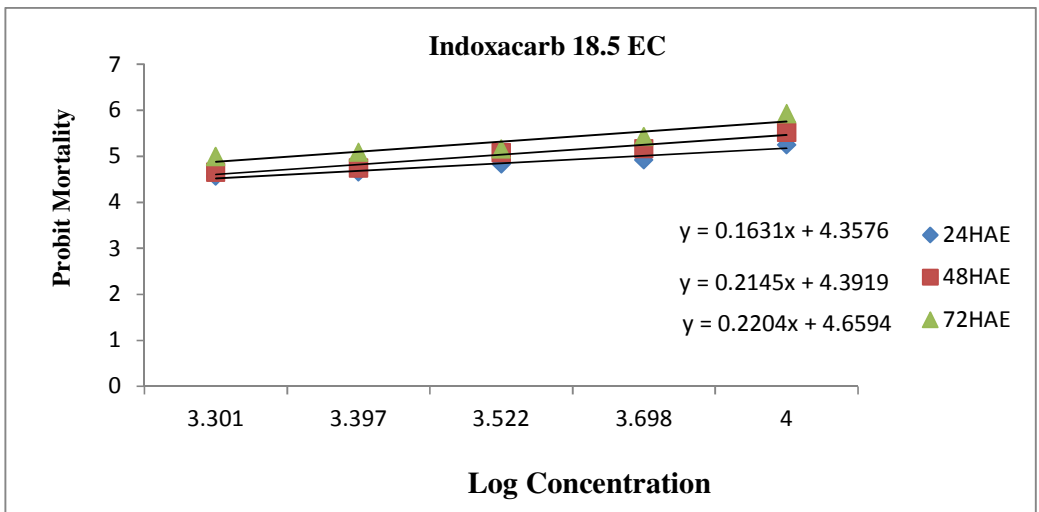
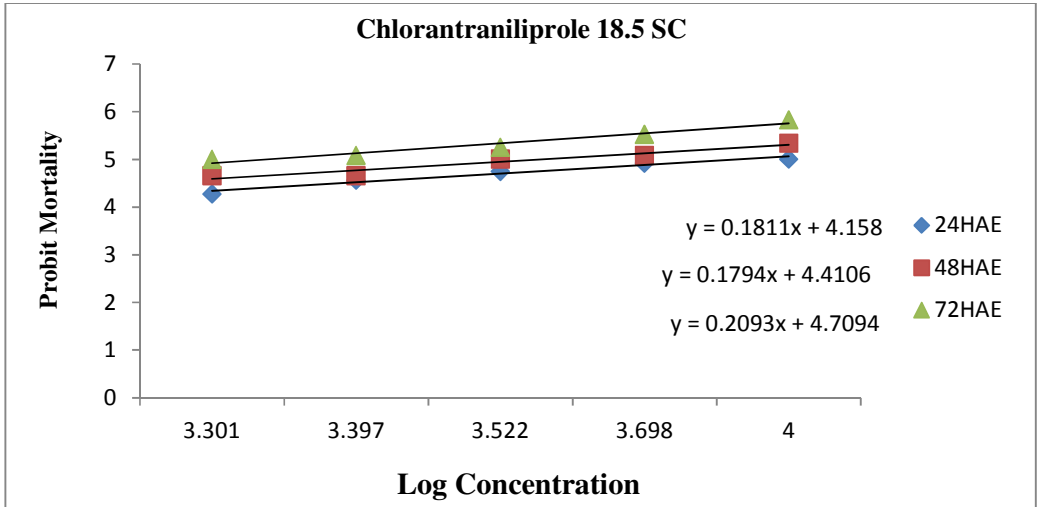
In other words, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC50) is as follows, Indoxacarb 15.8 EC > Spinosad 45 SC > Emamectin benzoate 5G> Chlorantraniliprole (Coragen) > Dichlorvos 45 SC > Lambda cyhalothrin 5 EC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

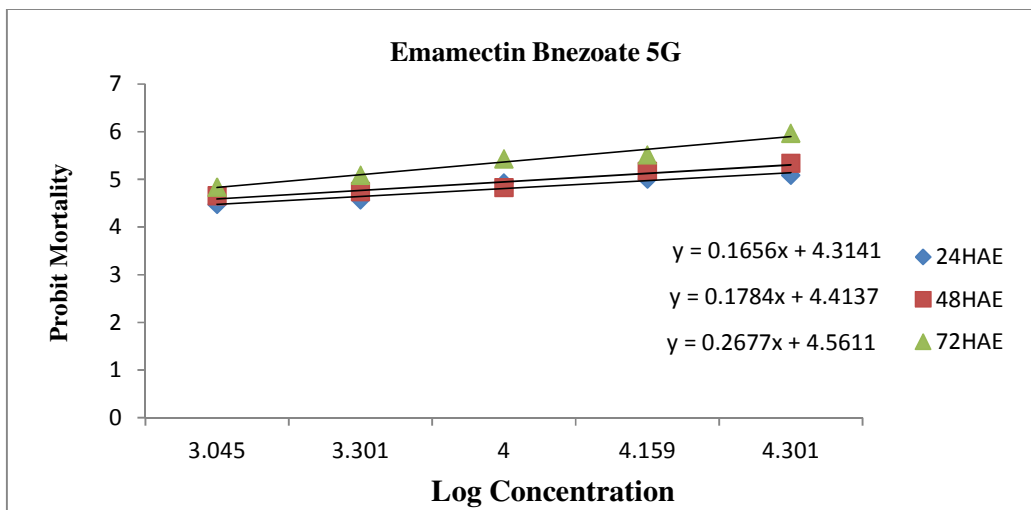
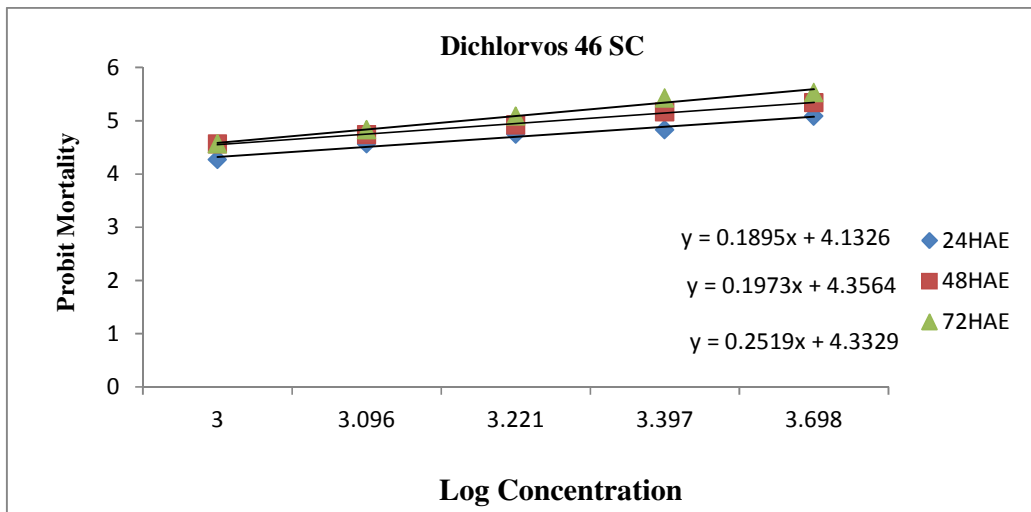
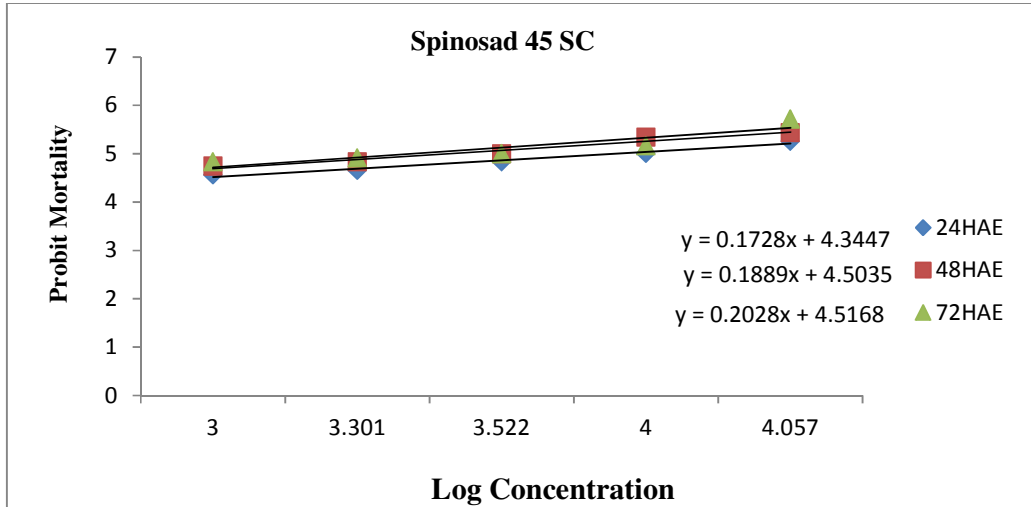
At 48 HAF, Spinosad 45 EC reported highest larval mortality rate with LC₅₀ value of 0.000209% followed by Emamectin benzoate 5 G (0.000217%), Chlorantraniliprole (Coragen) (0.000272%), Lambda cyhalothrin 5 EC (0.000572%), Dichlorvos 45 SC (0.000583%), Flubendiamide 480 SC (0.001836%) and Imidacloprid 17.5 SC (0.004740%). The lowest larval mortality was reported by Lufenuron 5 EC with LC₅₀ value of 0.007091%.

Table 4.3.4: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Tehri Garhwal population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.000161	0.000499	0.008076	0.020683	Y=4.158+0.181x	0.000314	0.008705
	48	0.000072	0.000272	0.007128	0.3936595	Y=4.410+0.179x	0.000089	0.001230
	72	0.000043	0.000426	0.001937	1.499090	Y=4.709+0.209x	0.000011	0.000205
Indoxacarb 15.8 EC	24	0.000100	0.000390	0.011095	0.978107	Y=4.357+0.163x	0.000224	0.762058
	48	0.000088	0.000244	0.003030	1.226188	Y=4.391+0.214x	0.000127	0.000406
	72	0.000045	0.000134	0.001975	3.093346	Y=4.659+0.220x	0.000014	0.000212
Lamdacyhalothrin 5 EC	24	0.000220	0.001125	0.0620724	0.1974795	Y=4.107+0.197x	0.000577	0.040046
	48	0.000079	0.000572	0.0740449	0.4062085	Y=4.441+0.163x	0.000192	0.1915142
	72	0.000056	0.000365	0.036164	1.938587	Y=4.493+0.186x	0.000044	0.001014
Spinosad 45EC	24	0.000062	0.000450	0.05843249	0.175839	Y=4.344+0.172x	0.000199	0.108057
	48	0.000034	0.000209	0.01813501	0.3976571	Y=4.503+0.188x	0.000045	0.000493
	72	0.000032	0.000178	0.01219752	1.719271	Y=4.516+0.202x	0.000036	0.000366
Dichlorovas 45SC	24	0.000327	0.000981	0.014671	0.2392119	Y=4.132+0.189x	0.000625	0.1132740
	48	0.000196	0.000583	0.008519	0.5133094	Y=4.356+0.197x	0.000337	0.001318
	72	0.000196	0.000453	0.003571	0.5304780	Y=4.332+0.251x	0.000273	0.000646
Emamectin benzoate 5G	24	0.000030	0.000472	0.4231053	1.162892	Y=4.314+0.165x	0.000159	0.00521
	48	0.000022	0.000217	0.058742	0.013985	Y=4.413+0.178x	0.000069	0.001372
	72	0.000010	0.000053	0.003344	2.043789	Y=4.561+0.267x	0.000021	0.000136
Imidachloprid 17.5 SC	24	0.000509	0.043679	0.062112	1.157926	Y=4.126+0.180x	0.002130	0.895584
	48	0.000042	0.004740	0.00541	1.432998	Y=4.420+0.170x	0.000325	0.00426
	72	0.000023	0.001469	41.126630	1.370686	Y=4.502+0.189x	0.000274	0.007882
Flubendiamide 480SC	24	0.000618	0.003146	0.172500	0.406005	Y=4.273+0.173x	0.001661	0.188269
	48	0.000348	0.001836	0.110145	0.434912	Y=4.453+0.170x	0.000650	0.006504
	72	0.000209	0.000848	0.026774	1.791302	Y=4.607+0.213x	0.000110	0.001482
Lufenuron 5EC	24	0.003725	0.012079	0.218521	0.494704	Y=4.086+0.181x	0.007150	1.521081
	48	0.002548	0.007091	0.088132	1.307278	Y=4.204+0.214x	0.004689	0.020066
	72	0.001121	0.003267	0.045516	0.416324	Y=4.623+0.201x	0.000700	0.004987

Mean larval wt.=0.0232g/larva (23.2 mg)





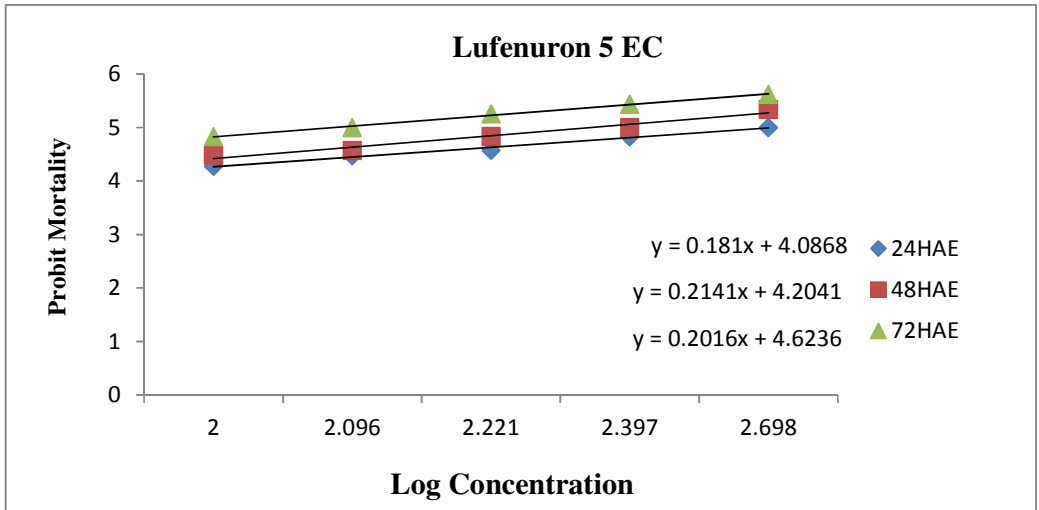
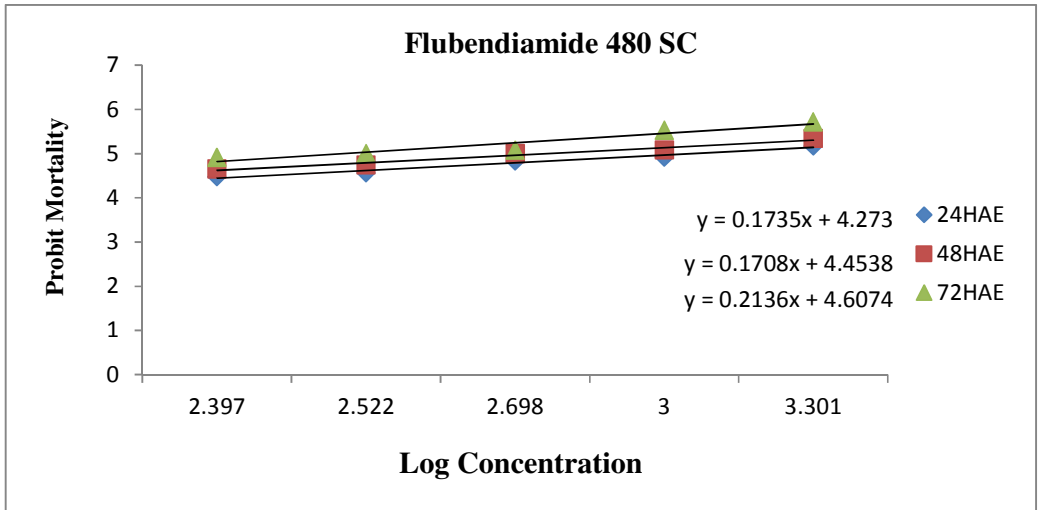
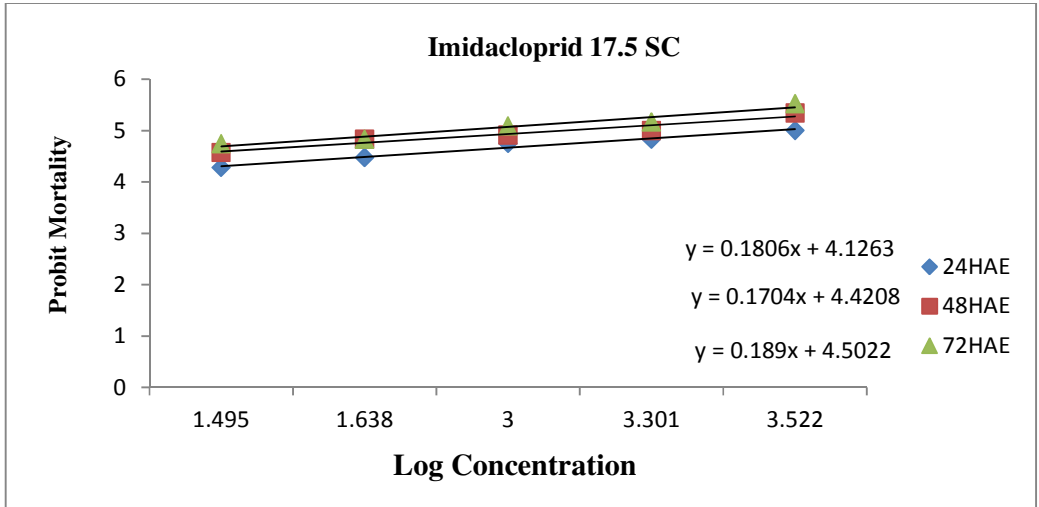


Fig. 4.3.4. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Tehri Garhwal population by leaf dip bioassay method

In other words, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Spinosad 45 SC > Emamectin benzoate 5G > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

At **72 HAF**, Emamectin benzoate 5 G reported highest larval mortality rate with LC₅₀ value of 0.000053% followed by Indoxacarb 15.8 EC (0.000134%), Lambda cyhalothrin 5 EC (0.000365%), Spinosad 45 EC (0.000178%), Chlorantraniliprole (Coragen) (0.000426%), Dichlorvos 45 SC (0.000453%), Flubendiamide 480 SC (0.000848%) and Imidacloprid 17.5 SC (0.001469%). The lowest larval mortality was reported by Lufenuron 5 EC with LC₅₀ value of 0.003267%.

In other words, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > Indoxacarb 15.8 EC > Spinosad 45 SC > Lambda cyhalothrin 5 EC > Chlorantraniliprole (Coragen) > Dichlorvos 45 SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

Resistance ratio for *S. litura* populations collected from this district against chlorantraniliprole was found to be, 2.40, 2.37 and 5.15 time more as compared to the susceptible population at 24, 48 and 72HAF, respectively. This ratio for indoxacarb 15.8 EC was 2.29, 2.43 and 1.92 times, for lambda cyhalothrin 5 EC, 3.74, 4.50 and 5.62 times, for spinosad 45SC, 3.55, 2.68 and 3.74 times, for dichlorvos 46 SC it was, 3.49, 2.46 and 2.46 times, for emamectin benzoate 5G, 7.87, 9.62 and 2.83 times, for imidacloprid 17.5 SC, 40.91, 42.88 and 20.03 times, for flubendiamide 480SC, 3.21, 3.49 and 2.88 times and for lufenuron 5EC it was 3.49, 3.01 and 2.47 times at 24, 48 and 72 HAF, respectively.

4.3.5. Pithoragarh

Among the various insecticides tested against third instar larvae, at **24 HAF** the results revealed that Emamectin benzoate 5 G was highly toxic with LC₅₀ value of 0.000394% followed by Indoxacarb 15.8 EC (0.000411%), Chlorantraniliprole (Coragen) (0.000499%), Spinosad 45 EC (0.000582%), Lambda cyhalothrin 5 EC

(0.000955%), Dichlorvos 45 SC (0.001236%), Flubendiamide 480 SC (0.003273%) and Lufenuron 5 EC (0.009332%). Imidacloprid 17.5 SC was found to be least toxic with LC₅₀ value 0.047415% (Table No. 4.3.5).

The order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as Emamectin benzoate 5G > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Spinosad 45 SC > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

Among the various insecticides tested against third instar larvae, **at 48 HAF** the results revealed that Emamectin benzoate 5 G was highly toxic with LC₅₀ value 0.000119% followed by Indoxacarb 15.8 EC, Spinosad 45 EC Chlorantraniliprole (Coragen), Dichlorvos 45 SC, Lambda cyhalothrin 5 EC, Flubendiamide 480 SC and Lufenuron 5 EC with LC₅₀ values of 0.000215%, 0.000247%, 0.000335%, 0.000666%, 0.000745%, 0.002063%, 0.006569% respectively. The least toxicity was recorded by Imidacloprid 17.5 SC (0.011833%).

The order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as Emamectin benzoate 5G > Indoxacarb 15.8 EC > Spinosad 45 SC > Chlorantraniliprole (Coragen) > Dichlorvos 45 SC > Lambda cyhalothrin 5 EC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

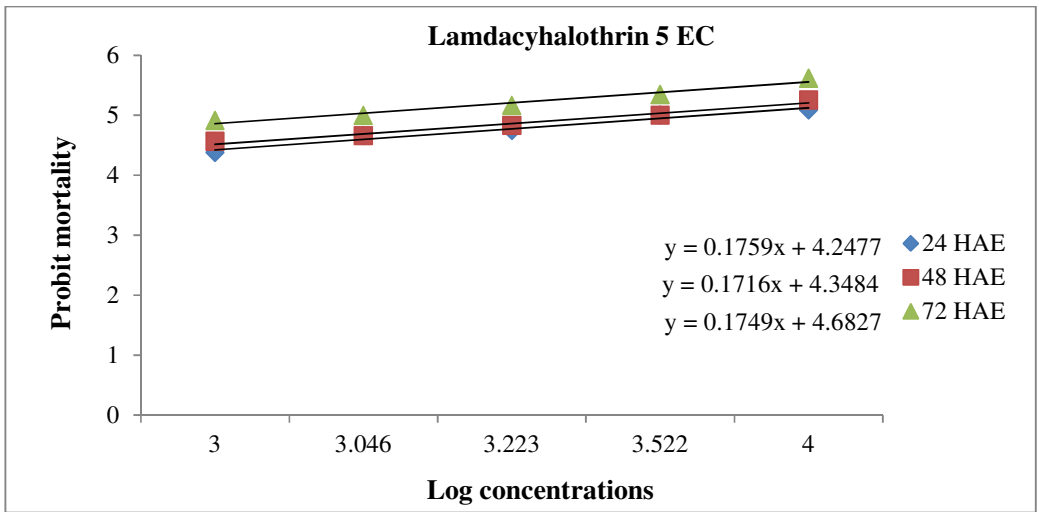
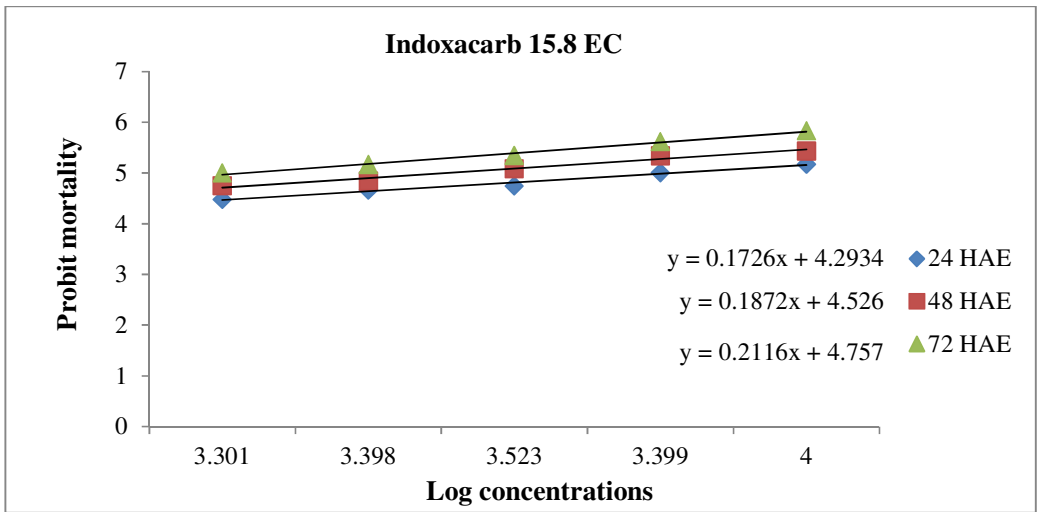
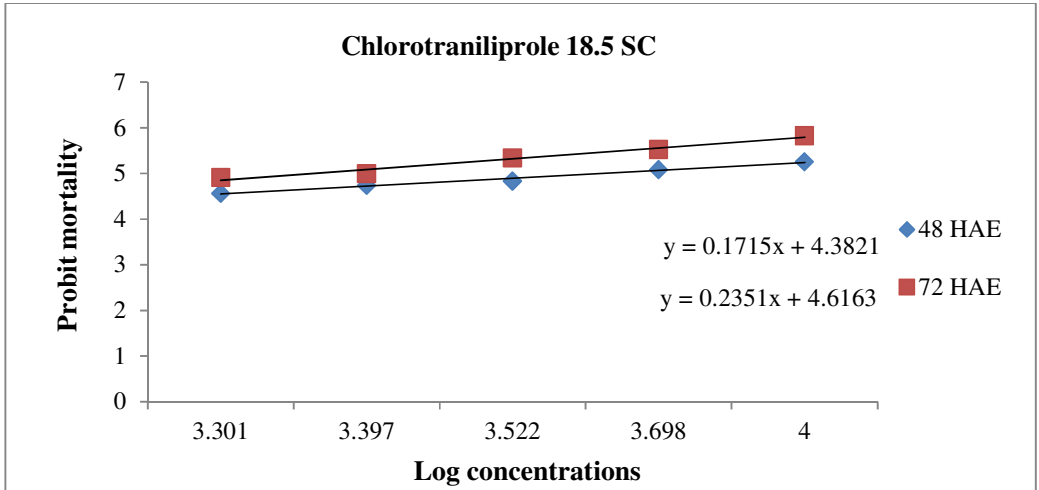
Among the various insecticides tested against third instar larvae, **at 72 HAF**, the results revealed that Indoxacarb 15.8 EC with LC₅₀ value of 0.000118% followed by Spinosad 45 EC (0.000130%), Chlorantraniliprole (Coragen) (0.000145%), Lambda cyhalothrin 5 EC (0.000257%), Dichlorvos 45 SC (0.000522%), Emamectin benzoate 5 G (0.000522%), Flubendiamide 480 SC (0.000796%) and Imidacloprid 17.5 SC (0.002192%). The least toxicity was recorded by Lufenuron 5 EC (0.003553%).

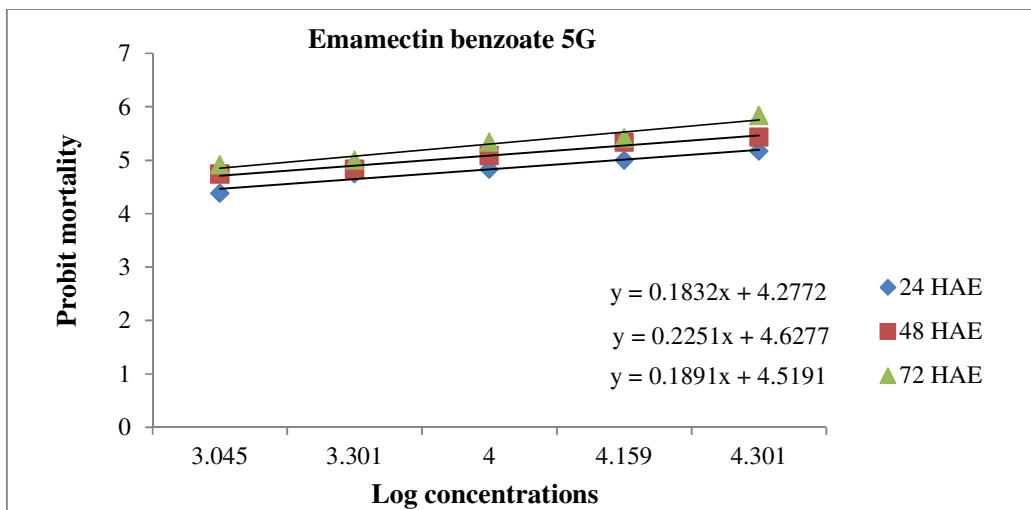
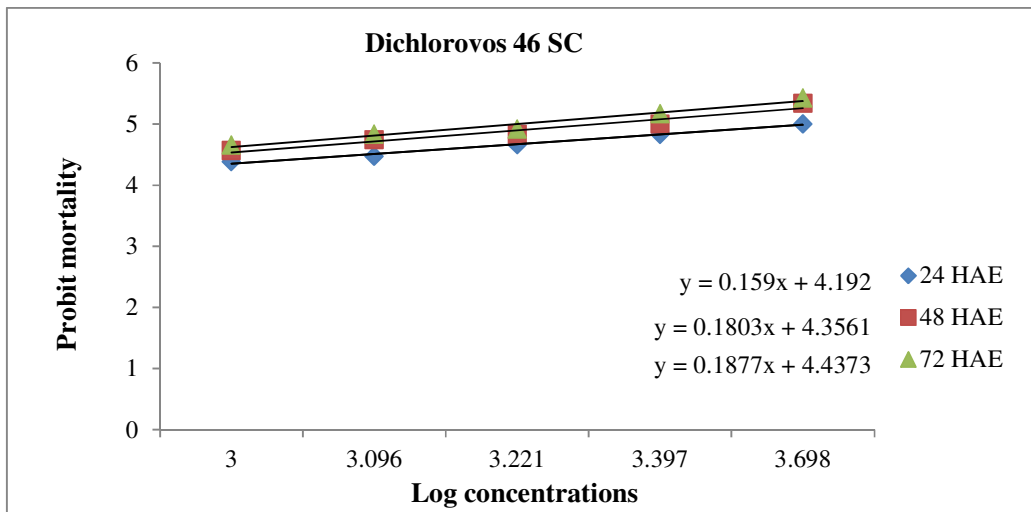
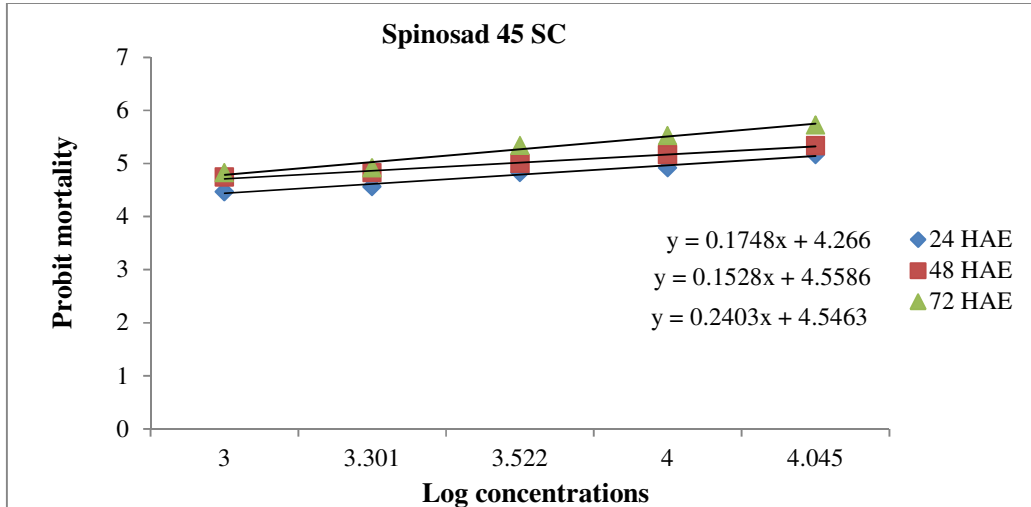
The order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Indoxacarb 15.8 EC > Spinosad 45 SC > Chlorantraniliprole (Coragen) > Lambdacyhalothrin 5 EC > Emamectin benzoate 5G > Dichlorvos 45 SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

Table 4.3.5: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Pithoragarh population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.000161	0.000499	0.008076	0.020683	Y=4.159+0.180x	0.000314	0.008705
	48	0.000095	0.000335	0.007452	0.529768	Y=4.382+0.171x	0.000189	0.002926
	72	0.000056	0.000145	0.001518	1.287642	Y=4.616+0.235x	0.000040	0.000216
Indoxacarb 15.8 EC	24	0.000118	0.000411	0.008872	0.541674	Y=4.293+0.172x	0.000251	0.012312
	48	0.000067	0.000215	0.003721	0.683960	Y=4.526+0.187x	0.000064	0.000364
	72	0.000041	0.000118	0.001579	0.769732	Y=4.757+0.211x	0.000012	0.000190
Lamdaacyhalothrin 5 EC	24	0.000158	0.000955	0.080242	0.409285	Y=4.247+0.175x	0.000470	0.104179
	48	0.000100	0.000745	0.104275	1.207125	Y=4.348+0.171x	0.000319	2.303396
	72	0.000026	0.000257	0.028971	1.394792	Y=4.247+0.174x	0.000000	0.000228
Spinosad 45EC	24	0.000084	0.000582	0.068986	0.079582	Y=4.266+0.174x	0.000272	0.030929
	48	0.000026	0.000247	0.061154	0.074627	Y=4.558+0.152x	0.000009	0.002054
	72	0.000032	0.000130	0.004005	0.068917	Y=4.546+0.240x	0.000034	0.000227
Dichlorovas 45SC	24	0.000319	0.001236	0.034630	0.464116	Y=4.192+0.159x	0.000688	0.521432
	48	0.000196	0.000666	0.013555	1.042933	Y=4.356+0.180x	0.000666	0.003982
	72	0.000161	0.000522	0.009409	0.922371	Y=4.437+0.187x	0.000522	0.001141
Emamectin benzoate 5G	24	0.000033	0.000394	0.176011	1.154650	Y=4.227+0.183x	0.0001471	0.067227
	48	0.000012	0.000119	0.033044	0.427943	Y=4.519+0.189x	0.000014	0.000330
	72	0.000161	0.000522	0.009409	0.9223712	Y=4.627+0.225x	0.000234	0.001141
Imidachloprid 17.5 SC	24	0.000484	0.047415	0.057712	0.8231404	Y=4.155+0.170x	0.001988	1.130726
	48	0.000182	0.011833	0.092365	0.656059	Y=4.260+0.182x	0.001530	0.091544
	72	0.000174	0.002192	0.098745	1.073131	Y=4.531+0.161x	0.000000	0.409821
Flubendiamide 480SC	24	0.000761	0.003273	0.1186234	0.208912	Y=4.192+0.186x	0.001835	0.042604
	48	0.000368	0.002063	0.1436385	0.995101	Y=4.420+0.170x	0.000815	0.030210
	72	0.000170	0.000796	0.035757	0.3734353	Y=4.689+0.184x	0.000032	0.001470
Lufenuron 5EC	24	0.002674	0.009332	0.202381	0.182281	Y=4.255+0.167x	0.005691	0.864545
	48	0.001616	0.006569	0.207411	1.317231	Y=4.429+0.161x	0.003096	23.990730
	72	0.000991	0.003553	0.082319	0.6249746	Y=4.639+0.172x	0.000158	0.005943

Mean larval wt.=0.0232g/larva (23.2 mg)





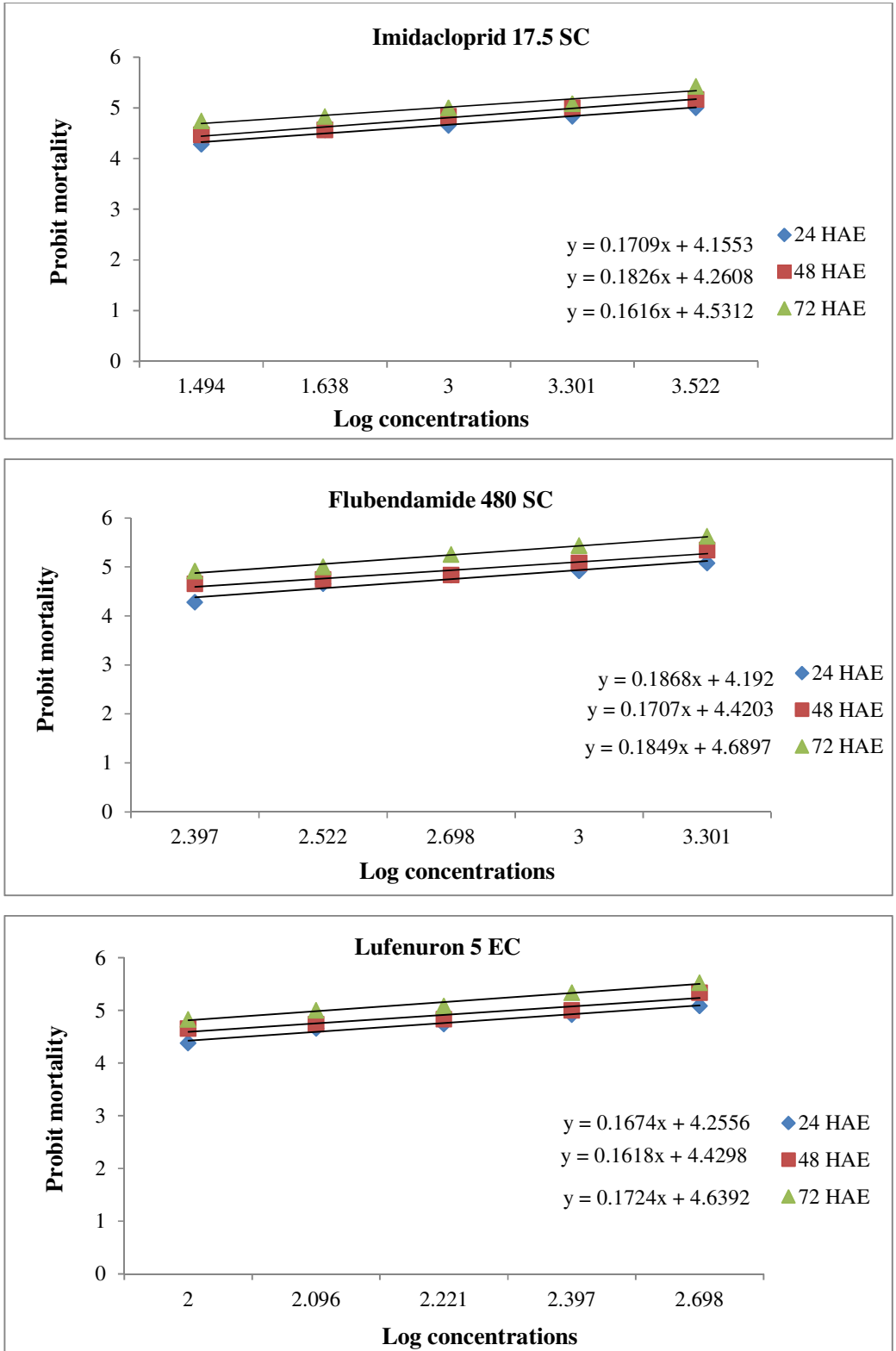


Fig. 4.3.5 Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Pithoragarh population by leaf dip bioassay method

The *S. litura* population of this district showed resistance ratio of 2.40, 2.37 and 5.15 folds greater as compared to susceptible population at 24, 48 and 72 HAF against chlorantraniliprole 20 SC. The resistance ratio was found to be 2.41, 2.14 and 1.69 times for indoxacarb 15.8 SC, for lambda cyhalothrin 5EC, 3.18, 5.86 and 3.96 times, for spinosad 45SC, 4.59, 3.16 and 2.73, for dichlorvos 46SC, 4.39, 2.18 and 2.83 times, for emamectin benzoate 5G it was, 6.57, 5.28 and 27.87 times, for imidacloprid 17.5SC, **44.41**, **107.06** and **29.89** times, for flubendiamide 480SC, 3.34, 3.92 and 2.70 times, whereas for lufenuron 5EC the resistance ratio was 2.69, 2.79 and 2.68 times more as compared to that of susceptible population at 24, 48 and 72 HAF, respectively.

4.3.6. Dehradun

At 24 hr HAF, among the various insecticides tested, Emamectin benzoate 5 G was found to be most toxic against third instar larvae with LC₅₀ value of 0.000386% (Table No. 4.3.6) followed by Indoxacarb 15.8 EC (0.000392%), Chlorantraniliprole (Coragen) (0.000417%), Spinosad 45 EC (0.000486%), Dichlorvos 45 SC (0.000933%), Lambda cyhalothrin 5 EC (0.001070%), Flubendiamide 480 SC (0.002732%) and Lufenuron 5 EC (0.009332%). The least toxicity was recorded by Imidacloprid 17.5 SC (0.031443%).

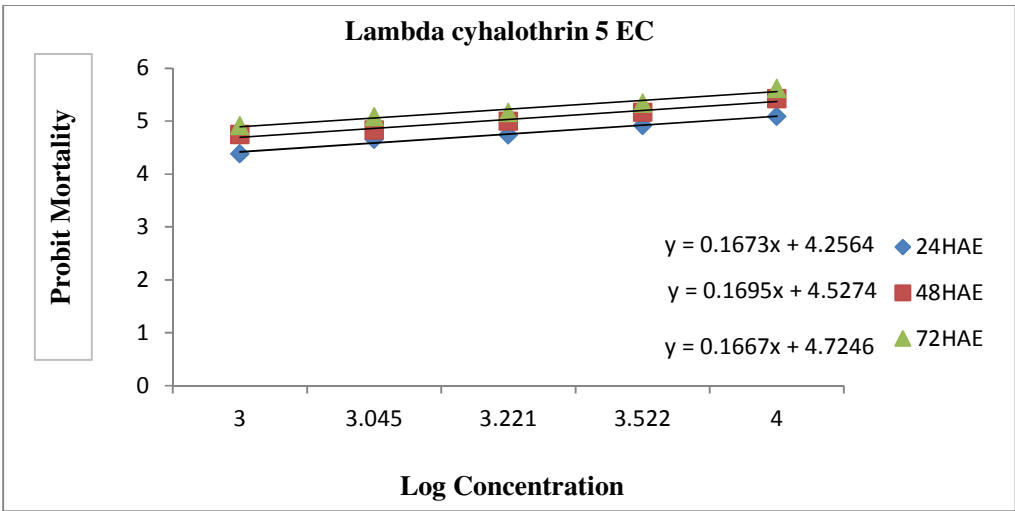
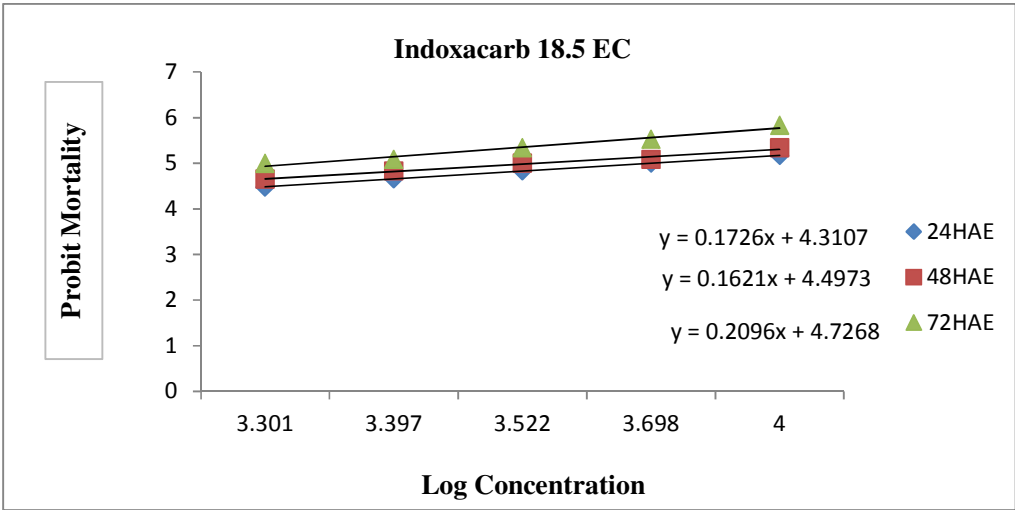
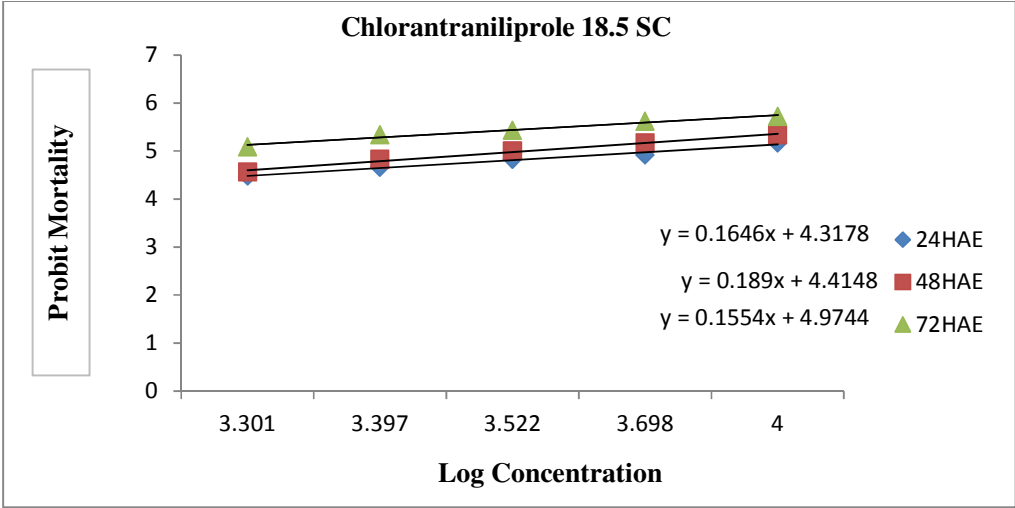
The ascending order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Spinosad 45 SC > Dichlorvos 46 SC > Lambda cyhalothrin 5 EC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

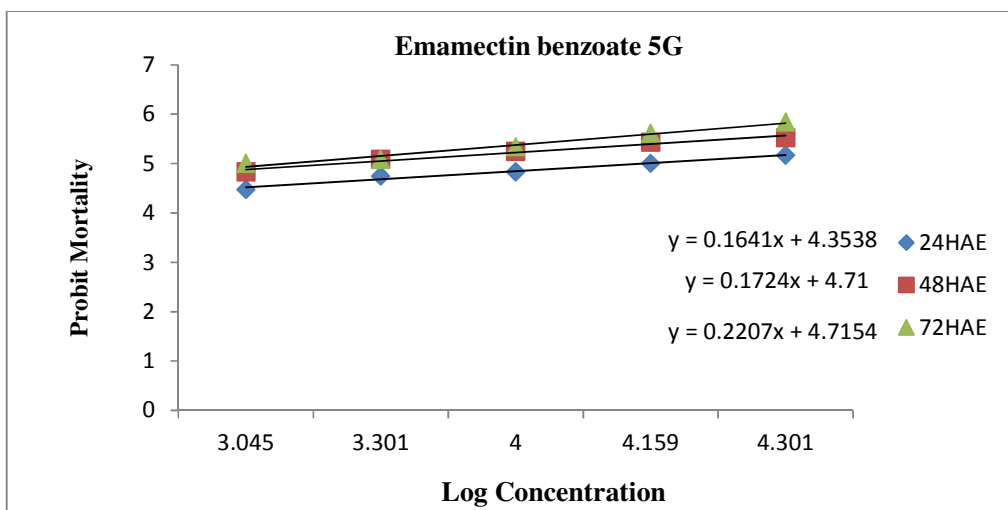
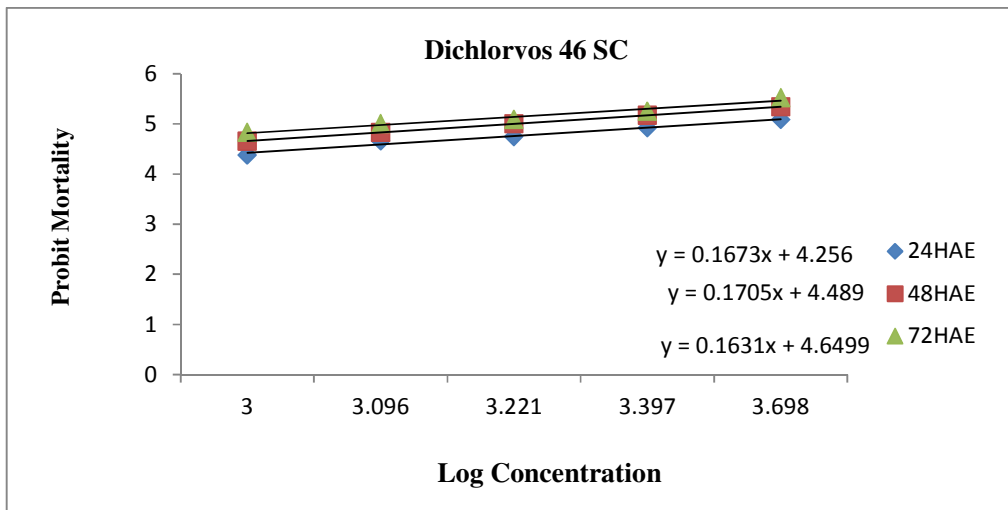
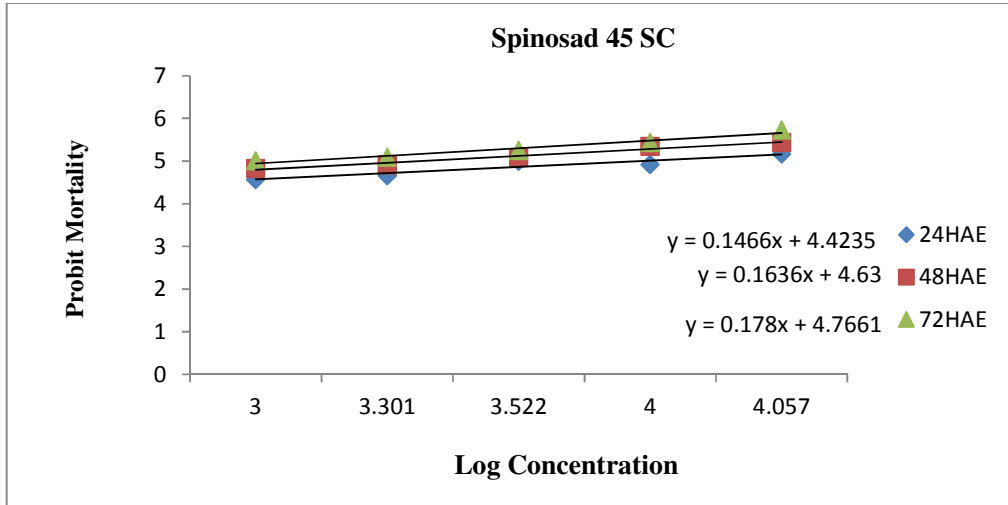
At 48 HAF, among the various insecticides tested, Emamectin benzoate 5 G was found to be most toxic against third instar larvae with LC₅₀ value of 0.000056% followed by Spinosad 45 EC (0.000164%), Chlorantraniliprole (Coragen) (0.000271%), Indoxacarb 15.8 EC (0.000272%), Lambda cyhalothrin 5 EC (0.000382%), Dichlorvos 45 SC (0.000522%), Flubendiamide 480 SC (0.001648%) and Lufenuron 5 EC (0.006209%). The least toxicity was recorded by Imidacloprid 17.5 SC (0.014726%).

Table 4.3.6: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Dehradun population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraniliprole (Coragen)	24	0.000114	0.000417	0.010137	0.3613760	Y=4.317+0.164x	0.000250	0.052584
	48	0.000090	0.000271	0.004155	0.1253378	Y=4.414+0.189x	0.000143	0.000563
	72	0.000022	0.000083	0.002303	0.089253	Y=4.974+0.155x	0.000009	0.000164
Indoxacarb 15.8 EC	24	0.000115	0.000392	0.008072	0.2463380	Y=4.310+0.172x	0.000240	0.006156
	48	0.000072	0.000272	0.007128	0.3936595	Y=4.497+0.162x	0.000089	0.001230
	72	0.000042	0.000125	0.001793	1.143050	Y=4.726+0.209x	0.000012	0.000200
Lamdacyhalothrin 5 EC	24	0.000157	0.001070	0.1197323	0.4309263	Y=4.256+0.167x	0.000501	7.615325
	48	0.000048	0.000382	0.061499	1.267431	Y=4.527+0.169x	0.000005	0.001890
	72	0.000022	0.000177	0.031294	1.156109	Y=4.724+0.166x	0.0000297	0.000406
Spinosad 45EC	24	0.000049	0.000486	0.135914	0.4150321	Y=4.423+0.146x	0.000185	0.00143
	48	0.000022	0.000164	0.028437	0.19635	Y=4.63+0.163x	0.000002	0.000406
	72	0.000013	0.000087	0.010305	0.261909	Y=4.766+0.178x	0.000000	0.000194
Dichlorovas 45SC	24	0.000267	0.000933	0.020237	0.182116	Y=4.256+0.167x	0.000569	0.086440
	48	0.000149	0.000522	0.011451	0.271337	Y=4.489+0.170x	0.000191	0.001378
	72	0.000093	0.000363	0.010280	0.678688	Y=4.649+0.163x	0.000001	0.000640
Emamectin benzoate 5G	24	0.000026	0.000386	0.302800	0.615686	Y=4.353+0.164x	0.000129	0.000421
	48	0.000004	0.000056	0.031519	0.781335	Y=4.71+0.172x	0.000047	0.000155
	72	0.000006	0.000043	0.004767	0.348327	Y=4.715+0.220x	0.000013	0.000140
Imidachloprid 17.5 SC	24	0.000282	0.031443	0.034312	0.977800	Y=4.214+0.169x	0.001650	0.5990165
	48	0.000118	0.014726	0.002134	0.951525	Y=4.315+0.165x	0.001214	0.1785854
	72	0.000035	0.001535	16.486960	0.115372	Y=4.503+0.189x	0.000337	0.006998
Flubendiamide 480SC	24	0.000498	0.002732	0.180618	0.218443	Y=4.350+0.164x	0.001369	0.2371928
	48	0.000351	0.001648	0.074322	0.794129	Y=4.436+0.188x	0.000589	0.004532
	72	0.000123	0.000665	0.042646	1.239176	Y=4.743+0.178x	0.000001	0.001323
Lufenuron 5EC	24	0.002674	0.009332	0.202381	0.182281	Y=4.256+0.167x	0.005691	0.8645447
	48	0.001657	0.006209	0.160464	1.187816	Y=4.420+0.170x	0.002985	0.002985
	72	0.001616	0.004857	0.072885	0.550935	Y=4.444+0.196x	0.002210	0.008642

Mean larval wt.=0.0232g/larva (23.2 mg)





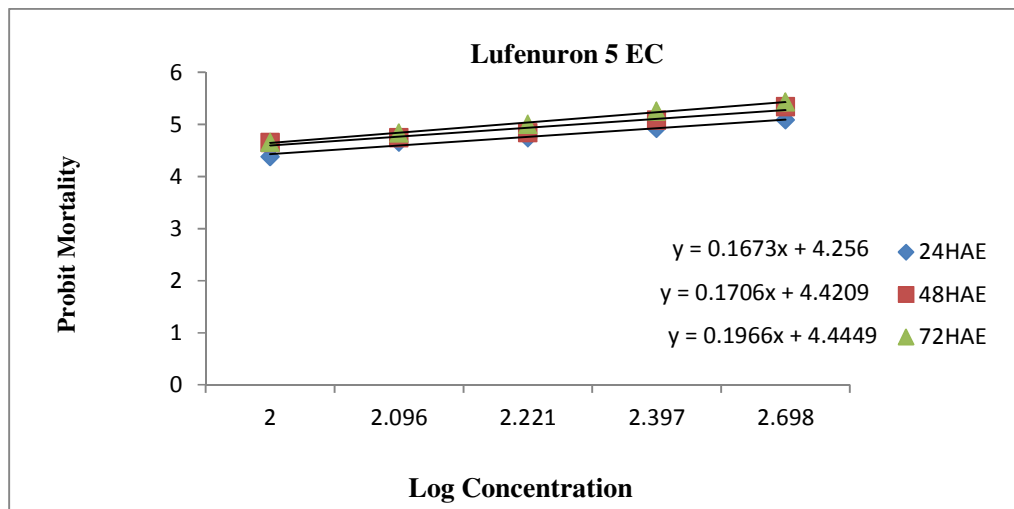
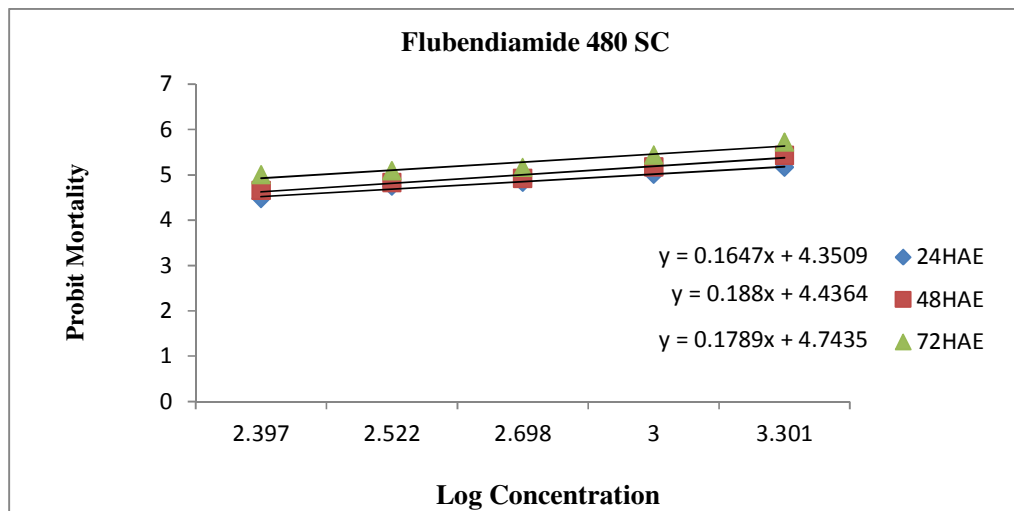
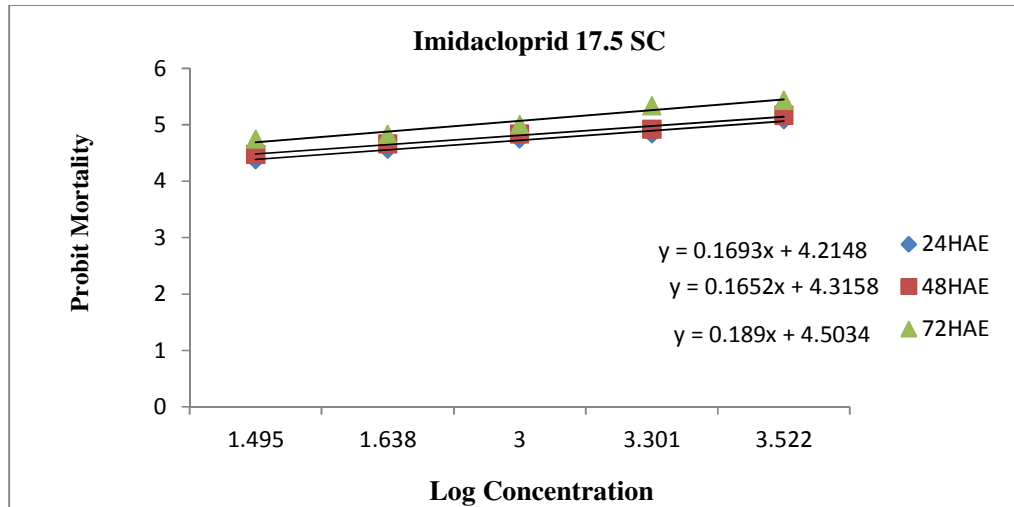


Fig. 4.3.6. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Dehradun population by leaf dip bioassay method

The ascending order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > Spinosad 45 SC > Chlorantraniliprole (Coragen) > Indoxacarb 15.8 EC > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

At **72 HAF**, among the various insecticides tested, Emamectin benzoate 5 G was found to be most toxic against third instar larvae with LC₅₀ value of 0.000043% followed by Chlorantraniliprole (Coragen) (0.000083%), Spinosad 45 EC (0.000087%), Indoxacarb 15.8 EC (0.000125%), Lambda cyhalothrin 5 EC (0.000177%), Dichlorvos 45 SC (0.000363%), Flubendiamide 480 SC (0.000665%) and Imidacloprid 17.5 SC (0.001535%). The least toxicity was recorded by Lufenuron 5 EC (0.004857%).

The ascending order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5 G > Chlorantraniliprole (Coragen) > Spinosad 45 SC > Indoxacarb 15.8 EC > Lambda cyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

The ratio for resistance of the *S. litura* population, collected from this district was compared to that of the susceptible population and was found to be 2.01, 2.36 and 1.00 times higher for chlorantraniliprole 20SC at 24, 48 and 72 HAF, respectively. The resistance ratio of the collected population was found to be 2.30, 2.71 and 1.79 times against indoxacarb 15.8EC, 3.56, 3.01 and 2.73 times against lambda cyhalothrin 5EC, 3.83, 2.10 and 1.83 times against spinosad 45SC, 3.32, 2.21 and 1.97 times for dichlorvos 46SC, 6.43, 2.48 and 2.30 times for emamectin benzoate 5G, **29.45**, **133.23** and **20.93** times higher for imidacloprid 17.5SC, 2.79, 3.13 and 2.25 times against flubendiamide 480SC and 2.69, 2.63 and 3.67 times against lufenuron 5EC than that of the susceptible population at 24, 48 and 72 HAF, respectively.

4.3.7. Champawat

At **24 HAF**, Imidacloprid 17.5 SC was found to be most lethal with LC₅₀ value of 0.000365%, followed by indoxacarb 15.8 EC (0.000417%), chlorantraniliprole (Coragen) (0.000444%), spinosad 45 EC (0.000461%), dichlorvos 45 SC (0.001163%), lambda cyhalothrin 5 EC (0.001504%), flubendiamide 480 SC (0.003122%) and

lufenuron 5 EC (0.009366%). emamectin benzoate 5 G (0.024701%) was found to be least toxic against the third instar larvae (Table No. 4.3.7).

To rephrase it, the order of toxicity of these insecticides against third instar larvae of *S. litura* (Fab.), based on median lethal concentration (LC₅₀) is as follows, emamectin benzoate 5G > indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > spinosad 45 SC > dichlorvos 45 SC > lambda cyhalothrin 5 EC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

At 48 HAF, Emamectin benzoate 5 G was found to be highly lethal with LC₅₀ value of 0.000126% followed by spinosad 45 EC (0.000172%, spinosad 45 EC (0.000172%), indoxacarb 15.8 EC (0.000228%), chlorantraniliprole (Coragen) (0.000237%), lambda cyhalothrin 5 EC (0.000538%), dichlorvos 45 SC (0.000636%), flubendiamide 480 SC (0.001848%) and lufenuron 5 EC (0.006704%). Imidacloprid 17.5 SC (0.021355%) was reported as least lethal insecticide against third instar larvae.

To rearticulate it, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.), based on median LC₅₀ is as follows, emamectin benzoate 5G > spinosad 45 SC > indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

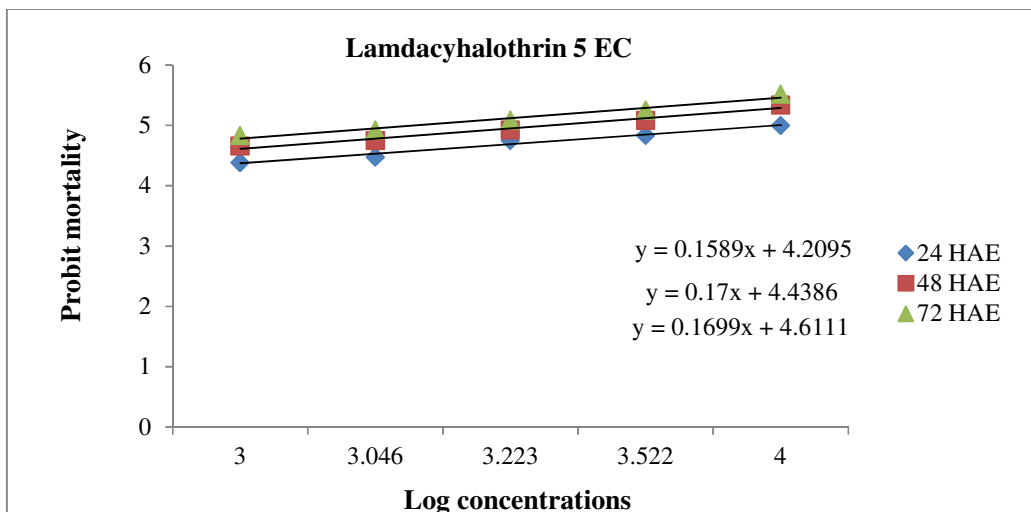
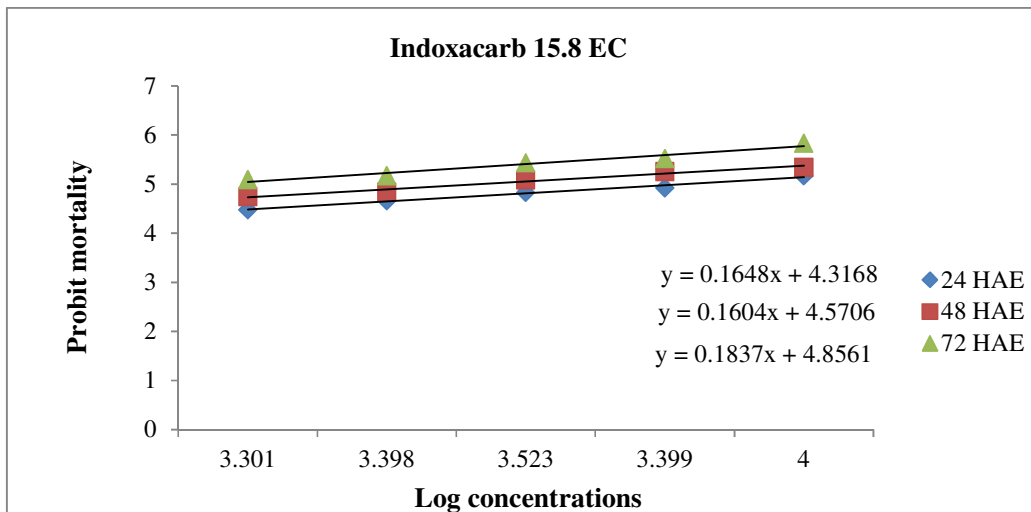
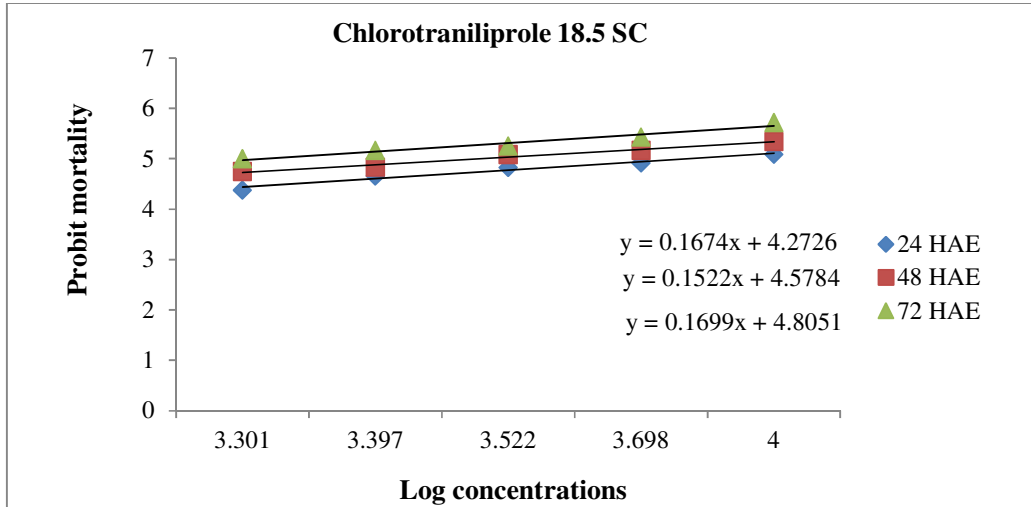
Once more, **at 72 HAF**, emamectin benzoate 5 G was found to be the most toxic insecticide with LC₅₀ value of 0.000050%, followed by spinosad 45 EC (0.000074%), indoxacarb 15.8 EC (0.000100%), chlorantraniliprole (Coragen) (0.000117%), lambda cyhalothrin 5 EC (0.000271%), dichlorvos 45 SC (0.000400%), flubendiamide 480 SC (0.000461%) and Imidacloprid 17.5 SC (0.001631%). Lufenuron 5 EC (0.004367%) was found to be least toxic against third instar larvae.

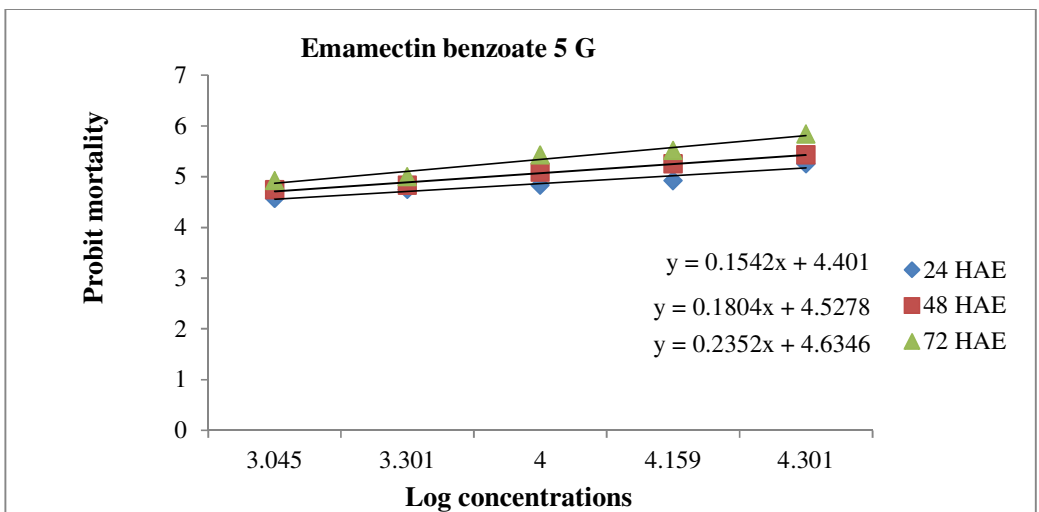
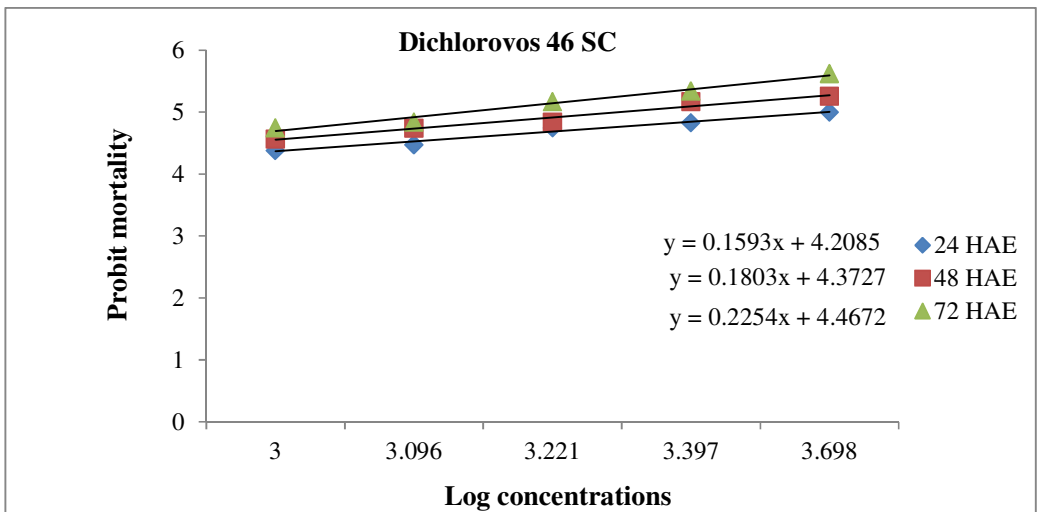
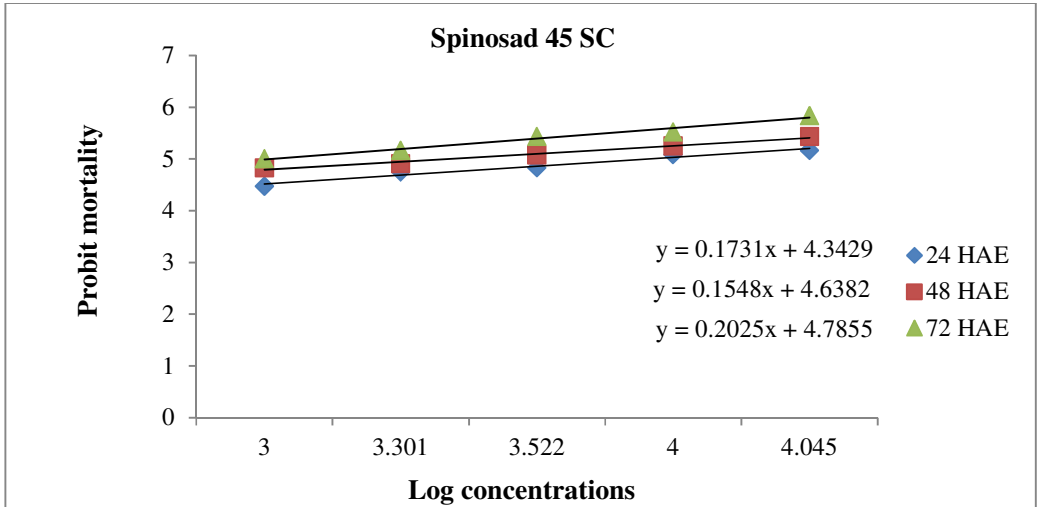
To put it in another manner, the order of toxicity of different insecticides based on their LC₅₀ against the third instar larvae of *S. litura* (Fab.) can be described as follows, emamectin benzoate 5G > spinosad 45 SC > indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > imidacloprid 17.5 SC > lufenuron 5 EC.

Table 4.3.7: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Champawat population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.000130	0.000444	0.009195	0.055049	Y=4.272+0.167x	0.000273	0.017447
	48	0.000057	0.000237	0.007732	0.370540	Y=4.5788+0.152x	0.000002	0.000839
	72	0.000031	0.000117	0.003031	0.777967	Y=4.805+0.169x	0.00002	0.000205
Indoxacarb 15.8 EC	24	0.000114	0.000417	0.010137	0.361376	Y=4.316+0.164x	0.000250	0.052584
	48	0.000060	0.000228	0.006104	0.391423	Y=4.570+0.160x	0.000023	0.000515
	72	0.000029	0.000100	0.002054	0.893964	Y=4.856+0.183x	0.000000	0.000178
Lamdaacyhalothrin 5 EC	24	0.000196	0.001504	0.2279632	0.562149	Y=4.209+0.158x	0.000634	0.25313
	48	0.000070	0.000538	0.081315	1.220494	Y=4.438+0.17x	0.000138	0.043439
	72	0.000034	0.000271	0.044600	1.280027	Y=4.611+0.169x	0.00016	0.000673
Spinosad 45EC	24	0.000058	0.000461	0.075775	0.718162	Y=4.342+0.173x	0.000195	0.000052
	48	0.000019	0.000172	0.039733	0.089446	Y=4.638+0.154x	0.000000	0.000483
	72	0.000013	0.000074	0.004862	0.268627	Y=4.785+0.202x	0.000002	0.000158
Dichlorovas 45SC	24	0.000307	0.001163	0.030771	0.373095	Y=4.208+0.159x	0.000663	0.00213
	48	0.000193	0.000636	0.012032	0.658217	Y=4.372+0.180x	0.000363	0.002583
	72	0.000150	0.000400	0.004435	1.120830	Y=4.467+0.225x	0.000172	0.000594
Emamectin benzoate 5G	24	0.000021	0.000365	0.405265	0.729282	Y=4.40+0.154x	0.000110	0.000425
	48	0.000011	0.000126	0.046938	0.488625	Y=4.527+0.180x	0.000010	0.000416
	72	0.000008	0.000050	0.005208	1.573340	Y=4.634+0.235x	0.000017	0.000148
Imidachloprid 17.5 SC	24	0.000261	0.024701	0.032524	0.185158	Y=4.263+0.158x	0.001698	0.3593928
	48	0.000151	0.021355	0.029756	0.776512	Y=4.303+0.158x	0.001287	0.354377
	72	0.000016	0.001631	0.0021345	0.974719	Y=4.539+0.170x	0.000001	0.028236
Flubendiamide 480SC	24	0.000536	0.003122	0.238696	0.040641	Y=4.339+0.156x	0.001560	0.004213
	48	0.000310	0.001848	0.149554	0.543724	Y=4.325+0.200x	0.000493	0.025458
	72	0.000098	0.000461	0.021099	0.581435	Y=4.875+0.183x	0.000001	0.000966
Lufenuron 5EC	24	0.002917	0.009366	0.165433	0.758576	Y=4.186+0.184x	0.005877	0.178926
	48	0.001901	0.006704	0.149078	0.530350	Y=4.382+0.171x	0.003774	0.058577
	72	0.001163	0.004367	0.113470	2.199726	Y=4.536+0.178x	0.000368	0.008867

Mean larval wt.=0.0232g/larva (23.2 mg)





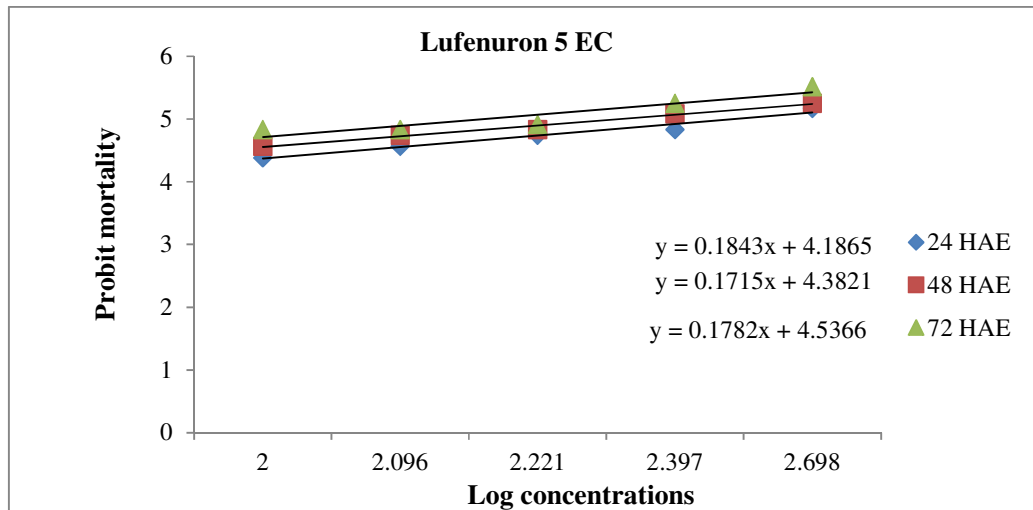
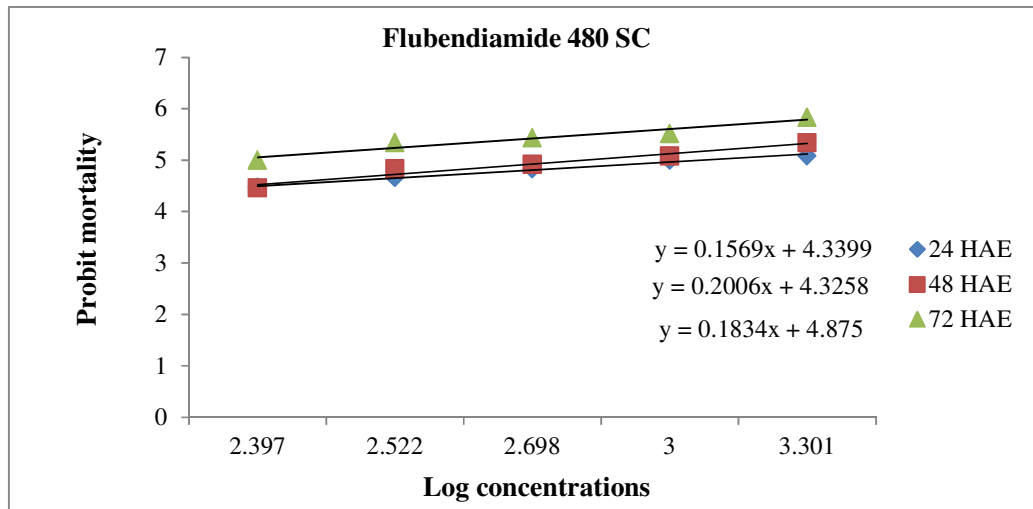
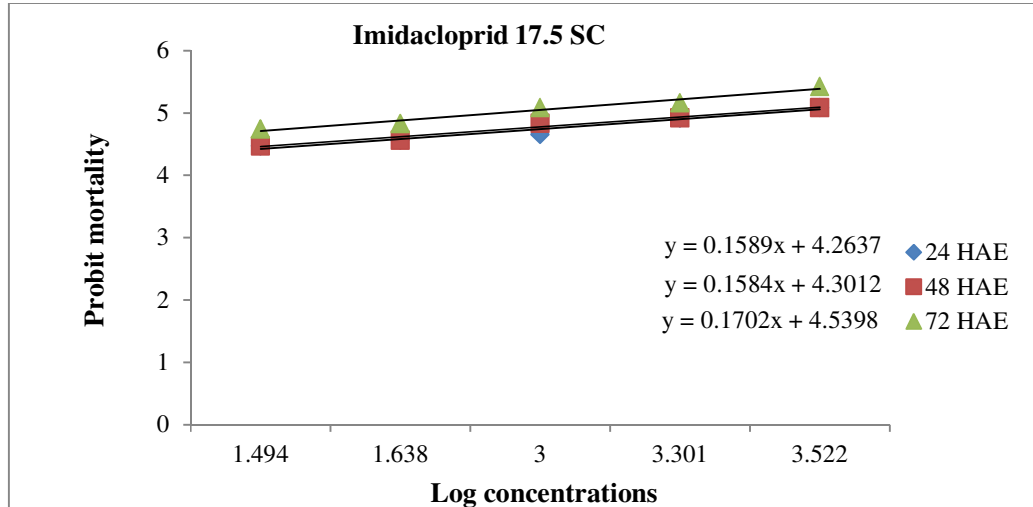


Fig. 4.3.7. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Champawat population by leaf dip bioassay method

The resistance ratio for the *S. litura* population collected from this district was found to be 2.14, 2.07 and 1.41 times higher than the susceptible population at 24, 48 and 72 HAF, respectively. Against indoxacarb 15.8 EC the resistance ratio was 2.44, 2.27 and 1.43 times, for lambda cyhalothrin 5 EC, 5.00, 4.24 and 4.18 times, for spinosad 45 SC, 3.64, 2.20 and 1.56 times, for dichlorvos 46 SC, 4.13, 2.69 and 2.17 times, for emamectin benzoate 5 G, 608, 5.59 and 2.67 times, for imidacloprid 17.5 SC, **23.14**, **193.21** and **22.24** times, for flubendiamide 480 SC, 3.11, 3.51 and 1.56, whereas, for lufenuron 5 EC, 2.70, 2.84 and 3.20 times, at 24, 48 and 72 HAF, respectively.

4.3.8. Almora

The toxicity studies against third instar larvae with various insecticides at **24 HAF**, revealed that indoxacarb 15.8 EC was found to be most toxic with LC₅₀ value of 0.000392% followed by chlorantraniliprole (Coragen) (0.000454%), emamectin benzoate 5 G (0.000521%), spinosad 45 EC (0.000571%), lambda cyhalothrin 5 EC (0.000971%), dichlorvos 45 SC (0.001089%), flubendiamide 480 SC (0.002840%) and lufenuron 5 EC (0.010008%). Imidacloprid 17.5 SC (0.062696%) was found to be least lethal (Table No. 4.3.8).

In clear text, the order of toxicity of these insecticides against the third instar larvae of *S. litura* (Fab.) based on median LC₅₀ is as follows, indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > emamectin benzoate 5 G > spinosad 45 SC > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

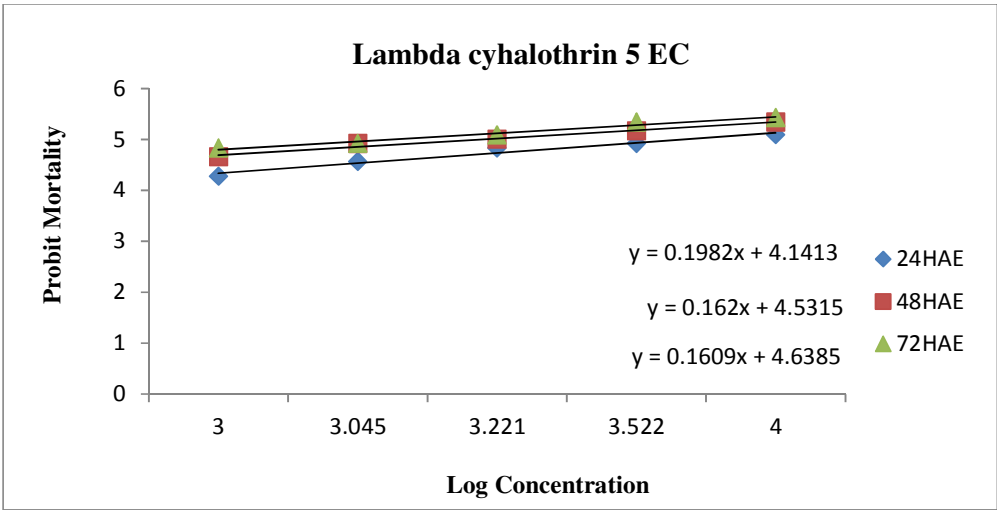
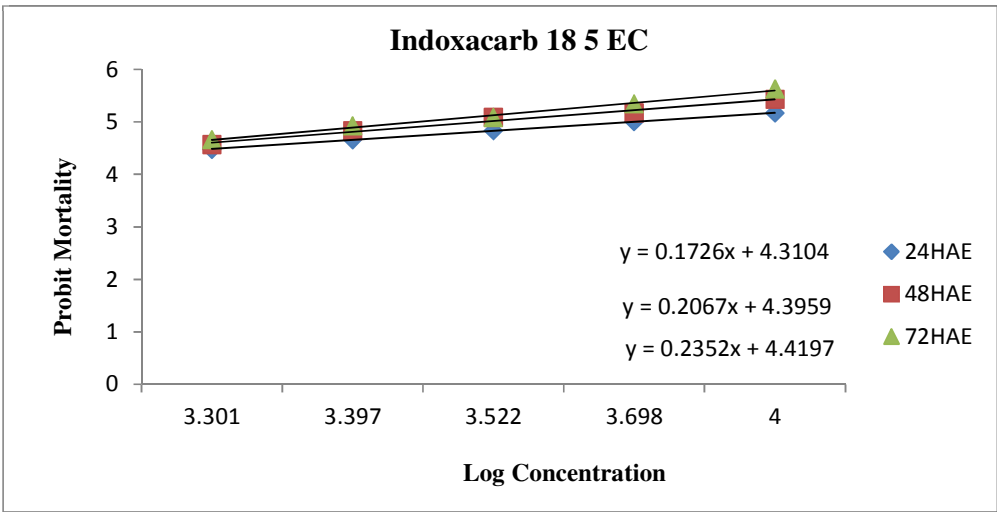
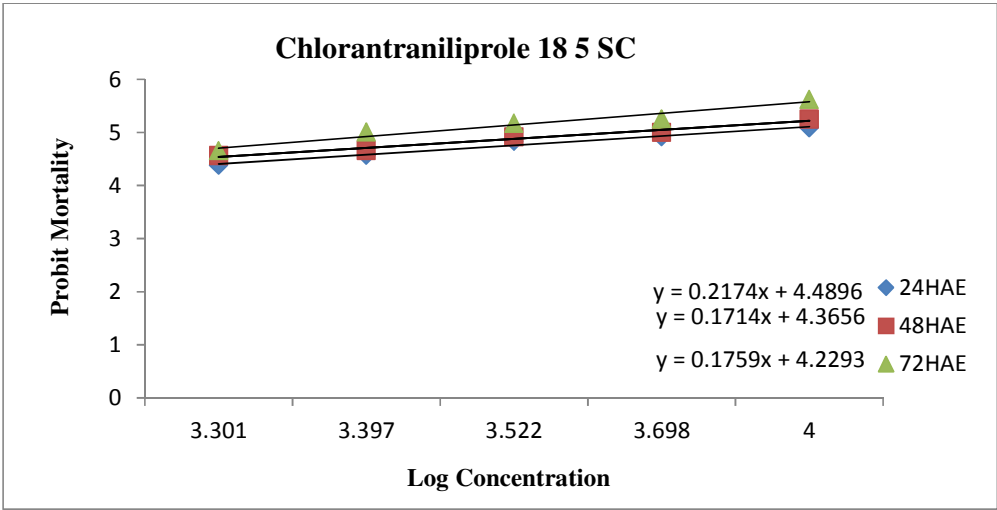
At **48 HAF**, indoxacarb 15.8 EC was found to be most toxic with LC₅₀ value of 0.000392% followed by chlorantraniliprole (Coragen) (0.000454%), emamectin benzoate 5 G (0.000521%), spinosad 45 EC (0.000571%), lambda cyhalothrin 5 EC (0.000971%), dichlorvos 45 SC (0.001089%), flubendiamide 480 SC (0.002840%) and lufenuron 5 EC (0.010008%). imidacloprid 17.5 SC (0.062696%) was found to be most lethal.

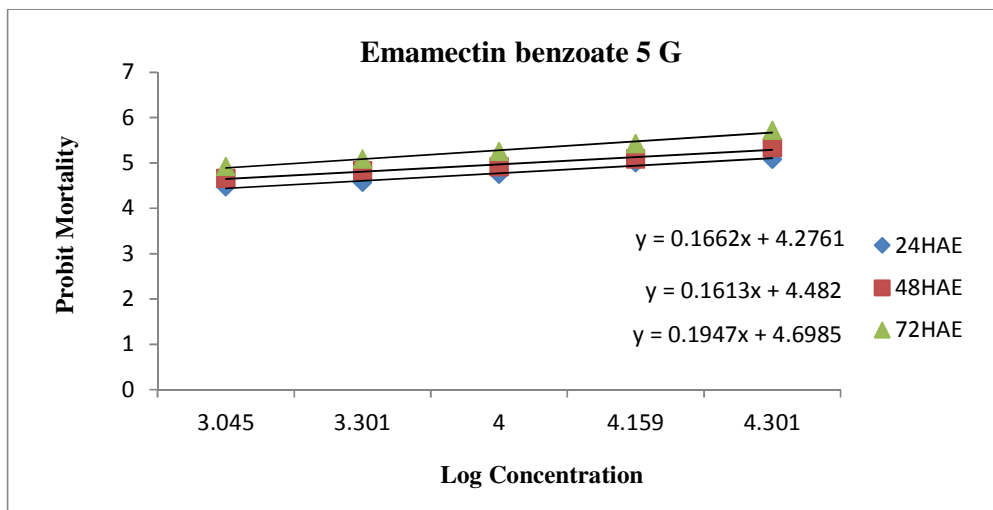
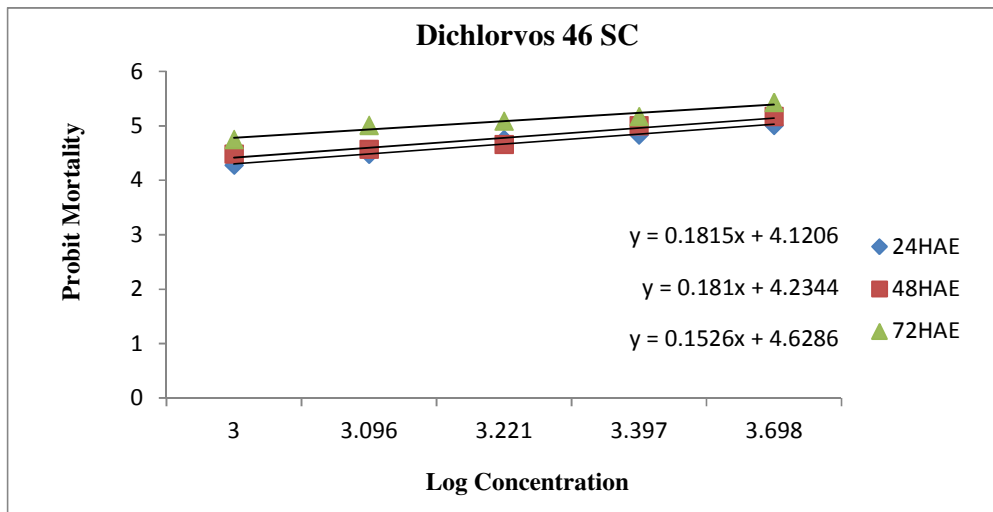
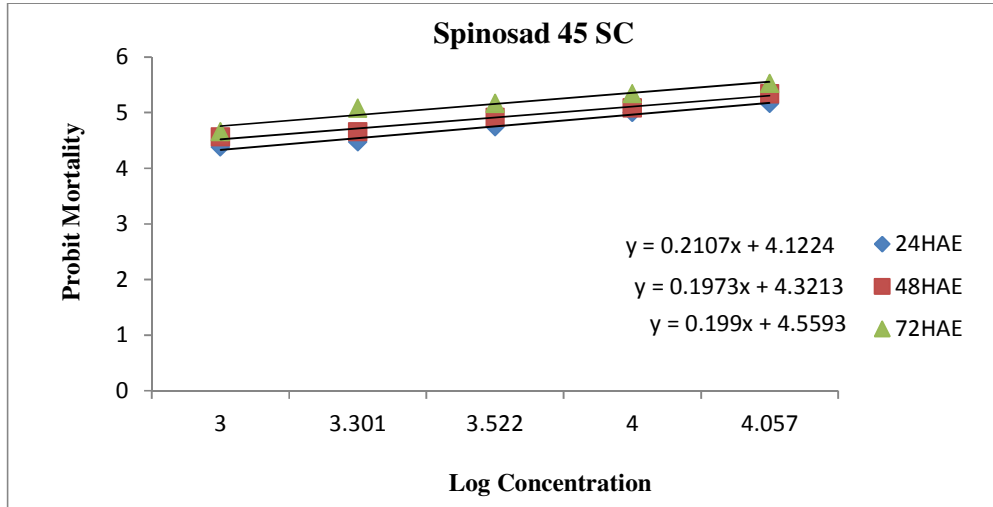
In another way, the order of toxicity levels of different insecticides based on median LC₅₀ was as follows, indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > emamectin benzoate 5 G > spinosad 45 SC > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

Table 4.3.8: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Almora population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraliniprole (Coragen)	24	0.000139	0.000454	0.008367	0.180383	Y=4.229+0.175x	0.000284	0.009252
	48	0.000099	0.000350	0.007833	0.617555	Y=4.365+0.171x	0.000202	0.004177
	72	0.000075	0.000200	0.002215	0.618558	Y=4.489+0.217x	0.000086	0.000297
Indoxacarb 15.8 EC	24	0.000115	0.000392	0.008072	0.246338	Y=4.310+0.172x	0.000240	0.006156
	48	0.000092	0.000253	0.003086	0.271260	Y=4.395+0.206x	0.000138	0.000430
	72	0.000083	0.000210	0.002027	0.726157	Y=4.419+0.235x	0.000106	0.000306
Lamdacyhalothrin 5 EC	24	0.000204	0.000971	0.045330	0.224398	Y=4.141+0.198x	0.000521	0.012576
	48	0.000055	0.000411	0.056658	0.443595	Y=4.531+0.162x	0.000034	0.002137
	72	0.000033	0.000270	0.046769	0.792755	Y=4.638+0.160x	0.000012	0.000678
Spinosad 45EC	24	0.000114	0.000571	0.030324	0.120406	Y=4.122+0.210X	0.000301	0.004105
	48	0.000064	0.000356	0.024601	0.074489	Y=4.321+0.197X	0.000166	0.001437
	72	0.000024	0.000154	0.014117	1.476637	Y=4.559+0.199	0.000014	0.000322
Dichlorovas 45SC	24	0.000347	0.001089	0.018163	0.180214	Y=4.120+0.181X	0.000670	0.035676
	48	0.000260	0.000883	0.017858	1.261212	Y=4.234+0.181X	0.000546	0.027078
	72	0.000103	0.000414	0.012763	0.358983	Y=4.628+0.152X	0.000001	0.000847
Emamectin benzoate 5G	24	0.000041	0.000521	0.273996	0.203236	Y=4.276+0.166x	0.000191	0.000712
	48	0.000014	0.000207	0.1454978	0.359635	Y=4.482+0.161x	0.000033	0.007285
	72	0.000006	0.000052	0.012336	0.509016	Y=4.698+0.194x	0.000001	0.000127
Imidachlopid 17.5 SC	24	0.001037	0.062696	0.072143	1.114692	Y=4.017+0.192x	0.003009	0.072312
	48	0.000229	0.020859	0.032541	1.131693	Y=4.224+0.177x	0.001636	0.265886
	72	0.000042	0.004740	0.00541	1.432998	Y=4.420+0.170x	0.000325	0.005214
Flubendiamide 480SC	24	0.000588	0.002840	0.110902	0.667838	Y=4.241+0.189x	0.001578	0.027311
	48	0.000368	0.002063	0.143639	0.995101	Y=4.420+0.170x	0.000815	0.030210
	72	0.000250	0.001199	0.056883	1.349018	Y=4.541+0.188x	0.000179	0.002382
Lufenuron 5EC	24	0.002959	0.010008	0.200956	0.544621	Y=4.194+0.176x	0.006110	0.7496876
	48	0.001762	0.005645	0.099137	0.263338	Y=4.442+0.180x	0.002917	0.014236
	72	0.001441	0.004202	0.058491	0.940434	Y=4.489+0.205x	0.001576	0.006635

Mean larval wt.=0.0232g/larva (23.2 mg)





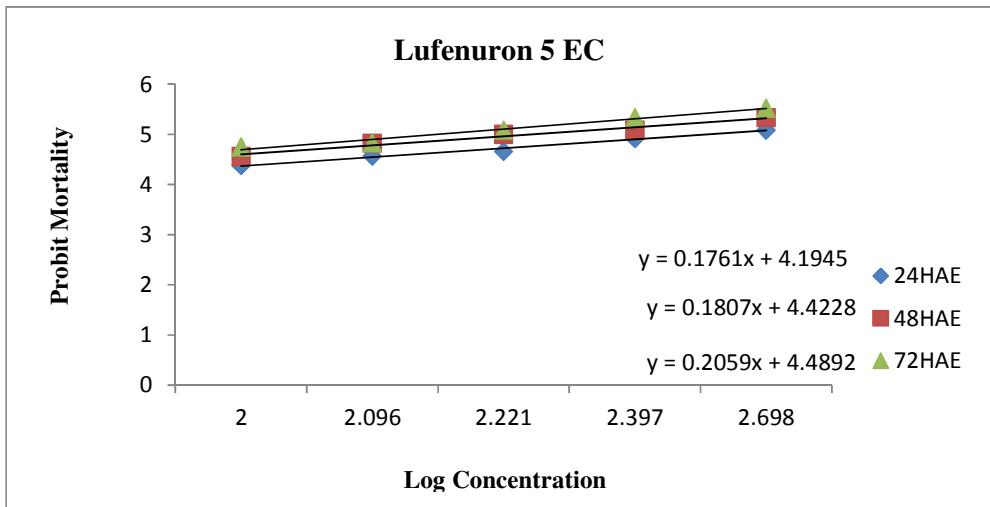
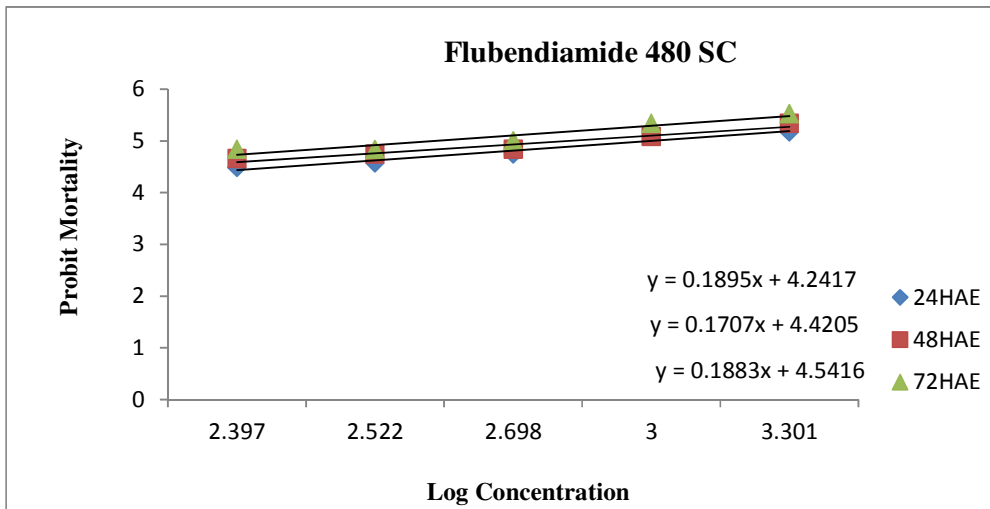
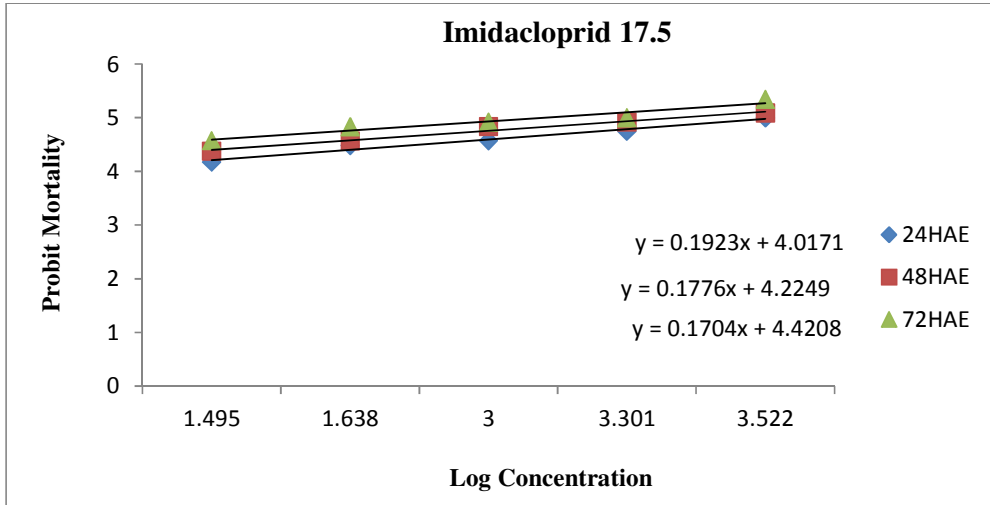


Fig. 4.1.3. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Almora population by leaf dip bioassay method

At 72 HAF, Emamectin benzoate 5 G was found to be the most toxic insecticide with LC₅₀ value of 0.000052% followed by spinosad 45 EC (0.000154%), chlorantraniliprole (Coragen) (0.000200%), indoxacarb 15.8 EC (0.000210%), lambda cyhalothrin 5 EC (0.000270%), dichlorvos 45 SC (0.000414%), flubendiamide 480 SC (0.001199%) and lufenuron 5 EC (0.004202%), whereas, imidacloprid 17.5 SC (0.004740%) was found to be least lethal among all.

In other words, the order of toxicity of all the insecticides against the third instar larvae of *S. litura* (Fab.) based on median LC₅₀ was as follows, emamectin benzoate 5G > spinosad 45 SC > chlorantraniliprole (Coragen) > indoxacarb 15.8 EC > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

The *S. litura* population collected from Almora showed 2.18, 3.05 and 2.42 folds resistance ratio as compared to the susceptible populations against chlorantraniliprole 20SC, respectively at 24, 48 and 72 HAF. This population showed 2.30, 2.52 and 3.01 times more resistance against indoxacarb 15.8EC, 3.23, 3.24 and 4.16 times more resistance ratio against lambda cyhalothrin 5EC, 4.51, 4.56 and 3.24 times more against spinosad 45SC, 3.87, 3.73 and 2.24 times more for dichlorvos 46SC, 8.68, 9.18 and 2.78 times more against emamectin benzoate 5G, **58.73, 188.72** and **64.64** times more for imidacloprid 17.5SC, 2.90, 3.92 and 4.07 times more against flubendiamide 480SC and 2.89, 2.40 and 3.18 times more resistance towards lufenuron 5EC at 24, 48 and 72 HAF, respectively.

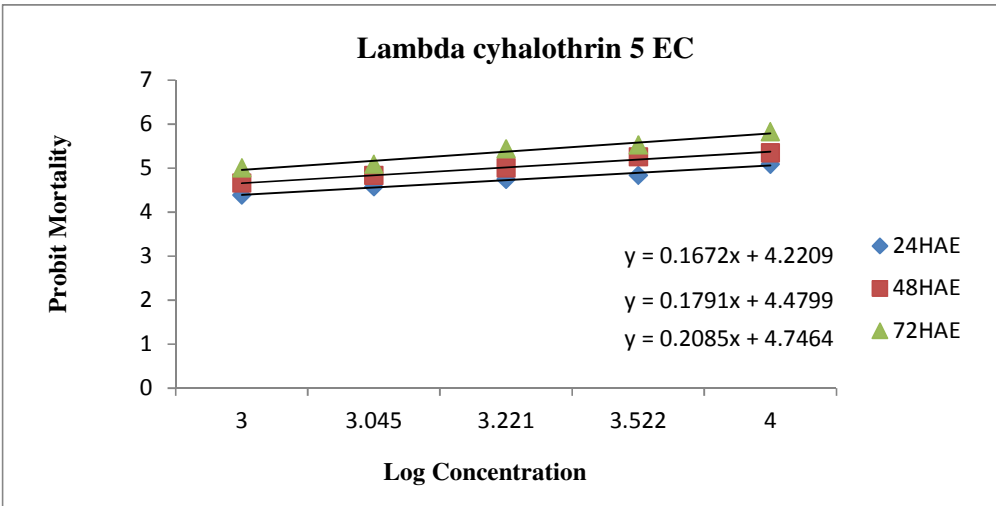
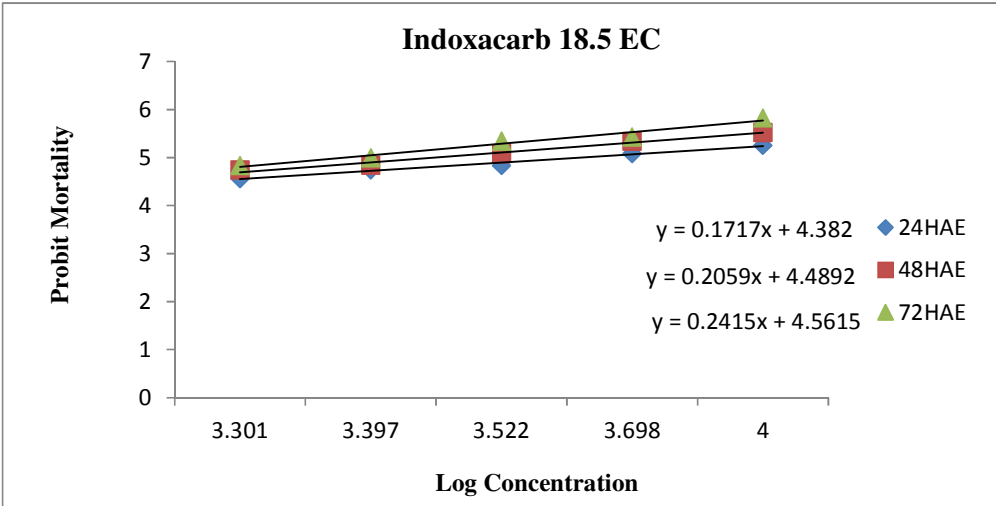
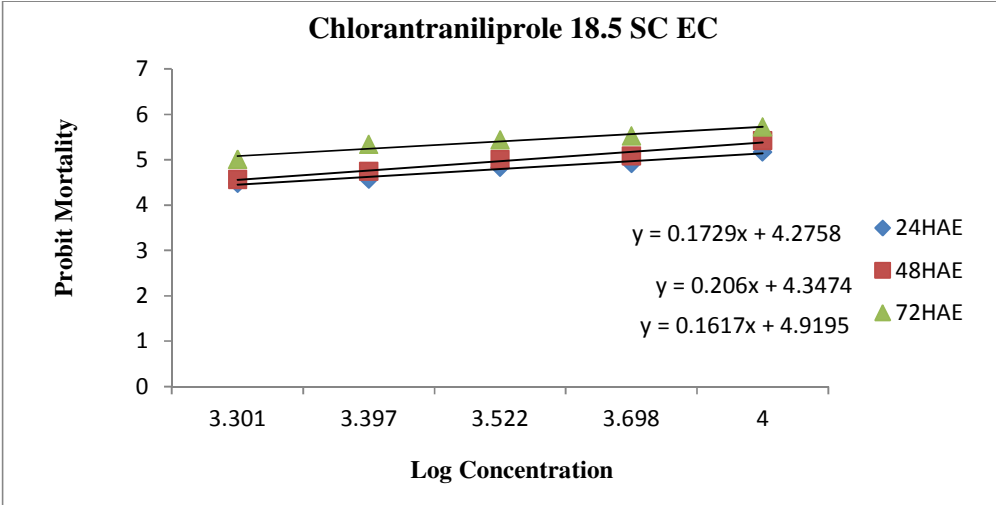
4.3.9 Pauri Gharwal

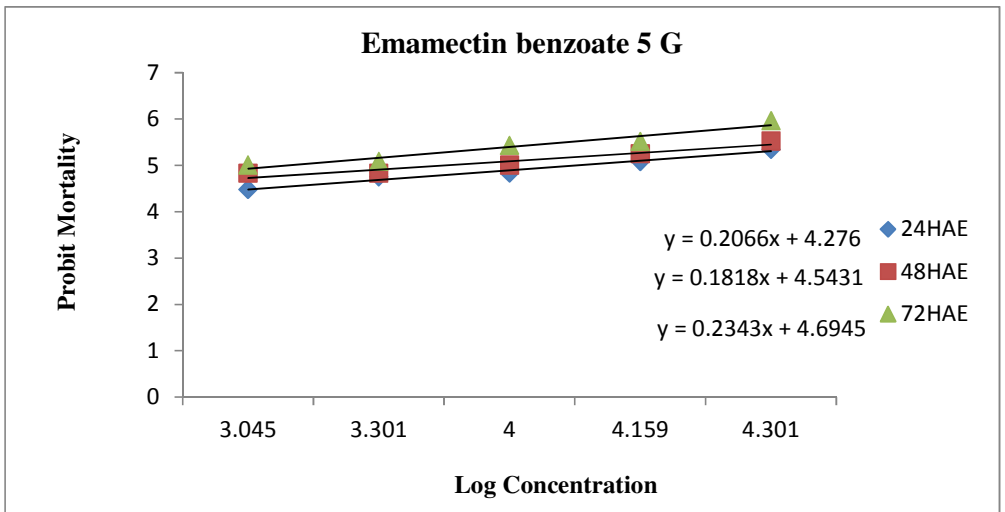
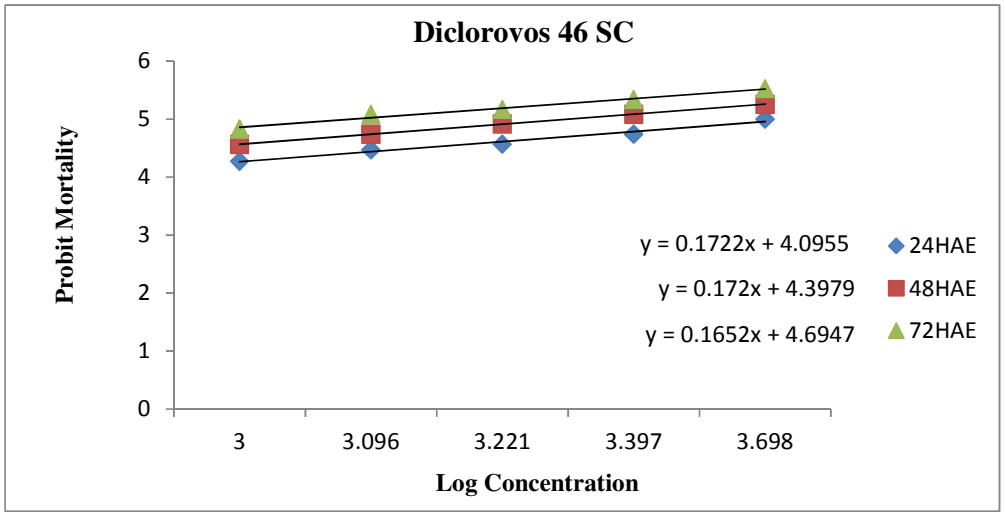
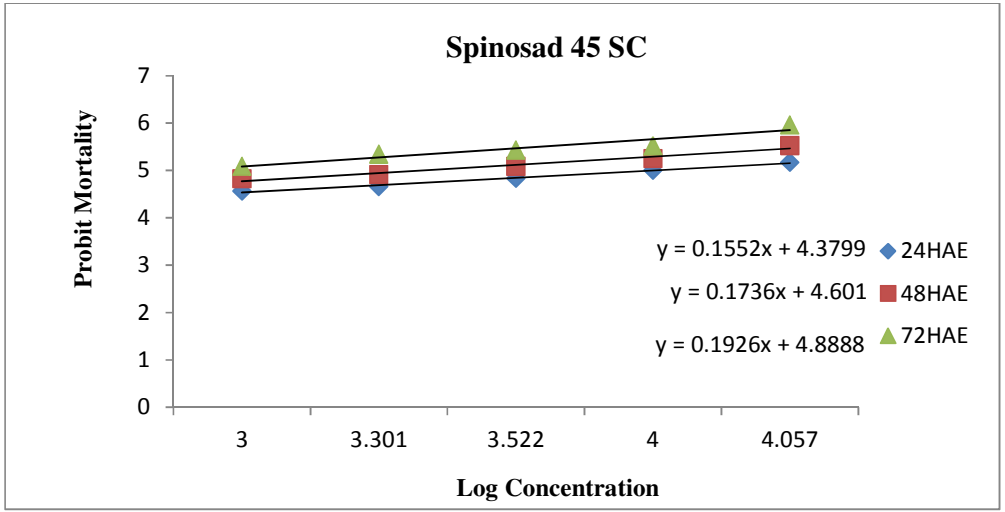
In the toxicity studies against third instar larvae with these insecticides at 24 HAF, emamectin benzoate 5 G was the most toxic insecticide with a median LC₅₀ value of 0.000264%, followed by indoxacarb 15.8 EC (0.000335%), chlorantraniliprole (Coragen) (0.000428%), spinosad 45 EC (0.000514%), lambda cyhalothrin 5 EC (0.001257%), dichlorvos 45 SC (0.001320%), flubendiamide 480 SC (0.003273%) and lufenuron 5 EC (0.010008%). Imidacloprid 17.5 SC (0.034620%) was found to be comparatively lesser toxic, as compared to others (Table No. 4.3.9).

Table 4.3.9: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Pauri Garhwal population at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraniliprole (Coragen)	24	0.000123	0.000428	0.009254	0.622776	Y=4.275+0.172x	0.000262	0.017936
	48	0.000098	0.000280	0.003698	0.789473	Y=4.347+0.206x	0.000163	0.000554
	72	0.000027	0.000097	0.002219	0.146753	Y=4.919+0.161x	0.000000	0.000176
Indoxacarb 15.8 EC	24	0.000095	0.000335	0.007452	0.529768	Y=4.382+0.171x	0.000189	0.002926
	48	0.000072	0.000210	0.002924	0.940034	Y=4.489+0.205x	0.000079	0.000332
	72	0.000064	0.000159	0.001500	1.159289	Y=4.561+0.241x	0.000057	0.000230
Lamdacyhalothrin 5 EC	24	0.000176	0.001257	0.159464	0.689592	Y=4.220+0.167x	0.000565	0.0062341
	48	0.000068	0.000414	0.036034	0.564598	Y=4.479+0.179x	0.000095	0.001315
	72	0.000026	0.000136	0.007870	1.439873	Y=4.746+0.208x	0.000003	0.000281
Spinosad 45EC	24	0.000057	0.000514	0.116636	0.083001	Y=4.379+0.155x	0.000210	0.00059
	48	0.000023	0.000168	0.021807	0.219511	Y=4.601+0.173x	0.000009	0.000391
	72	0.000008	0.000050	0.005040	1.095299	Y=4.888+0.192x	0.000000	0.000127
Dichlorovas 45SC	24	0.000381	0.001320	0.028115	0.548698	Y=4.095+0.172x	0.000745	0.001564
	48	0.000186	0.000641	0.013511	0.257105	Y=4.397+0.172x	0.000354	0.003558
	72	0.000090	0.000326	0.007749	0.232476	Y=4.694+0.165x	0.000006	0.000540
Emamectin benzoate 5G	24	0.000033	0.000264	0.045432	0.561380	Y=4.276+0.206x	0.000108	0.001548
	48	0.000012	0.000118	0.031007	0.274934	Y=4.543+0.181x	0.000014	0.000331
	72	0.000006	0.000041	0.004254	1.430205	Y=4.694+0.234x	0.000013	0.000134
Imidachloprid 17.5 SC	24	0.000351	0.034620	0.045871	0.247154	Y=4.222+0.160x	0.001829	0.655443
	48	0.000015	0.001224	0.002546	1.352796	Y=4.545+0.180x	0.000196	0.007631
	72	0.000026	0.001318	0.001964	0.615105	Y=4.517+0.190x	0.000263	0.006598
Flubendiamide 480SC	24	0.000761	0.003273	0.118623	0.208912	Y=4.19+0.187x	0.001835	0.042604
	48	0.000433	0.002289	0.137893	0.435053	Y=4.382+0.171x	0.001076	0.033684
	72	0.000100	0.000620	0.055156	0.399548	Y=4.801+0.159x	0.000522	0.001305
Lufenuron 5EC	24	0.002959	0.010008	0.200956	0.544621	Y=4.194+0.176x	0.006110	0.749688
	48	0.002144	0.005986	0.074953	1.478450	Y=4.292+0.213x	0.003715	0.012556
	72	0.000957	0.002746	0.036753	0.433704	Y=4.701+0.205x	0.000414	0.004260

Mean larval wt.=0.0232g/larva (23.2 mg)





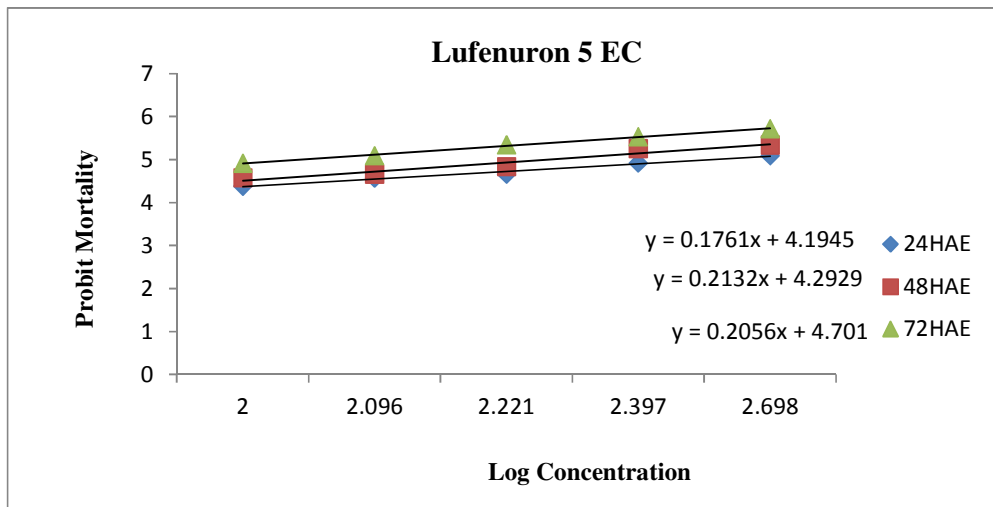
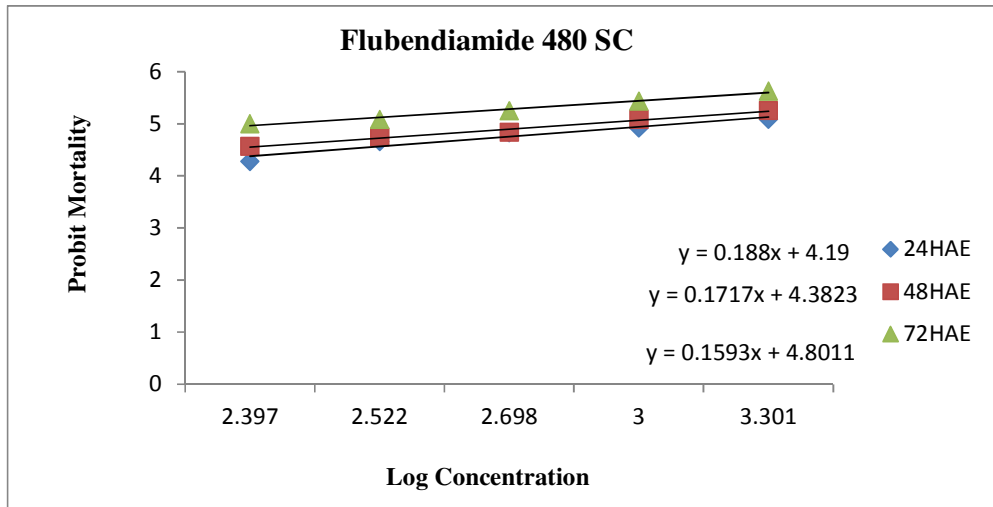
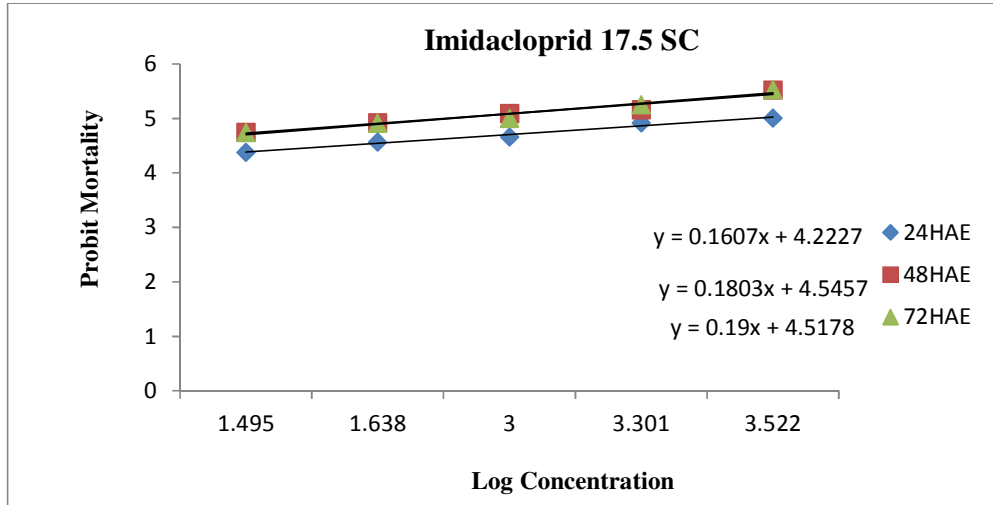


Fig. 4.3.9. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Pauri Garhwal population by leaf dip bioassay method

The order of toxicity of insecticides against the third instar larvae of *S. litura* (Fab.) LC₅₀ was follows, emamectin benzoate 5 G > indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > spinosad 45 SC > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC 45 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

At 48 HAF, emamectin benzoate 5 G showed to highest toxicity with LC₅₀ value of 0.000118%, followed by spinosad 45 EC (0.000168%), indoxacarb 15.8 EC (0.000210%), chlorantraniliprole (Coragen) (0.000280%), lambda cyhalothrin 5 EC (0.000414%), Dichlorvos 45 SC (0.000641%), lufenuron 5 EC (0.005986%), and flubendiamide 480 SC (0.002289%). Imidacloprid 17.5 SC (0.001224%) was found to be least toxic.

The outcomes can also be described in order of toxicity levels of different insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration LC₅₀ and can be stated as follows, emamectin benzoate 5 G > spinosad 45 SC > indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > lambda cyhalothrin 5 EC > Dichlorvos 45 SC > lufenuron 5 EC > flubendiamide 480 SC > Imidacloprid 17.5 SC.

At 72 HAF, insecticides followed more or less similar trend in their toxicity levels against third instar larvae of *S. obliqua* (Fab.) and emamectin benzoate 5 G was again found most toxic with LC₅₀ value of 0.000041% followed by spinosad 45 EC (0.000050%), Chlorantraniliprole (Coragen) (0.000097%), lambda cyhalothrin 5 EC (0.000136%), indoxacarb 15.8 EC (0.000159%), dichlorvos 45 SC (0.000326%), flubendiamide 480 SC (0.000620%) and lufenuron 5 EC (0.002746%) whereas, Imidacloprid 17.5 SC (0.001318%) was again found to be the least lethal.

The order of toxicity of these insecticides based on their median lethal concentration (LC₅₀) is as follows, emamectin benzoate 5G > spinosad 45 SC > Chlorantraniliprole (Coragen) > lambda cyhalothrin 5 EC > indoxacarb 15.8 EC > dichlorvos 46 SC > flubendiamide 480 SC > lufenuron 5 EC > Imidacloprid 17.5 SC.

The resistance ratio showed by the *S. litura* population collected from this district against chlorantraniliprole 20SC was found to be, 2.06, 2.44 and 1.17 times to that of the susceptible population at 24, 48 and 72 HAF, respectively. The same for indoxacarb 15.8 EC was, 1.96, 2.09 and 2.28 times, for lambda cyhalothrin 5EC it was, 4.18, 3.26 and 2.10 times, for spinosad 45 SC, 4.06, 2.15 and 1.05 times, for dichlorvos 46SC, 4.69, 2.71 and 1.77 times, for emamectin benzoate 5G, 4.40, 5.23 and 2.19

times, for imidacloprid 17.5 SC it was, **32.43**, **11.07** and **17.97** times, for flubendiamide 480 SC it was, 3.34, 4.35 and 2.10 times and for lufenuron 5 EC, this resistance ratio was found to be 2.89, 2.54 and 2.07 times at 24, 48 and 72 HAF, respectively.

4.3.10. Uttarkashi

At 24 HAF, indoxacarb 15.8 EC was found most toxic with LC₅₀ value of 0.000343%, followed by Chlorantraniliprole (Coragen) (0.000389%), lambda cyhalothrin 5 EC (0.000644%), spinosad 45 EC (0.000729%), Dichlorvos 45 SC (0.000909%), emamectin benzoate 5 G (0.000953%), flubendiamide 480 SC (0.003122%) and lufenuron 5 EC (0.006078%). Imidacloprid 17.5 SC (0.007509%) was found to be least effective (Table No. 4.3.10).

To rearticulate, the order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > lambda cyhalothrin 5 EC > spinosad 45 SC > Dichlorvos 45 SC > emamectin benzoate 5 G > flubendiamide 480 SC > lufenuron 5 EC > Imidacloprid 17.5 SC.

At 48 HAF, again, indoxacarb 15.8 EC was found most toxic with LC₅₀ value of 0.000236%, followed by chlorantraniliprole (Coragen) (0.000270%), spinosad 45 EC (0.000282%), emamectin benzoate 5 G (0.000283%), lambda cyhalothrin 5 EC (0.000324%), dichlorvos 45 SC (0.000583%), flubendiamide 480 SC (0.001733%) and imidacloprid 17.5 SC (0.002889%). Lufenuron 5 EC (0.005026%) was found to be least toxic.

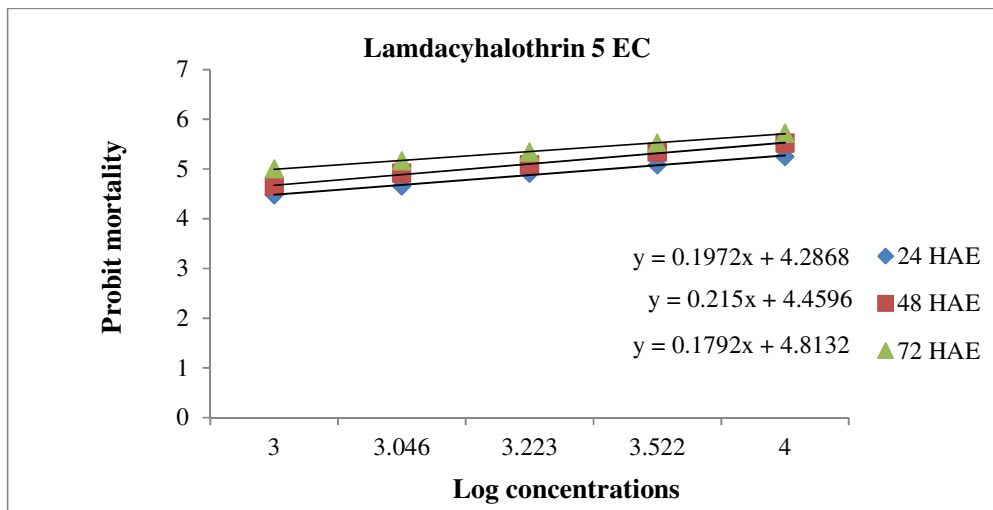
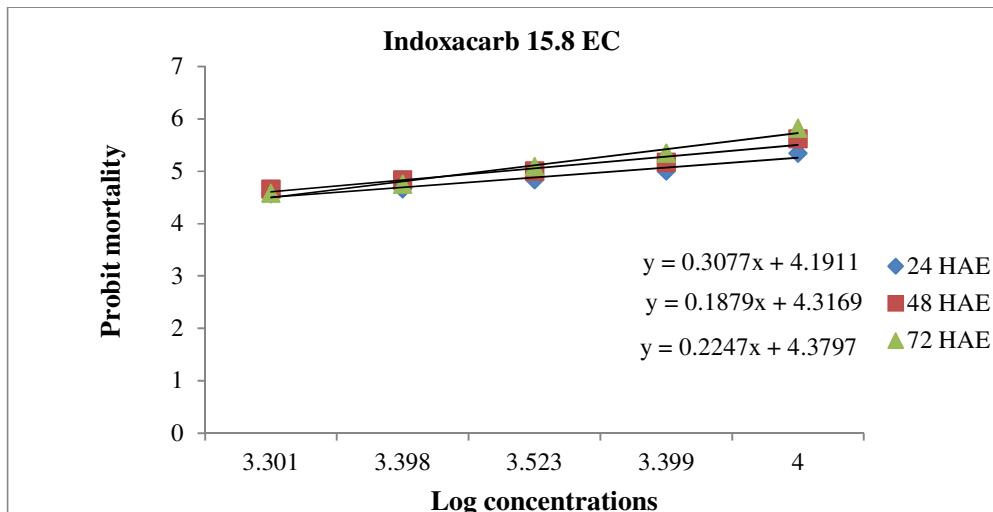
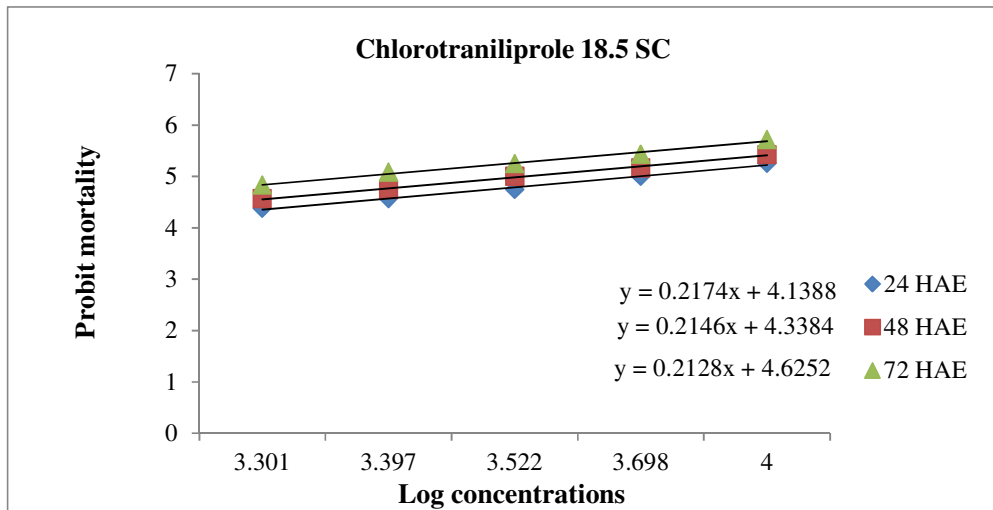
In clear text, the order of toxicity of various insecticides based on LC₅₀ was as follows, indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > spinosad 45 SC > emamectin benzoate 5 G > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > imidacloprid 17.5 SC > lufenuron 5 EC.

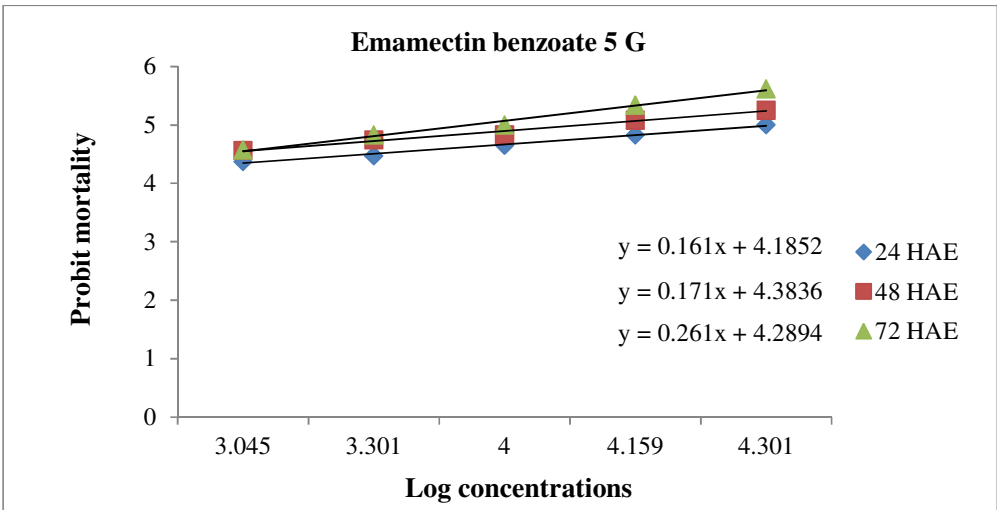
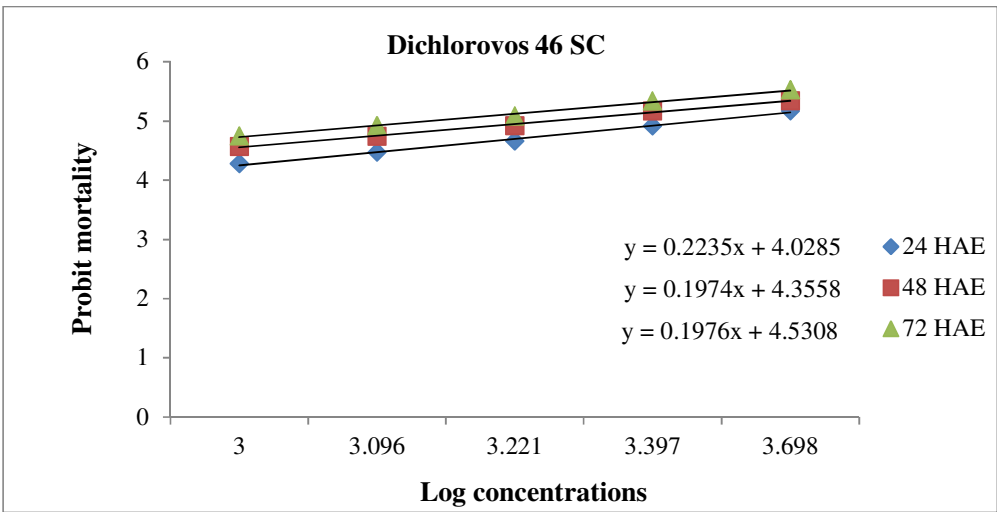
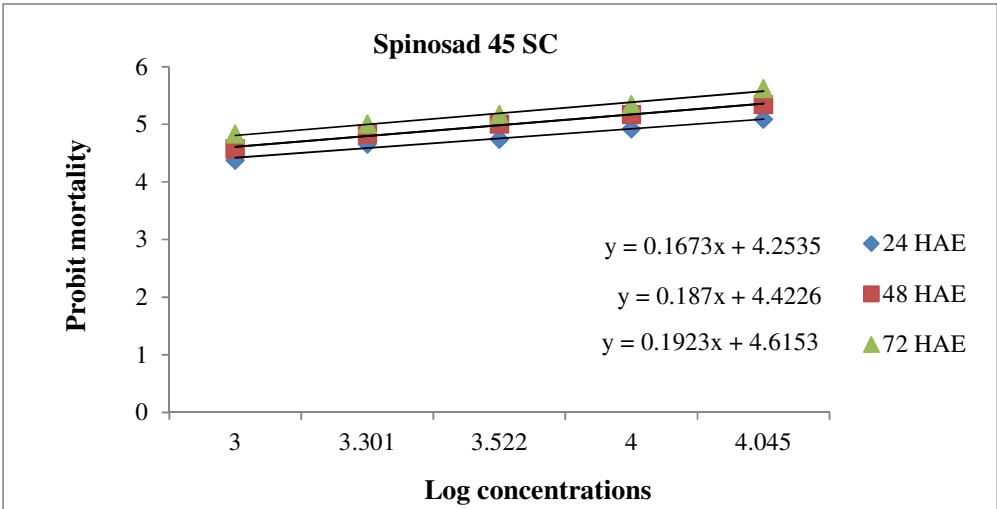
The toxicity studies against third instar larvae with various insecticides **at 72 HAF**, revealed that lambda cyhalothrin 5 EC was found most toxic with LC₅₀ value of 0.000123% followed by spinosad 45 EC (0.000136%), emamectin benzoate 5 G (0.000138%), chlorantraniliprole (Coragen) (0.000156%), indoxacarb 15.8 EC (0.000225%), dichlorvos 45 SC (0.000402%), imidacloprid 17.5 SC (0.000691%) and flubendiamide 480 SC (0.000876%). Lufenuron 5 EC (0.003728%) was found to be least effective.

Table 4.3.10: Dosage -mortality response of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Uttarkashi poulation at 24, 48 and 72 HAE

Insecticides (Trade name)	HAE (hr.)	LC Values (%)			Chi square	Regression equation Y=a+bx	Fiducial limits at LC ₅₀	
		LC ₃₀	LC ₅₀	LC ₉₀			Lower	Upper
Chlorantraniliprole (Coragen)	24	0.000145	0.000389	0.004447	0.809601	Y=4.138+0.217x	0.000263	0.001206
	48	0.000099	0.000270	0.003184	0.5909052	Y=4.3380.214x	0.000159	0.000481
	72	0.000056	0.000156	0.001918	0.5234302	Y=4.625+0.212x	0.000037	0.000234
Indoxacarb 15.8 EC	24	0.000110	0.000343	0.006352	1.278095	Y=4.191+0.307x	0.000206	0.001781
	48	0.000087	0.000236	0.002735	1.734406	Y=4.316+0.187x	0.000123	0.000376
	72	0.000109	0.000225	0.001326	2.339572	Y=4.379+0.224x	0.000150	0.000303
Lamdacyhalothrin 5 EC	24	0.000126	0.000644	0.035786	0.5740572	Y=4.286+0.197x	0.000322	0.003530
	48	0.000071	0.000324	0.013701	0.7554469	Y=4.459+0.215x	0.000093	0.000616
	72	0.000019	0.000123	0.012672	0.6857297	Y=4.813+0.179x	0.000153	0.000282
Spinosad 45EC	24	0.000085	0.000729	0.143570	0.6135874	Y=4.253+0.167x	0.000311	0.000812
	48	0.000043	0.000282	0.029537	0.5114236	Y=4.422+0.187x	0.000091	0.001072
	72	0.000022	0.000136	0.011826	0.3193557	Y=4.615+0.192x	0.000010	0.000279
Dichlorovas 45SC	24	0.000350	0.000909	0.009525	0.1981273	Y=4.028+0.223x	0.000616	0.003484
	48	0.000196	0.000583	0.008519	0.5133094	Y=4.355+0.197x	0.000337	0.001318
	72	0.000133	0.000402	0.006070	0.5942513	Y=4.530+0.197x	0.000124	0.000636
Emamectin benzoate 5G	24	0.000066	0.000953	0.6900309	0.2502076	Y=4.185+0.161x	0.000300	0.000979
	48	0.000024	0.000283	0.1260381	0.184719	Y=4.383+0.171x	0.000094	0.010025
	72	0.000027	0.000138	0.007746	0.5328113	Y=4.289+0.261x	0.000056	0.000281
Imidachloprid 17.5 SC	24	0.000211	0.007509	0.008134	0.5487770	Y=4.216+0.208x	0.001540	0.036619
	48	0.000077	0.002889	21.870470	1.083786	Y=4.341+0.213x	0.000696	0.011995
	72	0.000037	0.000691	0.9114238	1.967259	Y=4.431+0.266x	0.000178	0.002686
Flubendiamide 480SC	24	0.000536	0.003122	0.2386961	0.040641	Y=4.339+0.156x	0.001560	9.001111
	48	0.000397	0.001733	0.065290	0.099600	Y=4.414+0.188x	0.000173	0.004566
	72	0.000157	0.000876	0.060068	0.2655282	Y=4.695+0.165x	0.000004	0.001721
Lufenuron 5EC	24	0.001937	0.006078	0.1014185	0.553355	Y=4.364+0.188x	0.003480	0.017339
	48	0.001580	0.005026	0.086725	0.5722498	Y=4.453+0.187x	0.002170	0.010002
	72	0.001520	0.003728	0.033933	1.085994	Y=4.459+0.245x	0.001712	0.005323

Mean larval wt.=0.0232g/larva (23.2 mg)





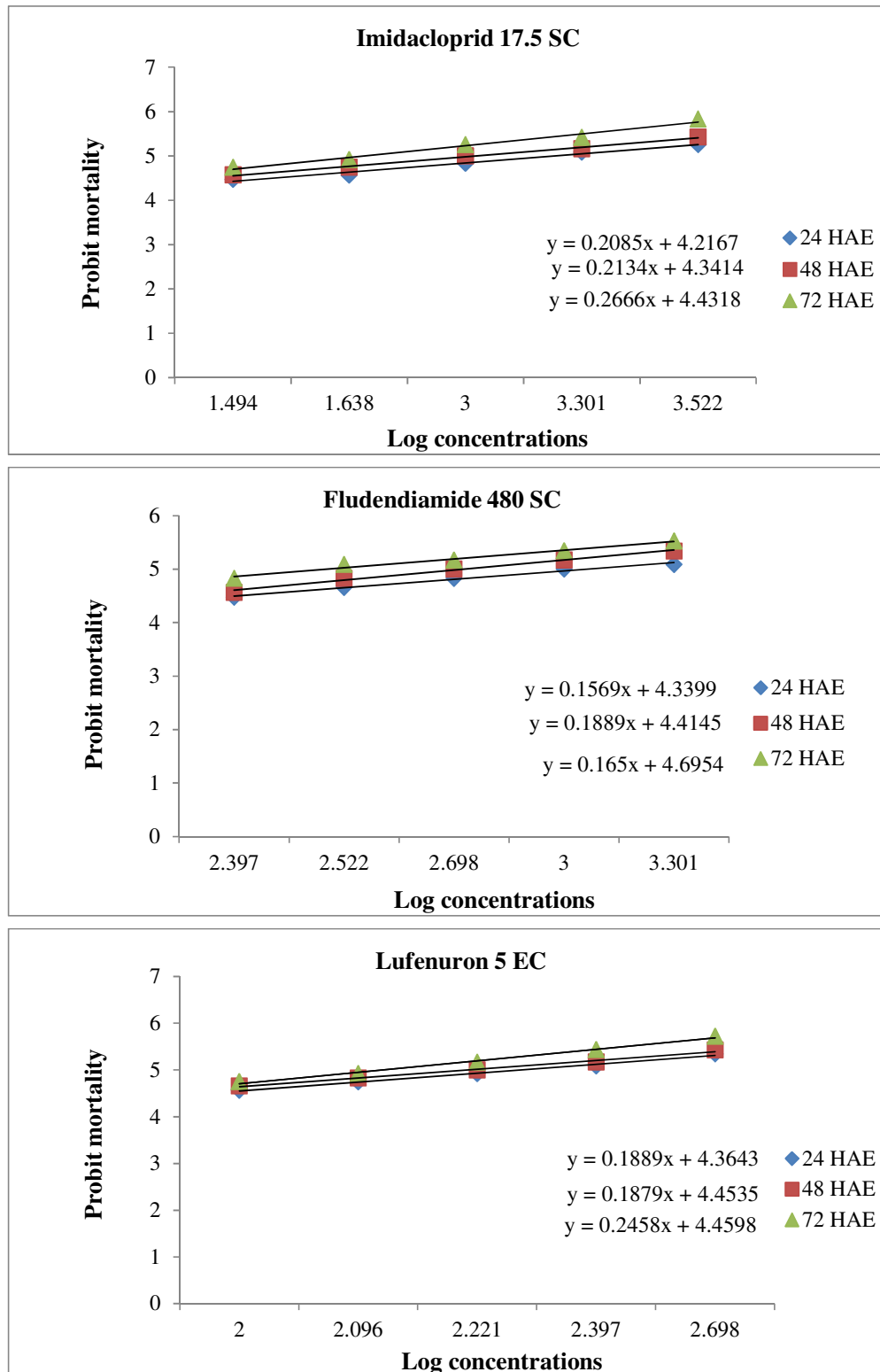


Fig. 4.3.10. Dosage - mortality of different insecticides against 3rd instar larvae of tobacco caterpillar, *Spodoptera litura* (Fab.) of Uttarakashi population by leaf dip bioassay method

Table no: 4.3.11 Resistance ratio of different insecticides to different populations of *S. litura* in Uttarakhand at 24, 48 and 72 HAF

Insecticides	HAF	U. S. Nagar	Nainital	Almora	Champawat	Pitoragarh	Pauri Gharwal	New Tehri	Uttarkashi	Dehradun	Haridwar
Chlorotraniliprole 18.5SC	24	2.06	2.90	2.18	2.14	2.40	2.06	2.40	1.87	2.01	1.78
	48	8.58	5.44	3.05	2.07	2.92	2.44	2.37	2.36	2.36	2.36
	72	1.10	3.08	2.42	1.41	1.75	1.17	5.15	1.89	1.00	2.42
Indoxacarb 15.8 EC	24	2.54	2.96	2.30	2.44	2.41	1.96	2.29	2.01	2.30	2.93
	48	2.09	2.93	2.52	2.27	2.14	2.09	2.43	2.35	2.71	3.29
	72	2.28	2.95	3.01	1.43	1.69	2.28	1.92	3.22	1.79	3.01
Lamdacyhalothrin 5 EC	24	4.29	2.71	3.23	5.00	3.18	4.18	3.74	2.14	3.56	5.36
	48	3.26	4.16	3.24	4.24	5.86	3.26	4.50	2.55	3.01	6.69
	72	2.10	3.87	4.16	4.18	3.96	2.10	5.62	1.90	2.73	5.39
Spinosad 45SC	24	4.06	3.31	4.51	3.64	4.59	4.06	3.55	5.75	3.83	5.37
	48	2.15	1.86	4.56	2.20	3.16	2.15	2.68	3.61	2.10	5.63
	72	1.05	2.23	3.24	1.56	2.73	1.05	3.74	2.86	1.83	3.79
Dichlorovas 46SC	24	4.27	4.13	3.87	4.13	4.39	4.69	3.49	3.23	3.32	4.01
	48	2.71	2.38	3.73	2.69	2.81	2.71	2.46	2.46	2.21	3.00
	72	1.77	2.00	2.24	2.17	2.83	1.77	2.46	2.18	1.97	2.38
Emamectin benzoate 5G	24	4.20	12.65	8.68	6.08	6.57	4.40	7.87	15.88	6.43	6.83
	48	5.23	14.10	9.18	5.59	5.28	5.23	9.62	12.55	2.48	7.54
	72	2.19	5.07	2.78	2.67	27.87	2.19	2.83	7.37	2.30	5.34
Imidachloprid 17.5 SC	24	32.43	12.06	58.73	23.14	44.41	32.43	40.91	7.03	29.45	11.40
	48	23.26	0.00	188.72	193.21	107.06	11.07	42.88	26.14	133.23	16.29
	72	17.97	0.00	64.64	22.24	29.89	17.97	20.03	9.42	20.93	6.82
Flubendiamide 480SC	24	3.42	3.49	2.90	3.19	3.34	3.34	3.21	3.19	2.79	3.83
	48	3.92	4.81	3.92	3.51	3.92	4.35	3.49	3.29	3.13	3.47
	72	2.10	3.66	4.07	1.56	2.70	2.10	2.88	2.97	2.25	3.73
Lufenuron 5EC	24	2.94	3.14	2.89	2.70	2.69	2.89	3.49	1.75	2.69	3.81
	48	2.54	2.72	2.40	2.84	2.79	2.54	3.01	2.13	2.63	2.39
	72	2.07	3.11	3.18	3.30	2.68	2.07	2.47	2.82	3.67	2.68

HAF- Hours After Feeding, **Resistance Ratio**=LC50 of field population/LC50 of Susceptible Population

In other words, the order of toxicity of various insecticides based on their LC₅₀ was as follows, lambda cyhalothrin 5 EC > spinosad 45 SC > emamectin benzoate 5G > chlorantraniliprole (Coragen) > indoxacarb 15.8 EC > dichlorvos 45 SC > imidacloprid 17.5 SC flubendiamide 480 SC > lufenuron 5 EC.

It is also observed that the *S. litura* population of Uttarkashi exhibited the resistance ratio to different insecticides are as follows, chlorantraniliprole 20 SC showed 1.87, 2.36 and 1.89 folds of resistance at 24, 48 and 72 HAF respectively. The same population showed resistance ratio against indoxacarb 15.8 EC as, 2.01, 2.35 and 3.22, against lambda cyhalothrin 5 EC as, 2.14, 2.55 and 1.90, against spinosad 45 SC, 5.75, 3.61 and 2.86, against dichlorvos 46 SC as, 3.23, 2.46 and 2.18, against emamectin benzoate 5 G as, 2.88, 3.55 and 4.37, against imidacloprid 17.25SC as, **7.03**, **26.14** and **9.42**, against flubendiamide 480SC, 3.19, 3.29 and 3.27 and against lufenuron 5EC as, 1.75, 2.13 and 2.82, respectively at 24, 48 and 72 HAF, as compared to that of susceptible population.

4.4 Bio-efficacy and economics of insecticides against tobacco caterpillar *Spodoptera litura* on Soybean

Observations recorded on larval population, per cent reduction over control (%ROC), seed yield and economics are presented here under.

4.4.1 First spray 2016

The larval population was found to be distributed homogeneously in all the treatments at one day before first spray of the insecticides. At one day after spraying the least larval population was noticed in flubendiamide 480 SC @ 0.2 ml/l with 5.99 larvae/meter row length (mrl), which was superior among the other treatments. This was followed by the next best treatments, having dichlorvos 45SC @ 1.5ml/l and spinosad 45 SC @ 0.25 ml/l with larval population of 7.44 and 7.54 larvae/mrl, respectively. These treatments were followed by lambda cyhalothrin 5 EC@ 0.30 ml/l, chlorantraniliprole 18.5 SC @ 0.2 ml/l, indoxacarb 15.8 EC @ 0.40 ml/l and imidacloprid 17.5 SC@ 0.5 ml/l, which were found at par with each other with the mean larval population of 8.20, 8.31, 8.64 and 8.78 larvae/mrl, respectively. The highest larval population was found in the untreated control (11.77 larvae/mrl). (Table-4.4.1).

Table No. 4.4.1. Efficacy of different insecticides against tobacco caterpillar (*S. litura*) on soybean during *kharif* 2016

Tr. No	Treatment	Mean number of larvae/meter row length									
		1 st Spray					2 nd Spray				
		1DBS	1 DAS	5 DAS	7DAS	% ROC	1DBS	1 DAS	5 DAS	7 DAS	%ROC
T1	Chlorotraniliprole 18.5EC@0.20 ml/l	10.78 (3.282) ^a	8.31 (2.888) ^b	6.00 (2.452) ^{ab}	2.55 (1.604) ^{ab}	46.68	6.66 (2.581) ^{bc}	3.55 (1.892) ^a	2.44 (1.574) ^{ab}	1.55 (1.262) ^{ab}	43.09
T2	Indoxacarb 15.8 EC@0.40 ml/l	10.33 (3.206) ^a	8.64 (2.943) ^b	5.54 (2.363) ^{ab}	3.22 (1.807) ^{ab}	44.18	5.67 (2.375) ^{abc}	3.66 (1.924) ^{ab}	2.55 (1.613) ^{ab}	1.14 (1.085) ^a	38.67
T3	Lamdacyhalothrin 5 EC@ 0.30ml/l	10.44 (3.235) ^a	8.20 (2.869) ^b	6.22 (2.498) ^b	3.99 (1.996) ^b	42.56	5.00 (2.239) ^{ab}	3.33 (1.824) ^a	2.44 (1.574) ^a	1.61 (1.283) ^{ab}	33.93
T4	Spinosad 45SC@0.25 ml/l	10.21 (3.188) ^a	7.54 (2.745) ^{ab}	5.55 (2.353) ^{ab}	3.22 (1.797) ^{ab}	45.98	4.33 (2.073) ^a	3.22 (1.793) ^a	2.55 (1.604) ^{ab}	1.89 (1.383) ^{ab}	26.16
T5	Dichlorovas 45SC@1.5ml/l	8.89 (2.984) ^a	7.44 (2.736) ^{ab}	6.22 (2.501) ^b	3.55 (1.892) ^b	38.93	6.22 (2.496) ^{abc}	4.89 (2.219) ^{ab}	3.55 (1.892) ^b	3.22 (1.793) ^c	23.31
T6	Emamectin benzoate 5G@0.30 g/l	10.78 (3.286) ^a	9.11 (3.025) ^b	6.65 (2.578) ^b	2.66 (1.642) ^{ab}	43.66	4.55 (2.144) ^{ab}	3.22 (1.807) ^a	1.78 (1.333) ^a	1.03 (1.034) ^a	37.99
T7	Imidachloprid 17.5 SC@0.5ml/l	9.55 (3.093) ^a	8.78 (2.963) ^b	7.33 (2.712) ^b	5.33 (2.313) ^c	32.55	7.22 (2.693) ^c	5.22 (2.288) ^b	3.00 (1.739) ^{ab}	2.44 (1.573) ^{bc}	33.93
T8	Flubendiamide 480SC@0.20 ml/l	8.00 (2.835) ^a	5.99 (2.455) ^a	4.00 (2.008) ^a	1.89 (1.383) ^a	48.35	4.22 (2.059) ^a	3.33 (1.824) ^a	2.00 (1.421) ^a	1.13 (1.077) ^a	32.50
T9	Lufenuron 5EC@0.5ml/l	10.24 (3.205) ^a	9.0 (3.003) ^b	6.89 (2.626) ^b	3.89 (1.981) ^b	39.08	5.55 (2.364) ^{abc}	4.00 (2.008) ^{ab}	2.88 (1.705) ^{ab}	1.66 (1.297) ^{ab}	32.31
T10	Control (Untreated)	9.33 (3.205) ^a	11.77 (3.433) ^c	11.78 (3.437) ^c	12.00 (3.469) ^d	0	13.22 (3.642) ^d	11.33 (3.368) ^c	12.33 (3.515) ^c	12.67 (3.565) ^d	0
	S.Em ±	0.1436	0.1207	0.1297	0.1098	-	0.1424	0.1214	0.1081	0.0883	-
	C.D. at 5%	0.4267	0.3588	0.3854	0.3263	-	0.4231	0.3607	0.3212	0.2624	-
	C.V.%	7.928	7.199	8.801	9.566	-	10.001	10.00	10.423	9.965	-

Figures in the parentheses are transformed values

NS- Non-significant, DBS- Day before spray, DAS- Days after spray

In vertical columns, means followed by same letter do not differ significantly by DMRT (P=0.05).

5 DAS the lowest insect population was found in the treatment flubendiamide 480 SC @ 0.2 ml/l with 4.00 larva/mrl and this was followed by spinosad 45 SC @ 0.25 ml/l, indoxacarb 15.8 EC @ 0.40ml/l and chlorantraniliprole 18.5 EC @ 0.20 ml/l with an at par larval population with each other of 5.55, 5.54 and 6.00 larva/mrl, respectively.

A similar trend in efficacy of the insecticides was observed at seven days after spraying wherein, the least mean number of larvae per meter row length was observed in the plots treated with flubendiamide 480 SC, followed by chlorantraniliprole, emamectin benzoate 5 G, indoxacarb 15.8 EC, spinosad 45 SC, dichlorvos 45SC, lufenuron 5 EC with insect population of 2.55, 2.66, 3.22, 3.22, 3.55, 3.89, 3.99 larvae/mrl, respectively and they were found to be at par with each other. The highest insect population was observed in plot treated with imidacloprid 17.5 SC (5.33 larvae/mrl). Whereas, 12.00 larvae/mrl, were found in untreated control.

Highest per cent reduction over control (ROC) was observed in flubendiamide 480 SC @ 0.20ml/l with 48.35 per cent which was at par with chlorantraniliprole 18.5 EC @0.20ml/l (46.68 per cent) and spinosad 45 SC @0.25ml/l (45.98 per cent). Followed by indoxacarb 15.8 EC @0.40 ml/l (44.18 per cent), emamectin benzoate 5 G @ 0.30g/l (43.66 per cent), lambda cyhalothrin 5EC @ 0.30ml/l (42.56 per cent), lufenuron 5 EC @ 0.5ml/l (39.08 per cent), dichlorvos 45 SC @ 1.5ml/l (38.93 per cent) and imidacloprid 17.5 SC @ 0.5ml/l (32.55 per cent).

4.4.2 Second spray

At one day before second spray flubendiamide 480 SC @ 0.20ml/l (4.22 larvae/mrl) was having least larval population along with the at par populations of spinosad 45 SC @ 0.25ml/l and emamectin benzoate 5 G @ 0.5 g/l with larval population of 4.33 and 4.55 larvae/mrl, respectively (Table No. 4.4.1). The next three treatments with populations of 5.00, 5.55 and 5.67 were lambda cyhalothrin 5 EC @ 0.30ml/l, lufenuron 5EC @ 0.5ml/l and indoxacarb 15.8EC @ 0.40 ml/ l. These three populations were at par with remaining two treatments of dichlorvos 45SC @ 1.5 ml/l (6.22 larvae/mrl) and chlorantraniliprole 18.5 EC @ 0.20ml/l (6.22 larvae/mrl). The highly significant larval populations were found in imidacloprid 17.5 SC @ 0.5ml/l (7.22 larvae/mrl) and untreated control (13.22 larvae/mrl).

At one day after spraying the lowest populations were recorded at par with each other in emamectin benzoate 5 G @ 0.30 g/l, spinosad 45 SC @ 0.25 ml/l, flubendiamide 480 SC @ 0.20 ml/l, lambda cyhalothrin 5 EC @ 0.30 ml/l and chlorantraniliprole 18.5 EC @ 0.20 ml/l with mean larval population of 3.22, 3.22, 3.33, 3.33, 3.55 larvae/mrl, respectively. Next best treatments were found to be indoxacarb 15.8 EC @ 0.40 ml/l (3.66 larvae/mrl), followed by lufenuron 5 EC @ 0.5 ml/l (4.00 larvae/mrl) and dichlorvos 45 SC @ 1.5 ml/l (4.89 larvae/mrl). Whereas, compared to other treatments, the highest population was found in imidacloprid 17.5 SC @ 0.5 ml/l (5.22 larvae/mrl).

Similarly, at 5 days after spraying the lowest larval population was recorded in emamectin benzoate 5 G @ 0.30 gm/l and flubendiamide 480 SC @ 0.20 ml/l with 1.78 and 2.00 larvae/mrl and they were followed by chlorantraniliprole 18.5 EC @ 0.20 ml/l, lambda cyhalothrin 5 EC @ 0.30 ml/l, indoxacarb 15.8 EC @ 0.40 ml/l, spinosad 45 EC @ 0.25 ml/l and lufenuron 5 EC @ 0.50 ml/l with an at par larval population of 2.44, 2.44, 2.55, 2.55 and 2.88 larvae/mrl. The highest population was found in imidacloprid 17.5 SC @ 0.5 ml/l (3.00) and dichlorvos 45 SC @ 1.5 ml/l (3.55). Whereas, 12.33 larvae/mrl were found in the untreated control.

At 7 days after spraying emamectin benzoate 5 G @ 0.30 gm/l recorded the lowest larval population of 1.03 larvae/mrl which was at par with the population recorded in plots treated with flubendiamide 480 SC @ 0.20 ml/l (1.13 larvae/mrl) and indoxacarb 15.8 EC @ 0.40 ml/l (1.14 larvae/mrl). These were followed by chlorantraniliprole 18.5 EC @ 0.20 ml/l, lambda cyhalothrin 5 EC @ 0.30 ml/l, lufenuron 5 EC @ 0.50 ml/l and spinosad 45 SC @ 0.25 ml/l with larval population of 1.55, 1.61, 1.66 and 1.89 larvae/mrl, respectively. Imidacloprid 17.5 SC @ 0.5 ml/l recorded 2.44 larvae/mrl along with dichlorvos 45 SC @ 1.5 ml/l recorded highest population of 3.22 larvae/mrl and thus found to be least effective when compared with untreated control plot (12.67).

Highest percent reduction over control was recorded in chlorantraniliprole 18.5 EC @ 0.20 ml/l with a significant reduction of 43.09%, followed by indoxacarb 15.8 EC @ 0.40 ml/l and emamectin benzoate 5 G @ 0.30 gm/l with 38.67 and 37.99%,

respectively. Moderate percent reduction was recorded in lambda cyhalothrin 5 EC @ 0.30 ml/l, lufenuron 5 EC @ 0.50 ml/l with 33.93 and 33.50%. Lowest percent reduction of 23.31% was recorded in dichlorvos 45 SC @ 1.5 ml/l.

4.4.3 First Spray 2017

As of previous year i.e. *Kharif* 2016 all the treatments recorded a uniform population at one day before spraying (Table No. 4.4.2). During the first day after spraying more or less similar trend was observed in the larval count as seen in one day before spray with flubendiamide 480SC @ 0.20ml/l (8.00 larvae/mrl), imidacloprid 17.8 SC @ 0.5ml/l (8.66 larvae/mrl), dichlorvos 45 SC @ 1.5ml/l (7.66 larvae/mrl), emamectin benzoate 5 G @ 0.5g/l (9.22 larvae/mrl), lufenuron 5 EC @ 0.5ml/l (9.33 larvae/mrl), spinosad 45 EC @ 0.25ml/l (9.33 larvae/mrl), chlorantraniliprole 18.5 EC @ 0.20 ml/l (9.66 larvae/mrl), lambda cyhalothrin 5 EC @ 0.30ml/l (10.00 larvae/mrl), and indoxacarb 18.8 EC @ 0.40ml/l (10.55 larvae/mrl).

During five days after spraying a significant reduction in larval population was observed in flubendiamide 480 SC @ 0.20ml/l with 4.33 larvae/mrl. This was at par with lufenuron 5 EC @ 0.5ml/l (5.55 larvae/mrl), spinosad 45 EC @ 0.25ml/l (5.66 larvae/mrl), imidacloprid 17.5 SC @ 0.5ml/l(5.89 larvae/mrl) and emamectin benzoate 5 G @ 0.30 g/l (6.00 larvae/mrl). It was followed by lambda cyhalothrin 5EC @ 0.30ml/l, chlorantraniliprole 18.5 EC @ 0.20ml/l and dichlorvos 45 SC @ 1.5 ml/l with larval population of 7.33, 7.33 and 7.66 larvae/mrl, respectively.

At seven days after spray flubendiamide 480 SC @ 0.20ml/l recorded significantly lesser population of *S. litura* with 2.03 larvae/mrl which was at par with population in plots treated with emamectin benzoate 5 G @ 0.30g/l (2.66 larvae/mrl), lufenuron 5 EC @ 0.5ml/l (3.33 larvae/mrl), spinosad 445 EC @ 0.25ml/l (3.33 larvae/mrl) and lamda cyhalothrin 5 EC @ 0.30ml/l (3.66 larvae/mrl). Comparatively, higher population was present in chlorantraniliprole 18.5 EC @ 0.20ml/l (4.33 larvae/mrl), dichlorvos 45 SC @ 1.5ml/l (4.33 larvae/mrl) and imidacloprid 17.5 SC @ 0.5ml/l (4.44 larvae/mrl).

Table No. 4.4.2 Efficacy of different insecticides against tobacco caterpillar (*S. litura*) on soybean during *kharif* 2017

Tr. No	Treatment	Mean number of larvae/meter row length									
		1 st Spray					2 nd Spray				
		1DBS	1 DAS	5 DAS	7DAS	% ROC	1DBS	1 DAS	5 DAS	7 DAS	% ROC
T1	Chlorotraniliprole 18.5EC@0.20 ml/l	12.00 (3.466) ^a	9.66 (3.112) ^a	7.33 (2.712) ^{ab}	4.33 (2.083) ^{bc}	26.56	6.33 (2.521) ^{ab}	4.55 (2.144) ^a	2.44 (1.573) ^{ab}	0.89 (0.938) ^{ab}	34.89
T2	Indoxacarb 15.8 EC@0.40 ml/l	12.00 (3.462) ^a	10.55 (3.252) ^a	8.00 (2.821) ^{ab}	4.66 (2.168) ^c	22.40	5.55 (2.364) ^a	3.56 (1.895) ^a	2.11 (1.450) ^a	1.22 (1.061) ^{ab}	35.01
T3	Lamdacyhalothrin 5 EC@ 0.30ml/l	11.93 (3.454) ^a	10.00 (3.158) ^a	7.33 (2.712) ^b	3.66 (1.909) ^{abc}	27.04	6.00 (2.445) ^{ab}	4.22 (2.059) ^a	2.44 (1.573) ^{ab}	1.89 (1.383) ^{bc}	29.66
T4	Spinosad 45EC@0.25 ml/l	11.33 (3.358) ^a	9.33 (3.043) ^a	5.66 (2.376) ^{abc}	3.33 (1.824) ^{abc}	30.80	6.33 (2.505) ^{ab}	3.89 (1.960) ^a	2.00 (1.420) ^a	0.89 (0.939) ^{ab}	39.99
T5	Dichlorovas 45SC@1.5ml/l	9.66 (3.099) ^a	8.78 (2.958) ^a	7.66 (2.768) ^b	4.33 (2.083) ^{bc}	16.73	6.33 (2.521) ^{ab}	4.66 (2.168) ^a	3.55 (1.892) ^{bc}	2.89 (1.709) ^c	20.15
T6	Emamectin benzoate 5G@0.30 g/l	11.44 (3.389) ^a	9.22 (3.043) ^a	6.00 (2.457) ^b	2.66 (1.641) ^{ab}	32.25	6.33 (2.504) ^{ab}	4.33 (2.083) ^a	2.55 (1.604) ^{ab}	1.11 (1.074) ^{ab}	34.39
T7	Imidachloprid 17.5 SC@0.5ml/l	10.00 (3.158) ^a	8.66 (2.944) ^a	5.89 (2.427) ^{abc}	4.44 (2.117) ^{bc}	23.32	7.33 (2.712) ^{ab}	5.55 (2.359) ^{ab}	4.00 (2.008) ^c	2.22 (1.505) ^c	24.45
T8	Flubendiamide 480SC@0.20 ml/l	10.33 (3.215) ^a	8.00 (2.832) ^a	4.33 (2.083) ^a	2.03 (1.438) ^a	36.82	6.00 (2.452) ^{ab}	4.11 (2.026) ^a	1.89 (1.383) ^a	0.55 (0.752) ^a	39.33
T9	Lufenuron 5EC@0.5ml/l	10.55 (3.252) ^a	9.33 (3.059) ^a	5.55 (2.364) ^{ab}	3.33 (1.824) ^{abc}	27.93	8.22 (2.873) ^b	6.66 (2.584) ^b	4.55 (2.141) ^c	2.89 (1.709) ^c	21.26
T10	Control (Untreated)	12.22 (3.497) ^a	10.44 (3.236) ^a	13.00 (3.611) ^d	10.55 (3.249) ^d	0	10.89 (3.302) ^c	10.22 (3.197) ^c	8.89 (2.988) ^d	7.55 (2.755) ^d	0
	S.Em ±	0.1518	0.1438	0.1319	0.1362	-	0.1436	0.1297	0.0968	0.1297	-
	C.D. at 5%	0.4511	0.4274	0.3920	0.4046	-	0.4268	0.3854	0.2876	0.3856	-
	C.V. %	7.8852	8.1336	8.6784	11.596	-	9.497	9.9968	9.296	16.255	-

Figures in the parentheses are transformed values

NS- Non-significant, DBS- Day before spray, DAS- Days after spray

In vertical columns, means followed by same letter do not differ significantly by DMRT (P=0.05).

Significantly highest per cent reduction over control *i.e.* 36.82 per cent was observed in flubendiamide 480 SC @ 0.20ml/l. The next best reduction in this regard was observed in emamectin benzoate 5 G @ 0.30 g/l (32.25%) and spinosad 45 EC @ 0.25ml/l (30.80%). Following these were lufenuron 5 EC @ 0.5ml/l, lambda cyhalothrin 5 EC @ 0.30ml/l and chlorantraniliprole 18.5 EC @ 0.20ml/l with at par reduction over control of 27.93, 27.04 and 26.56 per cent, respectively. Imidacloprid 17.5 SC @ 0.5ml/l (23.32%) was found to be at par with indoxacarb 15.8 EC @ 0.40ml/l (22.40%). The least per cent reduction over control was observed in dichlorvos 45 SC @ 1.5ml/l (16.73%).

4.4.4 Second spray

The lowest population of *S. litura* larva was observed in the case of indoxacarb 15.8 EC @ 0.40ml/l (5.55larvae/mrl) at one day before spray (Table No. 4.4.2). Other than this all the eight treatments recorded to have larval population at par with each other. On one day after spraying the least larval population was observed in indoxacarb 15.8 EC @ 0.40ml/l (3.56 larvae/mrl) followed by spinosad 45 SC @ 0.25ml/l(3.89 larvae/mrl), flubendiamide 480SC @ 0.20ml/l (4.11 larvae/mrl), lambda cyhalothrin 5 EC @ 0.30ml/l (4.22 larvae/mrl), emamectin benzoate 5G @ 0.30g/l (4.33 larvae/mrl), chlorantraniliprole 18.5 EC @ 0.20ml/l (4.55 larvae/mrl), dichlorvos 45 SC @ 1.5ml/l (4.66 larvae/mrl). Comparatively higher population was observed in plots treated with imidacloprid 17.5 SC @ 0.5ml/l (5.55 larvae/mrl) and lufenuron 5 EC @ 0.5ml/l (6.66 larvae/mrl).

During five days after spraying plots treated with flubendiamide 480 SC @ 0.20ml/l with 1.89 larvae/mrl followed by spinosad 45 SC @ 0.25ml/l with 2.00 larvae/mrl, indoxacarb 15.8 EC @ 0.40ml/l with 2.11 larvae/mrl, chlorantraniliprole 18.5 EC @ 0.20ml/l 2.44 larvae/mrl, lambda cyhalothrin 5 EC @ 0.30ml/l with 2.44 larvae/mrl and emamectin benzoate 5 G @ 0.30g/l with 2.55 larvae/mrl. Comparatively more population was observed in dichlorvos 45 SC @ 1.5ml/l with 3.55 larvae/mrl, imidacloprid 17.5 EC @ 0.5ml/l with 4.00 larvae/mrl and lufenuron 5 EC @ 0.5ml/l with 4.55 larvae/mrl.

At seven days after spray least population was found in flubendiamide 480SC @ 0.20ml/l (0.55 larvae/mrl) followed by chlorantraniliprole 18.5 EC @ 0.20ml/l (0.89 larvae/mrl) and spinosad 45 SC @ 0.25ml/l (0.89 larvae/mrl). Next treatment, found effective emamectin benzoate 5 G @ 0.30g/l (1.22 larvae/mrl), indoxacarb 15.8 EC @ 0.40ml/l (1.22 larvae/mrl), lambda cyhalothrin 5 EC @ 0.30ml/l (1.89 larvae/mrl), imidacloprid 17.5 SC @ 0.5ml/l (2.22 larvae/mrl), lufenuron 5 EC @ 0.5ml/l (2.89 larvae/mrl), dichlorvos 45 SC @ 1.5ml/l (2.89 larvae/mrl).

The best per cent reduction over control was observed in spinosad 45 SC @ 0.25ml/l with 39.99 per cent and flubendiamide 480 SC @ 0.20ml/l with 39.33 per cent. Followed by indoxacarb 15.8 EC @ 0.40ml/l with 35.01 per cent, chlorantraniliprole 18.5 EC @ 0.20ml/l with 34.89 per cent, emamectin benzoate 5 G @ 0.30g/l with 34.39 per cent and lambda cyhalothrin 5 EC @ 0.30ml/l with 29.66 per cent. Comparatively lesser per cent reduction was observed in the case of imidacloprid 17.5 SC @ 0.5ml/l (24.45%), lufenuron 5 EC @ 0.5ml/l (21.26%) and dichlorvos 45 SC @ 1.5ml/l (20.15%).

4.4.5 Efficacy of different insecticides against *S. litura* during 2016 and 2017 *kharif*

During the *kharif* season of 2016 the mean number of larvae per meter row length was found least in plots treated with insecticide flubendiamide 480 SC @ 0.20ml/l in restricting population to the least among all the insecticides with an average of 3.054 larvae/mrl, it was at par with spinosad 45 SC @ 0.25ml/l (3.996 larvae/mrl), chlorantraniliprole 18.5 EC @ 0.20ml/l (4.068 larvae/mrl), emamectin benzoate 5 G @ 0.30g/l (4.076 larvae/mrl) and indoxacarb 15.8 EC @ 0.40ml/l (4.128 larvae/mrl). Further, plots treated with lambda cyhalothrin 5 EC @ 0.30ml/l showed larval population of 4.298 larvae/mrl, whereas, lufenuron 5 EC @ 0.50ml/l and dichlorvos 45 SC @ 1.5ml/l showed at par populations of 4.718 and 4.813 larvae/mrl, respectively. Least effective treatment was found to be imidacloprid 17.5 SC @ 0.5ml/l with larval population of 5.349 larvae/mrl, which was found to be significantly lower than all of the other treatments. More or less similar results were also found in second year (*kharif*, 2017) with flubendiamide 480 SC @ 0.20ml/l having significantly less mean number of larvae per meter row length (3.484 larvae/mrl) followed by at par populations in

spinosad 45 SC @ 0.25ml (4.182 larvae/mrl), emamectin benzoate 5 G @ 0.30g/l (4.312 larvae/mrl) and chlorantraniliprole 18.5 EC @ 0.20ml/l (4.868 larvae/mrl), which was on par with lambda cyhalothrin 5 EC @ 0.30ml/l (4.923 larvae/mrl), indoxacarb 15.8 EC @ 0.40ml/l (5.018 larvae/mrl) and imidacloprid 17.5 SC @ 0.5ml/l (5.127 larvae/mrl). Lufenuron 5 EC @ 0.5ml/l and dichlorvos 45 SC @ 1.5ml/l were found to be least effective with larval population of 5.386 and 5.312 larvae/mrl, respectively. Thus, flubendiamide 480 SC @ 0.20ml/l along with spinosad 45 SC @ 0.25ml/l were found to be most significantly effective followed by emamectin benzoate 5 G @ 0.30g/l and chlorantraniliprole 18.5 EC @ 0.20ml/l (Table 4.4.3).

Per cent reduction over control during the first season was highest in chlorantraniliprole 18.5 EC @ 0.5ml/l with 44.885 per cent reduction in larval population over untreated control plots and was also found to be significantly higher than all the other treatments. It was followed by indoxacarb 15.78 EC @ 0.40ml/l, emamectin benzoate 5 G @ 0.30g/l and flubendiamide 480 SC @ 0.20ml/l where per cent reduction in larval population (41.425, 40.825 and 40.425%) was at par with each other. Lambda cyhalothrin 5 EC @ 0.30ml/l showed 38.245 per cent reduction over control was at par with spinosad 45 SC @ 0.25ml/l (36.07%), which was on par with lufenuron 5 EC @ 0.5ml/l (35.695%). Imidacloprid 17.5 SC @ 0.5ml/l and dichlorvos 45 SC @ 1.5ml/l were on par with per cent reduction over control of 33.24 and 33.12 per cent, respectively.

After pooling the data for the two years *i.e.* 2016 and 2017 *Kharif*, as presented in Table No. 4.4.4, flubendiamide 480 SC @ 0.20 ml/l was found to be most effective insecticidal treatment to lower the larval population of *S. litura* among all the insecticides with a highly significant mean larval population of 3.269 larvae/mrl and 39.25 per cent reduction of larval population over the control plots. The second best insecticidal treatment was found to be the chlorantraniliprole 18.5 EC @ 0.20 ml/l (4.468 larvae/mrl and 37.805 per cent reduction in larval population over the control) which was at par with emamectin benzoate 5 G @ 0.30 gm/l with 4.194 larvae/mrl and 37.0725 per cent reduction over control. Spinosad 45 SC @ 0.25 ml/l was also found to be at par with flubendiamide 480 SC @ 0.20 ml/l in restricting the *S. litura* population to 4.089 larvae/mrl but its per cent reduction of larval population over the control,

Table No. 4.4.3 Pooled data of bio-efficacy of different insecticides against *S. litura* of 2016 and 2017 kharif season:

Tr. No.	Chemical name	Mean no. larvae/mrl 2016	%ROC 2016	Mean no. larvae/mrl 2017	%ROC 2017	Pooled data (larvae/mrl)	
						(larvae/mrl)	%ROC
T1	Chlorantraniliprole 18.5SC @ 0.20 ml/l	4.068	44.885	4.868	30.725	4.468	37.805
T2	Indoxacarb 15.8 EC @ 0.40 ml/l	4.128	41.425	5.018	28.705	4.573	35.065
T3	Lambda cyhalothrin 5 EC @ 0.30ml/l	4.298	38.245	4.923	28.35	4.611	33.2975
T4	Spinosad 45SC @ 0.25 ml/l	3.996	36.07	4.182	35.395	4.089	35.7325
T5	Dichlorvos 46EC @ 1.5ml/l	4.813	31.12	5.312	18.44	5.063	24.78
T6	Emamectin benzoate 5G @ 0.30 g/l	4.076	40.825	4.312	33.32	4.194	37.0725
T7	Imidacloprid 17.5 SC @ 0.5ml/l	5.349	33.24	5.127	23.885	5.238	28.5625
T8	Flubendiamide 480SC @ 0.20 ml/l	3.054	40.425	3.484	38.075	3.269	39.25
T9	Lufenuron 5EC @ 0.5ml/l	4.718	35.695	5.386	24.595	5.052	30.145
T10	Control (Untreated)	11.979	-	10.109	-	11.044	-

35.7325 was significantly lower than that of the flubendiamide 480 SC @ 0.20 ml/l (39.25%). Whereas, on the other end of the comparison, lufenuron 5 EC @ 0.5ml/l, dichlorvos 45 SC @ 1.5ml/l and imidacloprid 17.5 SC @ 0.5ml/l were found to be the least effective insecticides during these two seasons, in order to lower the *S. litura* population with a mean larval population of 5.063, 5.238 and 5.052 larvae/ml, respectively. In pooled data, the least per cent reduction over control plots was observed in the dichlorvos 45 SC @ 1.5ml/l (24.78%), which was significantly lower than the nearest treatment, imidacloprid 17.5 SC @ 0.50 ml/l (28.5625%) and lufenuron 5 EC @ 0.5ml/l (30.145).

These results were found to be in accordance with the previous research works on the efficacy of insecticides for the management of *S. litura* on soybean. **Motaphale et. al, (2017)** studied on the efficacy and economics of different insecticides and bio-rational against *S. litura* in soybean and reported that rynaxypyr 20SC with 64.52 per cent reduction and emamectin benzoate with 58.84 per cent reduction at 3 days after first and second spray, respectively.

Patil and Mohite (2015) worked on the bio-efficacy of new molecules of insecticides against *S. litura* and reported that *S. litura* population at 3DAS recorded 0.45 larvae/plant in plots treated with flubendiamide 480 SC @200 ml/ha and on 7 DAS population was reduced to 0.37 larvae/plant and it was significantly superior over all other treatments. However, it was on par with spinosad 45 SC @ 187.5 ml/ha. At 7 days after application, flubendiamide 480 SC @ 200 ml/ha recorded significantly low survival of *S. litura* larvae as compared to other treatments. The *S. litura* population was reduced to 0.37 larvae/plant in the treatment with flubendiamide 480 SC @ 200 ml/ha. The treatment with spinosad 45 SC, lambda cyhalothrin 5 EC and emamectin benzoate 1.9 EC were next in order of efficacy in reducing the survival population of *S. litura* larvae

The results were also in similar with the field efficacy of some new insecticides against *S. exigua* per 10 plants that the pooled mean of two years were lowest in chlorantraniliprole 20% SC with 0.33 larvae/10 plants, spinosad 45%SC with 0.34 and flubendiamide 20% WG with 0.50 as against untreated plots 16.7 larvae/10 plants and recorded 98.0, 97.9 and 97.0 per cent reduction of *S. exigua* respectively (**Suneel**

Kumar and Sarada, 2015). Patil et al. (2015) reported flubendiamide 480 SC @ 200 ml/ ha as the best chemical and recorded minimum population of *S. litura* (0.30 larva per plant). Spinosad 45 SC (0.36 larva per plant), lambda cyhalothrin 5 EC (0.39 larva per plant) and emamectin benzoate 1.9 EC (0.40 larva per plant) were in next order of effective and also flubendiamide 480 SC was observed to be relatively safe to natural enemies.

4.4.6 Effect of different insecticides on soybean seed yield

Assessment of the effect of different insecticidal treatments on the soybean seed yield was observed by comparing the yield in different treatments with the yield of untreated control (Table No. 4.4.4). Highest yield for the first season (*Kharif*, 2016) was recorded in the plots, treated with emamectin benzoate 5 G @ 0.30 gm/l with 2514.89 kg/ha, with a percent increase in yield of 53.84 percent over control, which was significantly higher than other treatments and at par with that of chlorantraniliprole 18.5EC@0.20 ml/l (2491.91 kg/ha yield and 52.43% increase over control) and indoxacarb 15.8 EC@0.40 ml/l (2438.80 kg/ha yield and 49.18% increase over control). The next best yield was recorded in the plots treated with flubendiamide 480SC@0.20 ml/l (2186.73 kg/ha yield and 33.77% increase over control), followed by spinosad 45SC@0.25 ml/l (2137.42 kg/ha yield and 30.75% increase over control) and lambda cyhalothrin 5 EC@ 0.30ml/l (2033.49 kg/ha yield and 24.39% increase over control), which were at par with each other. Whereas, yields recorded within spinosad 45SC@0.25 ml/l (2137.42 kg/ha yield and 30.75% increase over control) and lambda cyhalothrin 5 EC@ 0.30ml/l (2033.49 kg/ha yield and 24.39% increase over control) were on par with imidacloprid 17.5 SC@0.5ml/l (1905.93 kg/ha yield and 16.59% increase over control) and the yield of later two were on par with the yields in plots treated with lufenuron 5EC@0.5g/l (1872.73 kg/ha yield and 14.56% increase over control) and dichlorvos 45SC@1.5ml/l (1841.02 kg/ha yield and 12.62% increase over control). The expected least yield was recorded in untreated control with 1634.76 kg/ha.

After the second season as well, the plots treated with emamectin benzoate 5G@0.30 g/l came up as the highest producing treatments with a significantly higher yield of 2919.87 kg/ha and a percent increase in yield over control of 52.24%, as

Table No. 4.4.4. Effect of different insecticides on soybean seed yield during 2016 and 2017

Tr. No.	Treatments	Kg/ha (2016)	% Yield increase	Kg/ha (2017)	% Yield increase
T1	Chlorantraniliprole 18.5EC@0.20 ml/l	2491.91 ^e	52.43	2907.73 ^d	51.61
T2	Indoxacarb 15.8 EC@0.40 ml/l	2438.80 ^e	49.18	2800.27 ^{cd}	46.00
T3	Lambda cyhalothrin 5 EC@ 0.30ml/l	2033.49 ^{bcd}	24.39	2473.89 ^{bc}	28.99
T4	Spinosad 45EC@0.25 ml/l	2137.42 ^{cd}	30.75	2564.64 ^{bcd}	33.72
T5	Dichlorvos 45SC@1.5ml/l	1841.02 ^{ab}	12.62	2307.04 ^{ab}	20.29
T6	Emamectin benzoate 5G@0.30 g/l	2514.89 ^e	53.84	2919.87 ^d	52.24
T7	Imidacloprid 17.5 SC@0.5ml/l	1905.93 ^{bc}	16.59	2291.07 ^{ab}	19.45
T8	Flubendiamide 480SC@0.20 ml/l	2186.73 ^d	33.77	2837.31 ^{cd}	47.94
T9	Lufenuron 5EC@0.5g/l	1872.73 ^b	14.56	2253.44 ^{ab}	17.49
T10	Control (Untreated)	1634.76 ^a	-	1917.93 ^a	-
	S.Em ±	0.1168	-	0.1901	-
	C.D. at 5%	0.3471	-	0.56485	-
	C.V. %	6.4047	-	8.6863	-

In vertical columns, means followed by same letter do not differ significantly by DMRT (P=0.05).

compared to other treatments and it was at par with chlorantraniliprole 18.5EC@ 0.20 ml/l (2907.73 kg/ha yield and 51.61% increase over control), flubendiamide 480SC@0.20 ml/l (2837.31 kg/ha yield and 47.94% increase over control), indoxacarb 15.8 EC@0.40 ml/l (2800.27 kg/ha yield and 46.00% increase over control) and spinosad 45SC@0.25 ml/l (2564.64 kg/ha yield and 33.72% increase over control). The yield in flubendiamide 480SC@0.20 ml/l, indoxacarb 15.8 EC@0.40 ml/l and spinosad 45SC@0.25 ml/l was on par with the yield recorded in lambda cyhalothrin 5 EC@ 0.30ml/l (2473.89 kg/ha yield and 28.99% increase over control) and the yield of last two was on par with dichlorvos 45SC@1.5ml/l (2307.04 kg/ha yield and 20.29% increase over control), imidacloprid 17.5 SC@0.5ml/l (2919.87 kg/ha yield and 19.45% increase over control) and lufenuron 5EC@0.5g/l (2253.44 kg/ha yield and 17.49% increase over control). Again the untreated control was the least producing treatments among all.

The results of the present investigation are found to be similar with the previous year research works where, **Motaphale et. al, (2017)** in their study on efficacy and economics of different insecticides and bio rational against *S. litura* in soybean reported rynaxypyr 20 SC resulted in significantly higher yield of 2443.00 kg/ha followed by spinosad 45 SC 2385.00 kg/ha. The highest gross income and net profit was recorded in rynaxypyr 20SC.

Patil and Mohite (2015) worked on the bio-efficacy of new molecules of insecticides against *S. litura*. Flubendiamide 480 SC @ 200 ml/ha recorded the highest yield of 2100.10kg/ha followed by emamectin benzoate 1.9 EC @ 2000ml/ha recorded the yield of 1933.6 kg/ha and these treatments were followed by lamda cyhalothrin 5 EC @ 40g/ha with 1730.4kg/ha.



*Summary
and
Conclusions*



The present investigation was undertaken to notice the incidence of major insect pests and their natural enemies of soybean in major districts of Uttarakhand, along with the comparative study on different soybean based artificial diets on growth, development and fecundity of Tobacco caterpillar, *Spodoptera litura*. Further, experimental trials were also been conducted to study the field resistance level and bio-efficacy of different insecticides against *S. litura*.

A roving survey was conducted in ten districts, U S Nagar, Nainital, Almora, Champawat, Pithoragarh, Pauri Garhwal, New tehri, Uttarkashi, Dehradun and Haridwar of Uttarakhand state. The laboratory experiments were conducted in the Soybean Entomology Laboratory of the Department of Entomology, and the field trials were conducted in Norman E Borlaug Crop Research Centre (NEBRC) of G.B. Pant University of Agriculture and Technology, Pantnagar. The salient findings in the present investigation have been presented under the following headings.

5.1 To ascertain the incidence of major insect pests and their natural enemies on soybean in major districts of Uttarakhand

The survey was conducted in different locations of U.S. Nagar, Almora, Nainital, Pauri Gharwal, Uttarkashi, Dehradun, New Tehri, Haridwar, Pithoragarh and Champawat districts during *kharif*, 2017.

The incidence of tobacco caterpillar *S. litura* was highest in Nainital district with mean number of larvae of 5.1 per meter row length. Almora recorded the second highest number of *S. litura* with 4.3 larvae/mrl followed by U. S Nagar recorded the 3.8 larvae/mrl. The rest districts recorded the moderate level of incidence of tobacco caterpillar like Champawat (3.6 larvae/mrl), Pithoragarh (3.16 larvae/mrl), Haridwar (3.02 larvae/mrl), New Tehri (2.9 larvae/mrl), Uttarkashi (2.9 larvae/mrl), Pauri Garhwal (2.6 larvae/mrl) and least incidence was observed in Dehradun (2.0 larvae/mrl).

The incidence of bihar hairy caterpillar *S. obliqua* was highest at its incidence in U. S. Nagar with 4.7 larvae per meter row length with Kashipur being its hotspot. The second position was Almora district which recorded the 4.4 larvae/mrl. The moderate level of incidence was recorded in Nainital (4.3 larvae/mrl), Haridwar (3.5 larvae/mrl), New Tehri (3.4 larvae/mrl), Champawat (3.2 larvae/mrl), Pauri Garhwal (3.1 larvae/mrl), Pithoragarh (3.02 larvae/mrl), Dehradun (3.0 larvae/mrl) and Uttarkashi recorded the lowest level of incidence of with 2.9 larvae/mrl.

The incidence of soybean semilooper *Thysanoplusia acuta* was highest at its incidence in U. S. Nagar with its mean number of larvae of 3.2 larvae per meter row length, the second highest incidence was observed in Nainital district with 3.2 larvae/mrl. Further the Almora, Dehradun, Pithoragarh, Haridwar, New Tehri and Chmpawat recorded moderate level of infestation with 3.1, 3.1, 2.96, 2.68, 2.6 and 2.6 larvae/mrl, respectively. The other districts observed less infestation and incidence of semilooper Pauri Garhwal (2.5 larvae/mrl) and Uttarkashi (2.3 larvae/mrl).

Chrysomelid beetle which is known to cause defoliation on soybean crop was found highest in its population in New Tehri district with 5.1 beetles per meter row length. Second position in the incidence of this pest was observed in Almora (4.9 beetle/mrl), followed by Uttarkashi (4.5 beetle/mrl), Nainital (4.4 beetle/mrl) with Majhera being one of its hotspot and Pauri Garhwal (4.1 beetle/mrl). Other districts like Pithoragarh (3.76 beetle/mrl), Haridwar (3.22 beetle/mrl) and Champawat (3.2 beetle/mrl) observed moderate level of incidence. Dehradun and U. S. Nagar recorded the lowest incidence of 2.22 and 2.0 beetle/mrl, respectively.

Whitefly incidence was observed to be highest in Nainital district with 6.5 whitelfy per three leaves followed by U. S. Nagar with 5.7 whitefly per three leaves and Haridwar with, 4.08 whitefly per three leaves. Dehradun (3.8 whitefly/3 leaves), Almora (3.7 whitefly/3 leaves), Champawat (3.5 whitefly/3 leaves), Uttarkashi (3.1 whitefly/3 leaves) and Pithoragarh (3.0 whitefly/3 leaves) recorded the moderate level of incidence of whitefly. New Tehri and Pauri Garhwal recorded the lowest incidence of whitefly with 2.9 and 2.5 whitefly/3 leaves, respectively.

Jassids incidence was found to be highest in Dehradun with 4.4 jassids per three leaves followed by Almora (3.8 jassids/3 leaves), Nainital (3.5 jassids/3 leaves), pauri

Garhwal (3.2 jassids/3 leaves), New Tehri (3.1 jassids/3 leaves) and Champawat (2.9 jassids/3 leaves), and these were to be moderate in its incidence. Lowest incidence was recorded in Pithoragarh (2.88 jassids/3 leaves) followed by U. S. Nagar (2.8 jassids/3 leaves), Uttarkashi (2.7 jassids/3 leaves) and in Haridwar (2.24 jassids/3 leaves).

The per cent stem fly infestation was highest in U. S.Nagar with 29.6 per cent, followed by Haridwar with 19.04 per cent, Nainital with 16.3 per cent, Almora with 13.2 per cent, Pauri Garhwal with 12.00 per cent and New Tehri with 11.4 per cent of moderate level stem fly infestation. Uttarkashi, Dehradun, Champawat and Pithoragarh districts were found to be having lesser stem fly infestation of 5.7, 5.2, 3.9 and 3.34 per cent, respectively.

The girdle beetle infestation was found to be highest in New Tehri with 6.2 per cent infestation followed by a moderate level of infestation found in Nainital (5.5%), Dehradun (5.3%), Uttarkashi (5.1%) and Pauri Garhwal (4.3%). Comparatively lower infestation was found in U. S. Nagar (3.9%), Pithoragarh (3.34%), Champawat (3.3%) and Almora (3.2%). The lowest per cent infestation of the pest was found in Haridwar with 2.92 per cent.

Population of natural enemies *viz*, lady bird beetle, *Eucanthacona* bug and spiders was also recorded during the survey in ten districts. Mean population of lady bird beetle, *Eucanthacona* bug and spiders was found to be highest in Nainital district, including 5.3 of lady bird beetle, 4.0 of *Eucanthacona* bug and 2.4 of Spiders, nearly followed by Almora with 3.8, 4.2 and 3.1 lady bird beetle, *Eucanthacona* and Spiders, respectively. The population of natural enemies was also comparatively higher in Uttarkashi district with mean population of 3.6 for lady bird beetle, 2.9 for *Eucanthacona* bug and 2.3 for spiders. This was followed by 3.6, 3.3 and 2.9 in U. S. Nagar, 3.4, 3.0 and 2.4 in New Tehri, 3.0, 3.1 and 2.4 in Pauri Garhwal, 3.2, 2.5 and 2.1 in Champawat, 3.14, 2.34 and 2.08 in Haridwar, 3.2, 2.36 and 2.12 in Pithoragarh district. The least natural enemy population was found in Dehradun district with a mean population of all three natural enemies, with 2.4, 2.0 and 2.34 (lady bird beetle, *Eucanthecona* bug and Spiders, respectively).

5.2 Comparative study of artificial diet along with Soybean leaves on growth and development and fecundity of tobacco caterpillar *Spodoptera litura*

A laboratory experiment was conducted to study the effect of soybean and other host based artificial diets on the growth and development of *S. litura*. The study revealed that, soybean based artificial diet (Diet II) was proved to consume lesser number of days to complete its larval stage *i.e* total larval period was 16.3 days whereas, chickpea based artificial diet (Diet I) recorded larval duration of 15.5 days. The other host based artificial diet recorded long duration to the completion of larval stage (Castor leaves based artificial diet Diet III 19.25, blackgram leaves based artificial diet Diet IV 20.83 and agar based artificial diet Diet V 25.63 days).

Highest larval growth index was recorded Diet II *i.e.* Soybean based artificial diet 5.47 and it was followed by Diet I with 4.74. Least larval growth index 3.49 was recorded on Diet V (Agar based artificial diet). Total development index was highest in Diet II (2.28) followed by Diet III (2.19).

5.3 Study of field resistance of tobacco caterpillar *Spodoptera litura* to newer insecticides collected from major districts of Uttarakhand state

The present investigation aimed to monitor level of different insecticidal toxicity and field resistance against third instar larvae of *S. litura* (Fab.). The larvae were collected from different locations of Uttarakhand state during 2016-17 and 2017-18 and leaf dip method of bioassay was carried out to know median lethal concentration (LC₅₀) of insecticides.

The U. S. Nagar population when subjected to leaf dip bioassay method at **48 HAF**, Emamectin benzoate 5G was found to be most toxic with LC₅₀ value of 0.000118%, followed by Spinosad 45EC (0.000168%), Indoxacarb 15.8 EC (0.000210%) Chlorantraniliprole (Coragen) (0.00028031%) Lambdacyhalothrin 5 EC (0.000414%), Dichlorvos 45SC (0.000641%) Flubendiamide 480 SC (0.002063%) and Imidacloprid 17.5 SC (0.002571%). Lufenuron 5 EC (0.005986%) was found to be least toxic against the larvae.

In other quarters, the order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > spinosad 45 SC > Indoxacarb 15.8 EC >

Chlorantraniliprole (Coragen) > Lambdacyhalothrin 5 EC > Dichlorvos 45SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

This population recorded 8.58 fold resistant towards chlorantraniliprole 20 SC at 48 HAF, 2.09 fold for indoxacarb 15.8 EC, 3.26 fold for lambda cyhalothrin 5 EC, 2.15 fold for spinosad 45 SC, 2.71 fold for dichlorvos 46 SC, 5.23 fold for emamectin benzoate 5G, 23.26 fold for imidacloprid 17.5 SC, 3.92 fold for flubendiamide 480 SC and 2.54 fold for lufenuron 5 EC when compared to susceptible population at 48 HAF.

The Nanital population of *S. litura* when tested with various insecticides **at 48 hr HAF**, revealed Spinosad 45 SC recorded to be highly toxic with LC₅₀ value of 0.000145% with resistance ratio (RR) 1.86 and followed by Indoxacarb 15.8 EC (0.000294%) with 2.93 RR, Emamectin benzoate 5G (0.000318%) with 14.10 RR, Lambda cyhalothrin 5 EC (0.000529%) with 4.16 RR, Dichlorvos 45SC (0.000562%) with 2.38 RR, Chlorantraniliprole (Coragen) (0.000624%) with 5.44 RR and Flubendiamide 480 SC (0.002533%) with 4.81 RR. Lufenuron 5 EC was found to be least lethal with LC₅₀ value of 0.006410% with 2.72 RR.

The order of toxicity of various insecticides to the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) can be stated as follows, Spinosad 45 SC > Indoxacarb 15.8 EC > Emamectin benzoate 5G > Lambda cyhalothrin 5 EC > Dichlorvos 46 SC > Chlorantraniliprole (Coragen) > Flubendiamide 480 SC > Lufenuron 5 EC.

Haridwar population of *S. litura* at **48 HAF**, Emamectin benzoate 5 G with LC₅₀ value of 0.00017% and Resistant Ratio (RR) 7.54 was found to be more toxic followed by Spinosad 45 EC (0.00044%) with 5.63 RR, Chlorantraniliprole (Coragen) (0.00027%) with 2.36 RR. Indoxacarb 15.8 EC (0.00033%) with 3.29 RR, Dichlorvos 45 SC (0.00071%) with 3.00 RR, Lambdacyhalothrin 5 EC (0.00085%) with 6.69 RR, Imidacloprid 17.5 SC (0.00180%) with 16.29 RR and Flubendiamide 480 SC (0.00183%) 3.47 RR. But, the larvae were found to be least mortal with Lufenuron 5 EC (0.00563%) with 2.39 RR.

In particular, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows,

Emamectin benzoate 5G > Chlorantraniliprole (Coragen) > Indoxacarb 15.8 EC > spinosad 45 SC > Dichlorvos 45 SC > Lambdacyhalothrin 5 EC > Imidacloprid 17.5 SC > Flubendiamide 480 SC > Lufenuron 5 EC.

S. litura population collected from New Tehri at **48 HAF**, Spinosad 45 EC reported highest larval mortality rate with LC₅₀ value of 0.000209% and Resistant Ratio (RR) 2.68 followed by Emamectin benzoate 5 G (0.000217%) with RR 9.62, Chlorantraniliprole (Coragen) (0.000272%) with RR 2.37, Lambdacyhalothrin 5 EC (0.000572%) with RR 4.5, Dichlorvos 45 SC (0.000583%) with RR 2.46, Flubendiamide 480 SC (0.001836%) with RR 3.49 and Imidacloprid 17.5 SC (0.004740%) with RR **42.88**. The lowest larval mortality was reported by Lufenuron 5 EC with LC₅₀ value of 0.007091% with RR 3.01.

In other words, the order of toxicity of various insecticides against third instar larvae of *S. litura* (*Fab.*) based on median lethal concentration (LC50) is as follows, Spinosad 45 SC > Emamectin benzoate 5G > Indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > Lambdacyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Imidacloprid 17.5 SC > Lufenuron 5 EC.

Among the various insecticides tested against third instar larvae of *S. litura* collected from Pithoragarh, at **48 HAF** the results revealed that Emamectin benzoate 5 G was highly toxic with LC₅₀ value 0.000119% and Resistant Ratio (RR) of 5.28 followed by Indoxacarb 15.8 EC, Spinosad 45 EC Chlorantraniliprole (Coragen), Dichlorvos 45 SC, Lambdacyhalothrin 5 EC, Flubendiamide 480 SC and Lufenuron 5 EC with LC₅₀ values of 0.000215% with RR 2.14, 0.000247% with RR 3.16, 0.000335% with RR 2.92, 0.000666% with RR 2.81, 0.000745% with RR 5.86, 0.002063% with RR 3.92, 0.006569% with RR 2.79 respectively. The least toxicity was recorded by Imidacloprid 17.5 SC (0.011833%) with RR **107.06**.

The order of toxicity of various insecticides against third instar larvae of *S. litura* (*Fab.*) based on median lethal concentration (LC50) can be stated as Emamectin benzoate 5G > Indoxacarb 15.8 EC > Spinosad 45 SC > Chlorantraniliprole (Coragen) > Dichlorvos 45 SC > Lambdacyhalothrin 5 EC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

Dehradun population of *S.litura* at **48 HAF**, among the various insecticides tested, Emamectin benzoate 5 G was found to be most toxic against third instar larvae with LC₅₀ value of 0.000056% and Resistant Ratio (RR) of 2.48 followed by Spinosad 45 EC (0.000164%) with RR 2.10, Chlorantraniliprole (Coragen) (0.000271%) with RR 2.36, Indoxacarb 15.8 EC (0.000272%) with RR 2.71, Lambdacyhalothrin 5 EC (0.000382%) with RR 3.01, Dichlorvos 45 SC (0.000522%) with RR 2.21, Flubendiamide 480 SC (0.001648%) with RR 3.13 and Lufenuron 5 EC (0.006209%) with RR 2.63. The least toxicity was recorded by Imidacloprid 17.5 SC (0.014726%) with RR **133.23**.

The ascending order of toxicity of various insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration (LC₅₀) is as follows, Emamectin benzoate 5G > Spinosad 45 SC > Chlorantraniliprole (Coragen) > Indoxacarb 15.8 EC > Lambdacyhalothrin 5 EC > Dichlorvos 45 SC > Flubendiamide 480 SC > Lufenuron 5 EC > Imidacloprid 17.5 SC.

Champawat population of *S.litura* at **48 HAF**, Emamectin benzoate 5 G was found to be highly lethal with LC₅₀ value of 0.000126% and Resistant Ratio (RR) of 5.59 followed by spinosad 45 EC (0.000172%) with RR 2.20, indoxacarb 15.8 EC (0.000228%) with RR 2.27, chlorantraniliprole (Coragen) (0.000237%) with RR 2.07, lambda cyhalothrin 5 EC (0.000538%) with RR 4.24, dichlorvos 45 SC (0.000636%) with RR 2.69, flubendiamide 480 SC (0.001848%) with RR 3.51 and lufenuron 5 EC (0.006704%) with RR 2.84. Imidacloprid 17.5 SC (0.021355%) with RR **193.21** was reported as least lethal insecticide against third instar larvae.

To rearticulate it, the order of toxicity of various insecticides against third instar larvae of *S. litura* (Fab.), based on median LC₅₀ is as follows, emamectin benzoate 5G > spinosad 45 SC > indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > lambdacyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

Population of *S.litura* collected from Almora district at **48 HAF**, indoxacarb 15.8 EC was found to most toxic with LC₅₀ value of 0.000392% and Resistant Ratio (RR) of 2.52 followed by chlorantraniliprole (Coragen) (0.000454%) with RR 3.05, emamectin benzoate 5 G (0.000521%) with RR 9.18, spinosad 45 EC (0.000571%)

with RR 4.56, lambda cyhalothrin 5 EC (0.000971%) with RR 3.24, dichlorvos 45 SC (0.001089%) with RR 3.73, flubendiamide 480 SC (0.002840%) with RR 3.92 and lufenuron 5 EC (0.010008%) with RR 2.40. imidacloprid 17.5 SC (0.062696%) with RR **188.72** was found to be most lethal.

In another way, the order of toxicity levels of different insecticides based on median LC₅₀ was as follows, indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > emamectin benzoate 5 G > spinosad 45 SC > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > lufenuron 5 EC > imidacloprid 17.5 SC.

Pauri Garhwal population of *S.litura* at **48 HAF**, emamectin benzoate 5 G showed to highest toxicity with LC₅₀ value of 0.000118% and Resistant Ratio (RR) 5.23, followed by spinosad 45 EC (0.000168%) with RR 2.15, indoxacarb 15.8 EC (0.000210%) with RR 2.09, chlorantraniliprole (Coragen) (0.000280%) with RR 2.44, lambdacyhalothrin 5 EC (0.000414%) with RR 3.26, Dichlorvos 45 SC (0.000641%) with RR 2.71, lufenuron 5 EC (0.005986%) with RR 2.54, and flubendiamide 480 SC (0.002289%) with RR 4.35. Imidacloprid 17.5 SC (0.001224%) was found to be least toxic with RR **11.07**.

The outcomes can also be described in order of toxicity levels of different insecticides against the third instar larvae of *S. litura* (Fab.) based on median lethal concentration LC₅₀ and can be stated as follows, emamectin benzoate 5 G > spinosad 45 SC > indoxacarb 15.8 EC > Chlorantraniliprole (Coragen) > lambdacyhalothrin 5 EC > Dichlorvos 45 SC > lufenuron 5 EC > flubendiamide 480 SC > Imidacloprid 17.5 SC.

Uttarakashi population of *S. litura* at **48 HAF**, again, indoxacarb 15.8 EC was found most toxic with LC₅₀ value of 0.000236% and Resistant Ratio (RR) of 2.35, followed by chlorantraniliprole (Coragen) (0.000270%) with RR 2.36, spinosad 45 EC (0.000282%) with RR 3.61, emamectin benzoate 5 G (0.000283%) with RR 3.55, lambda cyhalothrin 5 EC (0.000324%) with RR 2.55, dichlorvos 45 SC (0.000583%) with RR 2.46, flubendiamide 480 SC (0.001733%) with RR 3.29 and imidacloprid 17.5 SC (0.002889%) with RR 26.14. Lufenuron 5 EC (0.005026%) with RR 2.13 was found to be least toxic.

In clear text, the order of toxicity of various insecticides based on LC₅₀ was as follows, indoxacarb 15.8 EC > chlorantraniliprole (Coragen) > spinosad 45 SC > emamectin benzoate 5 G > lambda cyhalothrin 5 EC > dichlorvos 45 SC > flubendiamide 480 SC > imidacloprid 17.5 SC > lufenuron 5 EC.

5.4 To study the field efficacy and economics of major insecticides against tobacco caterpillar *Spodoptera litura* on Soybean

Efficacy of different insecticides against *S. litura* during the *kharif* seasons of two consecutive years, 2016 and 2017. To accomplish this study, soybean variety JS-335 in 10 treatments with 3 replications and number of larvae was recorded prior and after first, third and fifth days of spraying 9 insecticides, namely, chlorantraniliprole 18.5SC, indoxacarb 15.8EC, lambda cyhalothrin 5EC, spinosad 45SC, dichlorvos 46SC, emamectin benzoate 5G, imidacloprid 17.5SC, flubendiamide 480SC and lufenuron 5EC from 5 randomly selected plants from each quadrat (1 m x 1 m).

During the two year study period *i.e.* *Kharif* 2016 and 2017, flubendiamide 480 SC @ 0.20 ml/l was found to be the most effective insecticidal treatment among all the insecticides with a highly significant mean larval population of 3.269 larvae/mrl and 39.25 per cent reduction of larval population over the control plots. The second best insecticidal treatment was found to be the chlorantraniliprole 18.5 EC @ 0.20 ml/l (4.468 larvae/mrl and 37.805 per cent reduction in larval population over the control), followed by emamectin benzoate 5 G @ 0.30 gm/l with 4.194 larvae/mrl and 37.0725 per cent reduction over control, spinosad 45 SC @ 0.25 ml/l with 4.089 larvae/mrl and 35.7325 per cent reduction of larval population over the control. Whereas, lufenuron 5 EC @ 0.5ml/l, dichlorvos 45 SC @ 1.5ml/l and imidacloprid 17.5 SC @ 0.5ml/l were found to be the least effective insecticides during these two seasons, with 5.063, 5.238 and 5.052 larvae/mrl, respectively. During the experiment, least per cent reduction over control plots was observed in the dichlorvos 45 SC @ 1.5ml/l (24.78%).

After each season the assessment of the effect of different insecticidal treatments on the soybean seed yield was observed by comparing the yield in different treatments with the yield of untreated control during the two year study period and the highest yield was recorded in the plots treated with emamectin benzoate 5G, with a yield of 2514.89 kg/ha, 2919.87 kg/ha and 53.84 and 52.24 per cent increase in yield

over control for the year of 2016 and 2017, respectively. This was followed by chlorantraniliprole 18.5SC, with 2491.91 and 2907.73 kg/ha yield and 52.43 and 51.61 per cent increase in yield over control, indoxacarb 15.8EC, with 2438.80 and 2800.27 kg/ha yield and 49.18 and 46.00 per cent increase in yield over control, flubendiamide 480SC with, 2186.73 and 2837.31 kg/ha yield and 33.77 and 47.94 per cent increase in yield over control, spinosad 45SC with, 2137.42 and 2564.64 kg/ha yield and 30.75 and 33.72 per cent increase in yield over control, lambda cyhalothrin 5EC with, 2033.49 and 2473.89 kg/ha yield and 24.39 and 28.99 per cent increase in yield over control, imidacloprid 17.5SC with, 1905.93 and 2291.07 kg/ha yield and 16.59 and 19.45 per cent increase in yield over control, dichlorvos 46SC with 1841.02 and 2307.04 kg/ha yield and 12.62 and 19.45 per cent increase in yield over control. Among all the insecticidal treatments, the least yield was recorded in the plots treated with lufenuron with a yield of 1872.73 and 2253.44 kg/ha and a per cent increase in yield over control of 14.56 and 17.49 per cent.

Conclusion

- 1) From the above results it is noticed that the incidence of defoliators was highest in Nainital, Almora and U. S. Nagar, where the population of three of the four defoliators viz. tobacco caterpillar, *S. litura* (5.1, 4.3 and 3.8 larvae/mrl, respectively), bihar hairy caterpillar, *S. oblique* (4.3, 4.4 and 4.7 larvae/mrl, respectively) and semilooper, *T. acuta* (3.2, 3.1 and 3.2 larvae/mrl, respectively). Whereas, the highest incidence of the chrysomelid beetle, *Hispinae spp.* was found highest in Tehri Garhwal, followed by Almora and Uttarkashi with beetle population of 5.1, 4.9 and 4.5, respectively.
- 2) In this study the highest incidence of sucking pests i.e., whitefly (*B. tabbaci*) and jassids (*E. kerri*) was found in the district Nainital, followed by U. S. Nagar and Haridwar with mean whitefly population of 6.5, 5.7 and 4.08 per three leaves, respectively and for jassids in Dehradun, followed by Almora and Nainital with 4.4, 3.8 and 3.5 jassids per three leaves.
- 3) For stem borers' infestation, U.S. Nagar being highest with 29.65%, followed by Haridwar (19.07%) and Nainital (16.34%) were found highest stem fly

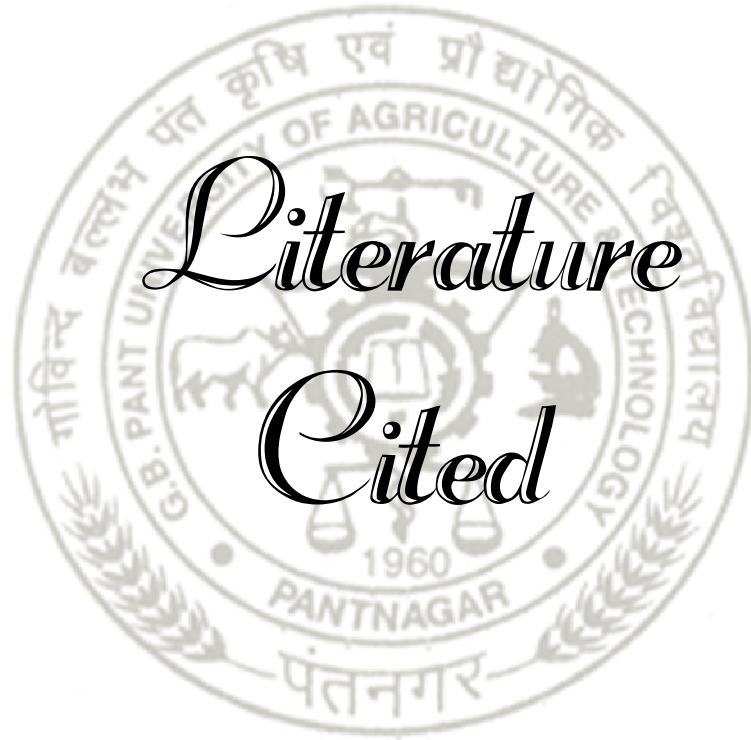
infestation and four districts, namely Tehri Garhwal followed by Nainital, Dehradun and U.S. Nagar found highest girdle beetle infestation.

- 4) Whereas, the three different natural enemies' viz. Coccinellid beetles, Eucanthecona bugs and spiders were found most abundant in three hilly districts of Uttarakhand, namely Nainital (11.7), followed by Almora (11.5) and Uttarkashi (10.3), where use of chemical insecticides is comparatively lower as compared to other districts of Tarai regions in the state.
- 5) In the study of the effect of soybean and other hosts based artificial diet on growth and development of tobacco caterpillar *S. litura*, the soybean based diet (Diet-II) was found most effective with tobacco caterpillar completing its life cycle with a larval period of 16.3 days with a larval growth index of 5.47 and total growth index of 2.27.
- 6) In field resistance study, the *S. litura* populations from different districts showed multiple resistance with highest resistance showed against Imidacloprid 17.5 SC (Confidor). Whereas, the most toxic insecticide was found to be emamectin benzoate 5G (Proclaim), followed by chlorantraniliprole 18.5 SC (coragen), indoxacarb 18.5EC (Avaunt) and spinosad 45SC (Tracer).
- 7) The best insecticidal treatments to control *S. litura* with a highest yield and cost benefit ratio were found to be the flubendiamide 480SC @ 0.20ml/l and emamectin benzoate 5G @ 0.30g/l.

Future Studies

- 1) Forecasting models need to be developed for the management of major insect pests of soybean in order to increase the productivity.
- 2) Further evaluation of toxicity of newer insecticides against *Spodoptera litura* (Fab.) need to be conducted.
- 3) Major artificial diets for *S. litura* should be identified and their role in insect nutrition should be studied, for their mass multiplication which will also be helpful in developing resistant cultivars.

- 4) Resistance studies should be conducted and suitable Integrated Resistance Management (IRM) practices and their knowledge should be given to farmers through extension work to reach all the soybean growing farmers in the state.



LITERATURE CITED

- Abbott, W.S. 1925.** A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, **18**:265-267
- Abdu-Allah, G. 2011.** Potency and residual activity of emamectin benzoate and spinetoram on *Spodoptera littoralis* (Boisduval). *African Entomology*, **19**(3): 733-737
- Abdullah Md., OuabSarnthoy and Sudawan Chaeychomsri. (2000).** Comparative Study of Artificial Diet and Soybean Leaves on Growth, Development and Fecundity of Beet Armyworm, *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae). *Kasetsart J. (Nat. Sci.)* 34 (3).
- Adimani, B.D. (1976).** Studies on the insect pests of soybean (*Glycine max* (L) Merrill) with special reference to the bionomics and control of the pod borer, *Cydia ptychora* Myr (Tortricidae: Lepidoptera) *M. Sc (Agri.) Thesis*. Univ. Agril. Sci., Bangalore (India), p. 149.
- Agnihotrudu, V. and Gour, T. B. 1982.** Control of cotton bollworms with fenvalerate in India. *Crop Protection*, **1** (2):231-234
- Ahmad, I., Gupta, R. K., Ahad, I. and Baghat, R. M. 2011.** Base line toxicity of different insecticides against tobacco caterpillar, *Spodoptera litura* strains after various intervals. *Research Journal of Agricultural Sciences*, **2**(2):252:254
- Ahmad, M. 2009.** Observed potentiation between pyrethroids and organophosphorus insecticides for the management of *Spodoptera litura*. *Crop Protection*, **28**: 264-268
- Ahmad, M. and Saleem, M. A. 2004.** Comparative efficacy of ten conventional and new chemistry insecticides against armyworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) under laboratory condition. *Pakistan Entomologist*, **26**(2): 1-4
- Ahmad, M., Arif, M.I. and Ahmad, M. (2007a).** Occurrence of insecticide resistance in field populations of *Spodoptera litura* (Lepidoptera :Noctuidae). *Pakistan. Crop Protec.*, **26** (6): 809-817.

- Ahmad, M., Sayyed, A. H., Saleem, M. A. and Ahmad, M., 2008**, Evidence for field evolved resistance to newer insecticides in *Spodoptera litura* (Lepidoptera: Noctuidae) from Pakistan. *Crop Protec.*, 27: 1367-1372.
- Ahmad, M., Sayyed, A.H., Crickmore, N. and Saleem, M.A. (2007b)**. Genetics and mechanism of resistance to deltamethrin in a field population of *Spodoptera litura* (Lepidoptera :Noctuidae). *Pest Manag. Sci.*, 63 (10): 1002-1010.
- Ahmad, M., Arif, M. I. and Ahmad, M. 2007**. Occurance of insecticide resistance in field populations of *Spodoptera litura* (Lepidoptera: Noctuidae) in Pakistan. *Crop Protection*, 26: 809-817
- Ahmad, M., Saleem, M. A. and Sayyed, A. H. 2009**. Efficacy of insecticide mixture against pyrethroid and organophosphate resistant population of *Spodoptera litura* (Lepidoptera: Noctuidae). *Pest Management Science*, 65: 266-274
- Ahmad, M., Sayyed, A. H. and Saleem, M. A. 2008**. Evidence for field evolved resistance to newer insecticides in *Spodoptera litura* (Lepidoptera: Noctuidae) from Pakistan. *Crop Protection*, 27: 1367-1372
- Ajanta, B., Alpana, Singh, B., Mahapatro, G. K. and Gupta, G. P., 2008**, Toxicity evaluation of emamectin benzoate against tobacco caterpillar (*Spodoptera litura*) by three different assay techniques. *Indian Journal of Entomology*, 70(3): 200-205.
- Amin, P. W. 1983**. Major field insect pests of groundnut in India and associated crop losses. In: B.H. Krishnamurthy Rao and K.S.R.K. Murthy (eds.), Proceedings of the National Seminar on Crop Losses due to Insect Pests. Hyderabad, Andhra Pradesh, India, 7-9 January, 1983, p. 337-344
- Amjad, M. and Haq, E. 2007**. Chemical control of *Diacrisia obliqua* Walker on sunflower. *Pakistan Journal of Agricultural Research*, 20(1/2): 92-93
- Anonymous, 2004**, Ann. Rep. All India coordinated Research Project on Soybean, Indore Centre, pp. 2-5
- Arora, A., Singh, I., Singh, G. and Arora, C. L. 2003**. Preliminary evaluation of toxicity of some metal dialkyl dithio carbamates against Bihar hairy caterpillar, *Spilosoma obliqua* (Walker). *Insect Environment*, 9(1): 22-24

- Arora, R. and Sidhu, H. S. 1992.** Studies on the interaction of diflubenzuron and fenvalerate against *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fab.). *Journal of Insect Science*, **5**(2):167-168
- Ascher, K. R. S., Eliahu, M., Ishaaya, I., Zur, M., and Ben-Moshe, E. 1986.** Synergism of pyrethroid-organophosphorous insecticide mixtures in insects and their toxicity against *Spodoptera litura* larvae. *Phytoparasitica*, **14**: 101-110
- Attique, M. N. R., Khaliq, A. and Sayyed, A. H. 2006.** Could resistance to insecticides in *Plutella xylostella* (Lepidoptera:Plutellidae) be overcome by insecticide mixtures? *Journal of Applied Entomology*, **130**: 122-127
- Babu, T. R. and Azam, K. M. 1982.** Relative efficacy of certain new synthetic pyrethroids against pest complex of bhendi. *Indian Journal of Plant Protection*, **9**(1):13-18
- Banerjee, L. G. 1959.** Morphology of the head capsule of *Aspongopus janus* (Fab.). *Agra University of Journal Research*, **9**:47-67
- Banu, H, Islam, M. N., Haque, S. M. A., Kamruzzaman, A. S. M. and Polan, M. S. 2007.** Effectiveness of some insecticides against jute hairy caterpillar *Spilarctia obliqua* (Walker). *International Journal of Sustainable Agricultural Technology*, **3**(5): 30-32
- Basera, A. 2009.** Medicinal plants and plant oils as growth regulators against *Bombyx mori* (Linn.) and *Spodoptera litura* (Fab.) and bioefficacy of some insecticides against pest species. Thesis, Ph.D., Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p.225
- Berg, H., Ankashah, D., Hassan, K, Muhammad, A., Widayanto, H. B. and Wirasto, H. B. (1995).** Soybean stem fly, *M. sojae* on Sumatra: Seasonal incidence and the role of parasitism. *International Journal of Pest Management* **41** (3) : 127-133.
- Bhanu, K. V. and Reddy, P. S. 2012.** Evaluation of field efficacy of imidacloprid 40%+ ethiprole 40% - 80 WG against plant hoppers in rice. *Pestology*, **36**(12): 29-34.

- Bhatnagar, S., Kumar, A., Karnatak, A. K. and Kumar, Y. 2013.** Evaluation of toxicity of some novel molecules of insecticides against *Spodoptera litura* (Fab.). *Indian forester*, **139**(11): 1024-1026
- Bhatt, N. A., Thumar, R. K. and Rojasara, Y. M. 2015.** Evaluation of synthetic insecticides for the control of *Spodoptera litura* (Fab.) infesting *bidi* tobacco under nursery conditions, p. 213-214. **In:** Sharma, D. R., Kumar, S. and Singh, B. (eds.), Proceedings of 4th Congress on Insect Science, April 16-17, 2015, Punjab Agricultural University, Ludhiana, India
- Bhatt, P. 2013.** Bioefficacy of botanicals and insecticide against polyphagous insects and phagostimulant activity of medicinal plants to *Bombyx mori* Linn. Thesis, Ph.D., Department Of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p.170
- Bhatt, P. and Srivastava, R. P. 2014.** Base line toxicity of insecticides against Bihar hairy caterpillar, *Spilosoma obliqua*. *Indian Journal of Plant Protection*, **42** (2): 175-177
- Bhattacharya, A., Barik, S. R. and Ganguly, P. 2009.** New pesticide molecules, formulation technology and uses: Present status and future challenges. *The Journal of Plant Protection Sciences*, **1**(1): 9-15
- Bhattacharya, S. and Pramanik A. 2005.** Studies on different aspects of efficacy of some commercial microbial pesticides against *Diacrlsia obliqua* on jute. *Indian Journal of Agricultural Research*, **39**(1): 47-51
- Bhatti, S. S., Ahmad, M., Yousaf, K. and Naeem, M. 2013.** Pyrethroids and new chemistry insecticides mixtures against *Spodoptera litura* (Noctuidae: Lepidoptera) under laboratory conditions. *Asian Journal of Agriculture Biology*, **1**(2): 45-50
- Bhuiyan, S. I. 1981.** Effectiveness of some insecticides for the control of hairy caterpillar. *Bangladesh Journal of Agricultural Research*, **6**(1): 33-38
- Biswas, S., Upadhyay, K. D. and Kumar, A. 1996.** Efficacy of some insecticides alone and in combination with Dipel (a bacterial formulation) against *Spilosoma obliqua* Walker. *Zeitschrift fur Angewandte Zoologie*, **81**(2): 227-235

- Brempong, C. Y, Saito, T. and Miyata, T. 1984.** Topical and injection toxicities of some pyrethroids in the tobacco cutworm, *Spodoptera litura* Fabricius. *Journal of Pesticide Science*, **9**(3):481-487
- Butani, D. K. and Verma, S. 1977.** Pests of vegetables and their control: Cucurbits. *Pesticides*, **11** (3): 37-41
- Chand, A. 2012.** Bioefficacy of some neonicotinoid, organophosphate and pyrethroid against insect pests of soybean. Thesis, M.Sc. (Ag.), Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p. 71
- Chandel, Y. S. and Gupta, R. K., (1995).** Effect of sowing date on incidence of insect pests of soybean (*Glycine max*). *Indian Journal of Agricultural Science*. 65 (8): 624-625.
- Chari, M. S. and Patel, N. G. 1972.** Efficacy some newer of insecticides against the tobacco leaf-eating caterpillar, *Spodoptera litura* (Fab.). *Indian Journal of Entomology*, **34**: 261-262
- Chaturvedi, S., Singh, K. J., Singh, O. P. and Dubey, M. P. (1998).** Seasonal incidence and damage of major insect pests of soybean in Madhya Pradesh. *Crop Research*., Hissar, 15 (2/3): 260-264.
- CheWunan, Tian Shi, Yidong Wu, and Yihua Yang. (2013).** Insecticide Resistance Status of Field Populations of *Spodoptera exigua* (Lepidoptera: Noctuidae) From China. *Journal of Economic Entomology*. 106: 4. 1857-1862.
- Chhabra, K. S. and Kooner, B. S. 1987.** Susceptibility of different stages of Bihar hairy caterpillar, *Diacrisia obliqua* Walker to some insecticides. *Pesticides*, **21**(6): 22-24
- Chilana, P. 2009.** Evaluation of medicinal plant extracts, novel molecules and conventional insecticides against silkworm species and polyphagous insect pests. Thesis, Ph.D., Department Of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p.225
- Chowdhury, K. R. and Srivastava, B. B. L. 1990.** Interaction of moulting inhibitor diamino-furyl-S-triazine with *Spilosoma obliqua* (Wlk.) *Annals of Agricultural Science Cairo*, **35**(2): 1011-1018.

- ChristianLuis, R. E., Pineda, S., Figueroa, J. I., Schneder, M. and Martnez, A. 2010.** Toxicity of sublethal effects of methoxyfenozide on *Spodoptera exigua* (Lepidoptera:Noctuidae). *Journal of Economic Entomology*, **103** (3): 662-667.
- Cole, L. M., Nicholson, R. A. and Casida, J. E. 1993.** Action of phenyl-pyrazole insecticides at the GABA-gated chloride channel. *Pesticide Biochemistry and Physiology*, **46**: 47-50
- Cooperative Economic Insect Report 1973.** Insects not known to occur in the United States [no. 194 of series]. Red pumpkin bug (*Coridius janus*) (Fab.), **23**(13): 197-198.
- CPC, 2004.** Crop protection compendium. Wallingford, UK: CAB International
- Dhaliwal, G. S. and Arora, R. 2001.** Integrated pest management: concepts and Approaches. *Kalyani Publishers*, New Delhi. p. 297.
- Dhaliwal, G. S. and Koul, O. 2010.** Quest for Pest Management: From Green Revolution to Gene Revolution. *Kalyani Publishers*, New Delhi.
- Dhamu, L., Chandrasekaran, S. and Regupathy, 2010,** Baseline toxicity of emamectin and spinosad to *Plutella xylostella* for resistance monitoring. *Resistance Pest Manag. Newsltr.*, 20(1): 27-32.
- Dhawan, A. K., Sarika, S., Bharathi, M. and Kamaldeep, S., 2007,** Susceptibility of *Spodoptera litura* (Fabricius) to some novel insecticides. *Pesticide Research Journal*, 19(2): 169-171.
- Dhawan, A. K., Kaur, A and Kumar, R 2007.** Relative toxicity of new insecticides against *Spodoptera litura*. *Annals of Plant Protection Sciences*, **15**(1): 238-239.
- Dhawan, A. K., Singh, R. and Shera, P. S. 2008.** Field efficacy of novaluron against tobacco caterpillar, *Spodoptera litura* (Fab.) on *Bt* cotton. *Pesticide Research Journal*, **20**(1): 75-78.
- Dhiman, S. C. 1981.** Hibernation in *Aspongopus janus*(Fab.). *Geobios*, **8**: 180-181
- Dhingra, S., Bhandari, J. K. S. and Shankarganesh, K. 2007.** Relative resistance of Bihar hairy caterpillars to insecticide mixtures. *Journal of Entomological Research*, **31** (3): 209-212

- Dhingra, S., Srivastava, C., Bhandari, J. K., Jha, A. N. and Haldar, J. 2008.** Susceptibility status of cabbage butterfly, *Pieris brassicae* (Linnaeus, Pieridae: Lepidoptera) to different synthetic pyrethroids. *Pesticide Research Journal*, **20**(1): 114-116
- Dhir, B. C., Mohapatra, H. K. and Senapathi, B. 1992.** Assessment of crop loss in groundnut due to tobacco caterpillar, *Spodoptera litura* (Fab.). *Indian Journal of Plant protection*, **20**: 215- 217
- Didonet, J., Sarmiento, R. de. A., Aguiar, R. W. de. S., Santos, G. R. dos and Erasmo, E. A. L. (2003)** Abundance of soybean pests and their natural enemies in Gurupi, Brazil. *Manejo Integrado de lagasy Agroecologia*, **69**: 50-57. *
- Dittrich, V., Uk S and Ernst G. H. 1990.** Chemical control of insecticide resistance in whiteflies (Hemiptera: Aleyrodidae) In: Gerling, D. (ed.), *Whiteflies: Their Bionomics, Pest status and Management*, Intercept, Hants, UK, pp. 263-285.
- Divakara Y.G and Doddamane Manjulakumari (2015).** Artificial diet formulation and its efficacy evaluation on development and reproduction of *Spodoptera litura* F. a polyphagous pest. *Indian Journal of Applied Research*. **5**(6). 55-57.
- Dutta, P. K. and Sharma, D. 1997.** Effect of *Bacillus thuringiensis* Berliner in combination with chemical insecticides against *Spodoptera litura* Fabricius on cabbage. *Crop Research Hisar*, **14**(3): 481-486.
- El-Mageed, Ahmad E. M. ABD and Shalaby, Shehata E. M. 2011.** Toxicity and biochemical impacts of some new insecticide mixtures on cotton leafworm *Spodoptera littoralis* (Boisd.). *Plant Protection Science*, **47**(4):166-175
- El-Sayed and El- Sheikh, 2015.** Comparative toxicity and sublethal effects of emamectin benzoate, lufenuron and spinosad on *Spodoptera littoralis* Boisid (Lepidoptera: Noctuidae). *Crop protection*, **67**:228-234.
- EPPO/CABI, 1997.** Quarantine Pests for Europe. 2nd edition. Edited by I. M. Smith, D. G. McNamara, P. R. Scott, and M. Holderness, CABI International, Wallingford, UK, p.1425.
- Farzana, P. and Tadishi, M. 2000.** Effects of sublethal dose of chlorfluazuron on ovarian development and oogenesis in the common cutworm *Spodoptera litura* (Lepidoptera: Noctuidae). *Annals of the Entomological Society of America*, **93**(5): 1131-1137

Feakin, S. D. 1973. Pest Control in Groundnuts. PANS Manual, 3rd edn. London: Centre for Overseas Pest Research, Overseas Development Administration

Finney, J. C. 1971. Probit analysis, Cambridge University Press, London, p. 333

Fletcher, (1922). Report of the imperial entomologist, *Sci. Rep. Agric. Res. Inst.*, PUSA, New Delhi. pp. 41-59.

Funderburk, J. E., McPherson, R. and Buntin, D. 1999. Soybean insect management, p. 273-290 *In* L. G. Heatherly and H. F. Hodges [eds.], Soybean Production in the Midsouth, CRC Press, Boca Raton, FL. 394 p.

Gangrade, G. A. 1962. Assessment of damage to tur (*Cajanus cajan*) in Madhya Pradesh by the tur pod fly, *Malanagromyza obtusa* Malloch. *Indian J. Agric. Sci.*, 33: 17-20.

Garad, G. P., Shivpuje, P. R. and Bilapte, G. G. 1984. Life fecundity tables of *Spodoptera litura* (Fab.) on different hosts. *Proceedings of the Indian Academy of Science*, 93: 29-33.

Goel, S. C. and Kumar, S. 1991a. Ovicidal action of synthetic pyrethroids on the eggs of Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) and *Sesamum sphinx*, *Acherontia styx* (Westwood). *Entomon*, 16: 237-39.

Goel, S. C. and Kumar, S. 1991b. Efficacy of synthetic pyrethroids and quinalphos against Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) and sesamum sphinx, *Acherontia styx* (Westwood) infesting sesamum (*Sesamum indicum* L.). *Journal of Entomological Research*, 15 (1): 15-19.

Guidry, K. 2010. Louisiana soybean enterprise budgets. LSU AgCenter Online: http://www.lsuagcenter.com/en/money_business/farm_business/budgets/2010_Soybean_Enterprise_Budgets.htm. Accessed 18 Jun 2012.

Gupta, D. S. 1983. Losses due to insect-pest in Haryana. In: Proc. of the Nat. Sem. on Crop Losses due to Insects Pests (eds. Krishnamurthy Rao, B.H. and Murthy, K. S. R. K.) A.P.A.U. Rajendranagar, pp. 33-42.

Gupta, G. and Bhattacharya, A. K. 2008a. Lethal and sub lethal effect of diflubenzuron and lufenuron on *Spilarctia obliqua* Walker. *Journal of Eco friendly Agriculture*, 3(2): 145-149.

- Gupta, G. and Bhattacharya, A. K. 2008b.** Assessing toxicity of post-emergence herbicides to the *Spilarctia obliqua* Walker (Lepidoptera: Arctiidae). *Journal of Pest Science*, **81**: 9-15.
- Gupta, G. and Yadav, S. R. 2011.** Toxicity of insecticides against two damaging larval stages of *Spilosoma obliqua* (Walker). *Journal of Insect Science Ludhiana*, **24**(2): 182-191.
- Gupta, G. and Yadav, S. R. 2012.** Management of *Spilarctia obliqua* (Wlk.) considering usage of different agrochemicals and their combinations. *Indian Journal of Agricultural Research*, **46**(2): 141-147.
- Gupta, G. P., Ajanta, B. and Seema, R., 2005,** Comparative toxicity of novel molecules and conventional insecticides against spotted bollworm, *Earias vitella* (Fabricius). *Pesticide Research Journal*, 17(1): 36-38.
- Gupta, G. P., Seema, R., Ajanta, B. and Raghuraman, M., 2004,** Relative toxicity of certain new insecticides against *Spodoptera litura* (Fabricius). *Pesticide Research Journal*, 16(1): 45-47.
- Gupta, G. P., Rani, S., Birah, A. and Raghuraman, M. 2004.** Relative toxicity of certain new insecticides against *Spodoptera litura* (Fabricius). *Pesticide Research Journal*, **16**(1): 45 47.
- Gupta, H. C. L., Singh, R., Jain, K. L. and Saxena, R. C. 1992.** Relative and residual toxicity of some synthetic pyrethroids. *Indian Journal of Entomology*, **54**(1): 34-38.
- Hardke, J. T., Temple, J. H. , Leonard, B. R. and Jackson, R. E. 2011.** Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera: Noctuidae). *Florida entomologist*, **94**(2): 272-278.
- Hardke, T. J., Joshua, H., Temple, Leonard, B. R. and Ackson, R. J., 2011,** Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera: Noctuidae), *Florida Entomologist*, 94(2): 272-278.
- Harikesh Singh and Bhattacharya, A. K., 2003,** Susceptibility of *Spodoptera litura* (Fab.) to diflubenzuron. *Annals of Plant Protection Science*, 11(2): 243-245

Hill, D. S., 1993, Agricultural insect pests of the tropics and their control. Cambridge University Press: Cambridge, London.

Hoda, M. Nasr, Mohamed, E. I. Badawy and Entsar, I. Rabea. 2010. Toxicity and biochemical study of two insect growth regulators, buprofezin and pyriproxyfen, on cotton leafworm *Spodoptera littoralis*. *Pesticide Biochemistry and Physiology*, **98**: 198–205.

Hole, U. B., Jadhav, S. R. and Teli, V. S., 2009, Bio-efficacy of insecticides against *Spodoptera litura* (Fabr.) infesting soybean. *Ann. Pl. Protec. Sci.*, 17(2): 322-324.

Hole, U. B., Jadhav, S. R. and Teli, V. S. 2009. Bio-efficacy of insecticides against *Spodoptera litura* (Fab.) infesting soybean. *Annals of Plant Protection Sciences*, **17**(2): 322-324.

<http://pib.nic.in/>

<http://www.cibrc.nic.in/>

[http://www.tsmg.com/download/ reports /Indian Agrochemicals Industry 2013](http://www.tsmg.com/download/reports/Indian%20Agrochemicals%20Industry%202013)

Huang, S., Xu, J. and Han, Z., 2006, Baseline toxicity data of insecticides against the common cutworm, *Spodoptera litura* (Fabricius) and a comparison of resistance monitoring methods. *International Journal of Pest Management*, **52**: 209-213.

Hummelbrunner, A. L. and Isman, M. B. 2001. Acute, sublethal, antifeedant and synergistic effects of monoterpenoid essential oil compounds on the tobacco cut worm (Lepidoptera: Noctuidae). *Journal of Agricultural and Food Chemistry*, **49**: 715–720.

Ingram, W. R. 1973. Improvement control of the vegetable army worm. *PANS*, **21** (1):162 -167.

Ishaaya, I., Mendelson, Z., Ascher, K. R. S. and Casida, J. E. 1985. Mixtures of synthetic pyrethroids and organophosphorous compounds for controlling the whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Phytoparasitica*, **13**: 76-77.

Jaglan, R. S. and Sircar, P. 1997. Relative toxicity of synthetic pyrethroid emulsion formulations against larvae of *Spilosoma obliqua* (Wlk.) and *Spodoptera litura* (Fab.). *Journal of Insect Science*, **10**(1): 52-54.

- Jaglan, R. S. and Sircar, P. 2003.** Role of solvent and emulsifier mixture in designing the toxicity of fenvalerate emulsion against larvae of *Spodoptera litura* (Fab.). *Annals of Agri Bio Research*, **8**(1): 51-54.
- Janakiraman, S. and Gupta, G. P. 2002.** Effect of modified artificial diet and insecticidal proteins on growth and development of tobacco cutworm (*Spodoptera litura*). *Indian Journal of Agricultural sciences*, **72**(12): 719-725.
- Jayanthi, P. D. K. and Padmavathamma, K. 2001.** Joint action of microbial and chemical insecticides on *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Journal of Tropical Agriculture*, **39**(2): 142-144.
- Jeughale, G.S. and Bhalkare, S.K. 2015.** Field resistance of *Spodoptera litura* (Lepidoptera :noctuidae) to newer chemistry insecticide indoxacarb in Vidarbha. *Internat. J. Plant Protec.*, **8**(1) : 194-198.
- Justin, C. G. L., Rabindra, R. J. and Jayaraj, S. 1989.** Increased insecticide susceptibility in *Heliothis armigera* (Hbn.) and *Spodoptera litura* (Fab.) larvae due to *Bacillus thuringiensis* Berliner treatment. *Insect Science and its Application*, **10** (5):573-576.
- Kadapatti, S. M., Krishna, N. L., Patil, S. V. and Lingappa S. 1996.** Field evaluation of insecticides against Bihar hairy caterpillar on sunflower. *Karnataka Journal of Agriculture Science*, **9**(2): 236-240.
- Kamala, N. V. (2000).** Development of IPM modules for soybean (*Glycine max* (L.) Merrill). *M.Sc. (Agri.) Thesis*, Uni. Agric. Sci., Bangalore, India.
- Kandru, S. and Dhingra, S. 2002.** Interactive effect of sublethal concentrations of fenvalerate and various microbial insecticides to larval instars of *Spilarctia obliqua* (Walker). *Annals of Plant Protection Sciences*, **10**(1): 31-37.
- Karuppaiah, V. and Chitra S., 2013,** Relative toxicity of newer insecticide molecules against *Spodoptera litura* (Fabr.). *Annals of Plant Protection Science*, **21**(2): 305-308.
- Karuppaiah, V. and Srivastava, C. 2013.** Relative toxicity of newer insecticide molecules against *Spodoptera litura*. *Annals of Plant Protection Sciences*, **21**(2): 305-308.

- Kaur, A., Kang, B. K. and Singh, B. 2007.** Toxicity of different insecticides against *Spodoptera litura* (Fabricius) in Punjab, India. *Pesticide Research Journal*, **19**(1): 47-50.
- Kennady, P., Kannan, K. and Ramesh, A. 2008.** Histopathological effects of Dimethoate on fat body of adult bug *Aspongopus janus* (Hemiptera: Pentatomidae). *Journal of Ecotoxicology and Environmental Monitoring*, **18**(2):197-199
- Khalid Ahmed, Hanumantha Rao, V. and Purnachandra Rao, P., 2000,** Relative toxicity of insecticides against mid-larval instar of *Spodoptera exigua* (Hubner). *Pestology*, **24**(7): 55-57.
- Khan, M. A. and Mumtaj, R. 2010.** Management of *Spilarctia obliqua* through *Bt* and chlorpyrifos combinations. *Annals of Plant Protection Science*, **18**(2): 489-556
- Khan, R. R., Ahmed, S. and Nisar, S. 2011.** Mortality responses of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) against some conventional and new chemistry insecticides under laboratory conditions. *Pakistan Entomologist*, **33**(2):147-150.
- Kim, Y. G., Cho, J. R., Lee, J. N., Kang, S. Y., Han, S. C., Hong, K. J., Kim, H. S., Yoo, J. K. and Lee, J. O. 1998.** Insecticide resistance in the tobacco cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *Journal Asia Pacific Entomology*, **1**: 115-122.
- Kitturmath, M. S., 2008,** Investigation on insecticide resistance in *Spodoptera litura* Fab. (Lepidoptera: Noctuidae). Ph. D. Thesis, Univ. Agric. Sci., Bengaluru, Karnataka (India).
- Kodandaram, M. H. and Dhingra, S. 2003.** Comparative toxicity of ester and non-ester pyrethroids against *Spodoptera litura* (Fab.). *Pesticide Research Journal*, **15**(1): 23-25.
- Kodandaram, M. H. and Dhingra, S. 2006.** Variation in the susceptibility and resistance of *Spodoptera litura* (Fab.) (Delhi and Punjab populations) to various synthetic pyrethroids. *Resistant Pest Management Newsletter*, **16**(1): 10-12
- Kodandaram, M. H. and Dhingra, S. 2007.** Variation in the toxicity of organophosphate insecticides to field populations of *Spodoptera litura* (Fab.). *Indian Journal of Plant Protection*, **35**(1): 53-56.

- Kodandaram, M. H., Rai, A. B. and Swamy, T. M. S. 2009.** Effect of biorational insecticides on susceptibility of *Spodoptera litura* (Fab) by different bioassay techniques. *Vegetable Science*, **36**(2): 188-192.
- Kodandaram, M.H. and Dhingra S. 2005.** Test of parallelism and relative potency of various insecticide mixtures and their individual insecticides to *Spodoptera litura* (Fabricius). *Shashpa*, **12**(1): 11-16.
- Koppel, A. L., Herbert Jr, D. A., Kuhar, T. P., Malone, S. and Arrington, M. 2011.** Efficacy of selected insecticides against eggs of *Euschistus servus* and *Acrosternum hilare* (Hemiptera: Pentatomidae) and the egg parasitoid *Telenomus podisi* (Hymenoptera: Scelionidae). *Journal of Economic Entomology*, **104**: 137-142.
- Korrat, E. E. E., Abdelmonem, A. E., Helalia A. A. R. and Khalifa, H. M. S. 2012.** Toxicological study of some conventional and nonconventional insecticides and their mixtures against cotton leaf worm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noectudae). *Annals Agric. Sci.*, **57**: 145-152.
- Kotikal, Y.K. and Devaiah, M. C. 1988.** Evaluation of some selected insecticides for their efficacy against black headed hairy caterpillar, *Spilosoma obliqua* (Walker) on mulberry. *Pesticides Bombay*, **22** (9): 11-15.
- Kranthi, K. R., Jadhav, D. R., Kranthi, S., Wanjara, R. R. and Ali, S. S., 2002,** Insecticide resistance in five major insect pests of cotton in India. *Crop Protection*, **21**: 449-460.
- Kranthi, K. R., Jadhav, D. R., Wanjari, R. R., Ali, S. S. and Russell, D. 2001.** Carbamate and organophosphate resistance in cotton pests in India, 1995 to 1999. *Bulletin of Entomological Research*, **91**: 37-46.
- Krishnaiah, M., Manjula, K. and Reddy, Y. A. N. 2015.** Evaluation of certain newer insecticides against *Spodoptera* and thrips in rabi groundnut, pp. 209-210. **In:** Sharma, D. R., Kumar, S. and Singh, B. (eds.), *Proceedings of 4th Congress on Insect Science*, April 16-17, 2015, Punjab Agricultural University, Ludhiana, India.
- Kuldeep and Shri Ram 2004.** Toxicity of diflubenzuron against *Spodoptera litura* Fab. and *Spilarctia obliqua* (Wlk.). *Indian Journal of Entomology*, **66**(4): 354-356.

- Kuldeep, Rahman, S. M. A and Shri Ram 2005.** Effect of sublethal doses of diflubenzuron against *Spodoptera litura* (Fab.) and *Spilarctia obliqua* (Wlk.). *Annals of Plant Protection Science*, **13**(1): 44-47.
- Kumar, A., Mehto, D. N. and Kumar, A. 1996.** Relative efficacy of different insecticides against the pests infesting urd (*Vigna mungo* L. (Hepper). *Journal of Entomological Research*, **20**(4): 309-312.
- Kumar, B. V. N. and Regupathy, A. 2000.** Generating base line data for insecticide resistance monitoring in *Spodoptera litura* (Fabricius). *Pesticide Research Journal*, **12**(2): 232-234.
- Kumar, N. N. , Acharya, M, Dabhi, M. V. and Khanapara, A. V. 2014.** Ecological life table and relative toxicity of insecticides against leaf eating caterpillar, *Spodoptera litura* (Fab.) on groundnut, *Legume Research*, **37** (6): 675-678.
- Kumar, Y. 2008.** Lethal and sublethal effects of synthetic pyrethroids against tobacco caterpillar, *Spodoptera litura* (Fabricius). Thesis, M.Sc., Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p. 78.
- Kundu, G. G. 1991.** Bihar hairy caterpillar, *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae) on soybean. *Indian Journal of Entomology*, **53**(3): 491-493.
- Kundu, G. G. and Srivastava, K. P. (1991).** Management of soybean stem fly, *Melanagromyza sojae* (Zehnt) in plants of North India. *Journal of Insect Science*. **4**(1): 50-53.
- Lakshman, L. and Verma, K. D. 1980.** Effect of host plants on the relative toxicity of certain insecticides against *Diacrisia obliqua*. *Indian Journal of Plant Protection*, **8**(1): 36-40.
- LeOra, S. 2003.** Poloplus, a user's guide to probit and logit analysis. LeOra Software, Berkeley.
- Lingaraj, S. T., Sridevi, D. and Ratnasudhakar, T., 2009,** Relative toxicity of selected novel insecticides against tobacco caterpillar, *Spodoptera litura*. *Indian Journal of Plant Protection*, **37**(1): 183-185.

- Luckmann, W. H. 1971.** The insect pests of soybean. *World Farm*, 13 (5): 18-19 & 22.
- Madrap, I. A., Pole, S. P. and Patange, N. R. (2007).** Development of pest tolerant soybean genotypes. *Proc. ISOR National Seminar*, pp.165-167.
- Madrap, I. A., Pole, S. P. and Patange, N. R., 2007,** Development of pest tolerant soybean genotypes. *Proc. ISOR National Seminar*, pp.165-167.
- Mahadevan, N. R. and Balasubramanian, M. 1981.** Efficiency of some newer insecticides against tobacco caterpillar, *Spodoptera litura* (Fab.) and green peach aphid, *Myzus persicae* (S.) on tobacco. *Pestology*, 5 (1):20-21
- Mandal, D., Bhowmik, P. and Baral, K. 2013.** Evaluation of insecticides for the management of Bihar hairy caterpillar, *Spilosoma obliqua* (Wlk.) (Lepidoptera: Arctiidae) in black gram (*Vigna mungo* L.). *The Bioscan*, 8(2): 429-431.
- Mandal, S. K. and Senapati, S. K. 1989.** Efficacy of insecticides and two organic acids for control of Bihar hairy caterpillar (*Spilosoma obliqua*) (Lepidoptera: Arctiidae). *Indian Journal of Agricultural Sciences*, 59(6): 378-380.
- Mandal, S. K., Kumar, B. and Prasad, D. 2000.** Efficacy of some foliar insecticides against *Spilosoma obliqua* (Walker) on brinjal. *Journal of Applied Biology*, 10 (2):189-190
- Mandal, S. M. A., Mishra, B. K. and Mohanty, A. K. (1998).** Effect of sowing dates on the incidence of insect pests and yield of soybean. *Environmental Ecology*. 16 (4): 970-971.
- Mayuravalli, V. V. L., Punnaiah, K. C., Reddi, G. P. V. and Rama Subba Rao, V.,1985,** Laboratory evaluation of the relative toxicity of decamethrin, permethrin and monocrotophos to the larvae of *Spodoptera litura* (Fabr.). *Indian Journal Agricultural Science*, 55(10): 645-647.
- Meena, N. L. and Sharma, U. S. (2005).** Effect of sowing date and row spacing on incidence of major insect pests of soybean, *Glycine max* (L.) Merrill. *Soybean Res.*, 4: 73-7.
- Meena, N. L. and Sharma, U. S. 2005,** Effect of sowing date and row spacing on incidence of major insect pests of soybean, *Glycine max* (L.) Merrill. *Soybean Research*, 4: 73-76.

- Misbahuddin, R. S. and Ehteshamuddin, S. 2000a.** Effect of phosphamidon on the alkaline phosphatase activity in the haemolymph of sap feeding insect pests *Aspongopus janus*, *Chrysocoris stollii* and *Dysdercus cingulatus*. *Environment and Ecology*, **18**(2): 323-325.
- Misbahuddin, R. S. and Ehteshamuddin, S. 2000b.** Effect of the systemic insecticide phosphamidon on LDH activity in the haemolymph of sap feeding insect pests *Aspongopus janus* and *Dysdercus cingulatus*. *Environment and Ecology*, **18**(2): 317-319.
- Mishra, R. K. and Sharma, R. N. 1989.** Host preference by adult *Aspongopus janus* (Fab.). *Indian Journal of Entomology*, **51**(4): 480-481.
- Mundhe, D. R. 1980.** Insect pest complex on soybean (*Glycine max* (L.) Merrill) in Marathwada region. *Journal of Maharashtra Agricultural University* 5: 259-260.
- Munir Ahmed, Mushtaq Ahmad Saleem and Mushtaq Ahmad, 2005,** Time-oriented mortality in leafworm, *Spodoptera litura* (Lepidoptera: Noctuidae) by some new chemistry insecticides. *Pakistan Entomon*, 27(1): 67-70.
- Murugesan, K. and Dhingra, S. 1998.** Evolving suitable bioassay technique for base-line data in detecting resistance level in the third instar larvae of *Spodoptera litura* (Fab.) to endosulfan formulated with different solvents. *Journal of Entomological Research*, **22** (3): 223-230.
- Murugesan, K. and Dhingra, S., 1995,** Variability in resistance pattern of various groups of insecticides evaluated against *Spodoptera litura* (Fabricius) during a period spanning over three decades. *Journal Entomological Research*, 19: 313-319.
- Nagalingam, B., Rao, B. N., Rosaiah, B., Krishnamurthy, B. H. and Laxminarayana, K. 1984.** Effect of some recent insecticides on *Spodoptera litura* Fabricius on coriander. *Pesticides*, **18** (6): 24-25.
- Nagia, D. K., Kmar, S. and Saini, M. L. 1990b.** Relative toxicity of some important insecticides to Bihar hairy caterpillar, *Spilosoma obliqua* (Wik). *Journal of Entomological Research*, **14**(1): 60-62.

- Nagia, D. K., Kumar, S. and Saini, M. L. 1990a.** Laboratory evaluation of some insecticides against Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) (Arctiidae: Lepidoptera) on castor (*Ricinus communis* L.). *Plant Protection Bulletin* (India), **42** (1 & 2): 13-16
- Nagia, D. K., Kumar, S, Sharma, P, Saini, M. L. 1989.** Efficacy of some insecticides against eggs and larvae of bihar hairy caterpillar, *Spilosoma obliqua* Walker infesting mustard crop *Brassica campestris*. *Plant Protection Bulletin* Faridabad., **41** (1-2): 45-48.
- Naik, R. L., Lolage, G. R., Kale, V. D. and Dethe, M. D. 2006.** Field bioefficacy of flufenzin and fenpyroximate on red spider mite, *Tetranychus cinnabarinus* (Boisd) infesting brinjal. *Journal of Entomological Research*, **30** (2): 133-137
- Nair, N., Sekh, K., Debnath, M., Chakraborty, S. and Somchoudhury, A. K. 2007.** Relative toxicity of some chemicals to Bihar hairy caterpillar, *Spilarctia obliqua* (Walker) (Arctiidae: Lepidoptera). *Journal of Crop and Weed*, **3**(1): 1-2
- Narayanamma, V. L. and Reddy, K. D. 2014.** Evaluation of newer insecticide molecules against lepidopteran pests in castor. *Indian Journal of Entomology*, **76**(4): 273-278
- Neumann, R. and Guyer, W. 1987.** Biochemical and toxicological differences in the modes of action of the benzoylureas. *Pesticide Science*, **20**(2): 147-156.
- Ngoyen Phi-Dieu Huyen, (2001).** Studies on the effect of selected insecticides on the abundance and diversity of insect pests of soybean. *M.Sc. (Agri.) Thesis*, Uni. Agric. Sci., Bangalore, (India)
- Ngoyen Phi-Dieu Huyen, 2001,** Studies on the effect of selected insecticides on the abundance and diversity of insect pests of soybean. *M.Sc. (Agri.) Thesis*, Uni. Agric. Sci., Bangalore, (India).
- Oerke, E. C., Dehne, H. W., Schonbeck, F. and Weber, A., 1994,** Crop Production and Crop Protection. Elsevier Science B. V., Amsterdam.
- Pal, S. 2012.** Bioactivity of some plant natural products against *Spodoptera litura* (Fab.) and *Bombyx mori* (Linn.) and efficacy of some insecticides against insect pests. Thesis, M.Sc. (Ag.), G.B. Pant University of Agriculture and Technology, Pantnagar. p.125.

- Pandey, A. K., Maurya, R. P. and Mall, P. 2014.** Bioefficacy of fenpyroximate 5EC against European red mite, *Panonychus ulmi* (Koch.) infesting apple. *Indian Journal of Entomology*, **76**(3): 197-201
- Pandey, R. 2011.** Bioefficacy of some medicinal plants and insecticides against *Bombyx mori* (Linn.) and *Spodoptera litura* (Fab.). Thesis, Ph.D., Department Of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p. 207.
- Pandey, V., Singh, A. K. and Sharma, R. P. 2010.** Biodiversity of insect pests associated with teak (*Tectona grandis* L. f.) in eastern Uttar Pradesh of India. *Research Journal of Forestry*, **4**: 136-144.
- Patel, L. C. 2014.** Sole and combined effect of some microbial and chemical insecticides against *Spilarctia obliqua* under laboratory condition. *International Journal of Plant Protection*, **7**(1): 232-234
- Patel, N. G. and Chari, M. S. 1980.** Screening of new insecticides in the control of tobacco leaf-eating caterpillar *Spodoptera litura* (Fab.). *Pesticides*, **14**(9): 35-37
- Patel, R. L. and Vyas, H. N. 1989.** Evaluation of toxicity of insecticides against the eggs of *Spodoptera litura* (Fab.) infesting groundnut. *Agricultural Science Digest Karnal*, **9**(2): 110-112.
- Patil, R. H. (2002).** Evaluation of insect pest management components in soybean ecosystem. *Ph. D. Thesis*, Univ of Agric. Sci. Dharwad (India), p. 63
- Patil, R. H., 2002,** Evaluation of insect pest management components in soybean ecosystem. Ph. D. Thesis, Univ of Agric. Sci. Dharwad (India), p. 63.
- Patil, R. K. 1995.** Control of *Spodoptera litura* (F.) in groundnut with newer insecticides. *Pestology*, **19**: 14-16.
- Patil, S. K., Patil, C. S. and Chandele, A. G. 2015.** Susceptibility of *Spodoptera litura* (Fabricius) to newer insecticides, pp. 238-239. **In:** Sharma, D. R., Kumar, S. and Singh, B. (eds.), *Proceedings of 4th Congress on Insect Science*, April 16-17, 2015, Punjab Agricultural University, Ludhiana, India.

- Paul, S. K., Bandyopadhyay, B. and Banerjee, A. 2009.** Relative toxicity of insecticides on larvae of *Spilosoma obliqua* Walker (Arcitiidae:Lepidoptera). *Journal of Environment and Ecology*, **27**: 1251-52.
- Pavela, R. 2005.** Insecticidal activity of some essential oils against larvae of *Spodoptera littoralis*. *Fitoterapia*, **76**(7): 691-696.
- Peerajade, D. A., Biradar, A. P. and Hosmath, J. A. 1999.** Chemical control of Bihar hairy caterpillar on sunflower. *Insect Environment*, **5**(2): 59
- Peter, C. and David, B. V. 1988.** Residual toxicity of some insecticides on groundnut to the first and third instar larvae of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Tropical Pest Management*, **34**(1): 24-26.
- Peter, C. and David, B. V. 1990.** Ovicidal activity of certain newer insecticides against *Spodoptera litura*. *Pesticide Research Journal*, **2**(1): 31-33.
- Pineda, S., Schneider, M. I., Smaghe, G., Martinez, A. M., Estal, P. del, Vinuela, E., Valle, J. and Budia, F. 2007.** Lethal and sublethal effects of methoxyfenozide and spinosad on *Spodoptera littoralis* (Lepidoptera: Noctuidae). *Journal of Economic Entomology*, **100**(3): 773-780.
- Pramanik, P. and Chatterjee, M. L. 2003.** Bioassay studies on some new insecticides against the diamondback moth, *Plutella xylostella* (L.) and tobacco caterpillar, *Spodoptera litura* (Fab.). *Indian Society of Pest Management and Economic Zoology*, Solan, **11** (2): 111-114.
- Prasad, D. and Chand, P. 1981.** Insecticidal control of Bihar hairy caterpillar, *Diacrisia obliqua* (Walker). *Indian Journal of Entomology*, **43**(1): 100-104.
- Prasad, K. D., Madhumathi, T., Rao, P. A. and Srinivasa Rao, V. 2007.** Joint toxicity of pyrethroids and organophosphorus insecticides to insecticide resistant *Spodoptera litura* on cotton. *Indian Journal of Plant Protection*, **35**(1): 113-115.
- Prasad, M. S. R. K. and Sachan, G. C. 1985.** Toxicity of some synthetic pyrethroids by three methods of application against *Diacrisia obliqua* (Walker). *Pesticides*, **19**(12): 50-53

- Prasad, R. G., Joshi, B. G. and Rao, S. N. 1986.** Relative efficacy of some insecticides and neem seed kernel suspension against tobacco caterpillar, *Spodoptera litura* Fabricius on tobacco. *Indian Journal of Plant Protection*, **14**(2): 69-74.
- Prasada Rao, G. M. V. and Grace, A. D. G. 2008,** Status of new insecticides vis-a-vis conventional insecticides against the American bollworm, *Helicoverpa armigera* (Hub.) Resistance Pest Manag. Newsltr., 18(1): 26-28.
- Purwar, J. P. and Yadav, S. R. 2003.** Field efficacy of pest controlling agents from different origins against tobacco caterpillar, *Spodoptera litura* on soybean. *Indian Journal of Entomology*, **65**: 382-385.
- Qamar, A., Khan, M. A., Jamal, K. and Khan, B. A. 1994.** Effect of juvenile hormone analogue, methoprene on the hairy caterpillar, *Spilosoma obliqua* (Walker). *Annals of Plant Protection Sciences*, **2**(2): 1-4
- Qin, H., Ye, Z., Huang, S., Ding, J. and Luo, R. 2004.** The correlations of the different host plants with preference level, life duration and survival rate of *Spodoptera litura* (Fabricius). *Chinese Journal of Eco-Agriculture*, **12**: 40-42
- Ragaei, M. and Sabry K. H. 2011.** Impact of spinosad and buprofezin alone and in combination against the cotton leafworm, *Spodoptera littoralis* under laboratory conditions. *Journal of Biopesticides*, **4**(2): 156-160.
- Rai, P. S., Sheshareddy, K. V. and Govindan, R. 1973.** A list of insect pests of soybean in Karnataka state. *Current Research*, 2:97-98.
- Ramakrishna Ayyar, T. V. 1963.** *Hand book of economic entomology for South India*, Government Press, Madras, p. 516.
- Ramakrishnan, N. and Saxena, V. S., 1984,** Insecticide resistance in the population of *Spodoptera litura* (Fab.) in Andhra Pradesh. *Pesticides*, 18: 23-27.
- Ramakrishnan, N., Saxena, V.S. and Dhingra, S. 1984.** Insecticide resistance to the population of *Spodoptera litura* (Fab.) in Andhra Pradesh. *Pesticides*, **18**(9):23- 27.
- Ramana, V. V., Reddy, G. P. V. and Murthy, M. M. K. 1988.** Synthetic pyrethroids and other bait formulations in the control of *Spodoptera litura* (Fab.) attacking rabi groundnut. *Pesticides*, **22**(1): 13-16.

- Ramanagouda, S. H. 2008.** Bioefficacy of newer insecticides and medicinal plant extracts against tobacco caterpillar, *Spodoptera litura* (Fab.). Thesis, M.Sc. (Ag.), Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p. 74.
- Ramanagouda, S. H. and Srivastava, R. P. 2009,** Bioefficacy of insecticides against tobacco caterpillar, *Spodoptera litura* (Fabr). *Indian Journal of Plant Protection*, 37(1&2): 14-19.
- Ramangouda, S. H. and Srivastava, R. P 2009.** Bioefficacy of insecticides against tobacco caterpillar, *Spodoptera litura*. *Indian Journal of Plant Protection*, 37(1/2): 14-19
- Ramaprasad, G., Joshi, B. G., Sitaramaiah, S. and Chari, M. S. 1989.** Efficacy of insecticides in bait formulations for control of fourth instar larvae of *Spodoptera litura* (Fabricius) in tobacco nurseries. *Indian Journal of Plant Protection*, 17(1): 53-57.
- Ramaprasad, G., Sitaramaiah, S., Joshi, B. G. and Rao, S. N. 1987.** Relative efficacy of neem seed kernel suspension, some synthetic pyrethroids and insecticides against *Spodoptera litura* (Fab.) in tobacco nurseries. *Indian Journal of Plant Protection*, 15 (2): 190-192.
- Ramzan, M. and Singh, D. 1980.** Chemical control of the tobacco caterpillar, *Spodoptera litura* (Fabricius), on cauliflower. *Journal of Research, Punjab Agricultural University*, 17(2): 236-239.
- Rao, G. M. V. P. 2008.** Status of insecticide resistance in Kurnool population of *Spodoptera litura*. *Indian Journal of Plant Protection*, 36(2): 173-175.
- Rao, G. M. V. P., Rao, N. H. and Reddy, T. Y. 2008.** Base line data for insecticide resistance monitoring in beet armyworm, *Spodoptera exigua* (Hubner) on chickpea. *Pesticide Research Journal*, 20(2): 201-203
- Rao, G. R. and Dhingra, S. 1996a.** Shift in the susceptibility level of *Spodoptera litura* (Delhi and Guntur populations) to cypermethrin and fenvalerate. *Journal of Entomological Research*, 20(3): 225-227.

- Rao, G. R. and Dhingra, S. 1996b.** Relative susceptibility of different larval instars of *Spodoptera litura* (Fabricius) to some synthetic pyrethroids. *Journal of Entomological Research*, **20**(2): 103-108.
- Rao, G. R. and Dhingra, S. 2000.** Variations in the efficacy of mixed formulations comprising vegetable oils and synthetic pyrethroids against susceptible (Delhi) and resistant (Guntur) larval populations of *Spodoptera litura* (Fabricius). *Journal of Entomological Research*, **24**(2): 115-120.
- Rao, G. R. and Dhingra, S. 1996.** Shift in the susceptibility level of *Spodoptera litura* (Delhi and Guntur populations) to cypermethrin and fenvalerate. *Journal of Entomological Research*, **20**: 225-227
- Rao, G. V. R., Wightman, J. A. and Ranga Rao, D. V. 1993,** World review of the natural enemies and diseases of *Spodoptera litura* (F.) (Lepidoptera: Noctuidae). *Insect Sci. Appl.*, **14**: 273-284.
- Rashad, R. K., Sohail, A. and Shahid, N. 2011,** Mortality responses of *Spodoptera litura* (Lepidoptera: Noctuidae) against some conventional and new chemistry insecticides under laboratory conditions. *Pakistan Entomon*, **33**(2): 147-150.
- Rawat, R. R., Zille singh and Kapoor, K. N. 1969.** Arthropod pests of soybean in Madhya Pradesh. *J. Agric. Agro Ind.*, **2**: 11-13.
- Reddy, A. V., Srihari, G. and Kumar, A. Kiran. 2014.** Newer Insecticides against Pod Borer *Spodoptera litura* and Thrips *Scirtothrips dorsalis* in Chilli (*Capsicum annum* Linn.). *Pesticide Research Journal*, **26**(1): 74-77.
- Reddy, K. S., Ramachandrarao, G., Rao, P. A. and Rajasekhar, P. 2005.** Bio efficacy of some newer insecticides against *Spodoptera litura* (Fab.) infesting sunflower, *Helianthusannuus* L. *Journal of Oilseeds Research*, **22**(1): 222-223
- Regupathy, A., Ramasubramanian and Ayyasamy, R. 2004.** Rationale behind the use of insecticide mixtures for the management of insecticide resistance in India. *Food Agriculture & Environment* **2**(2): 278-284
- Rehan, A., Freed, S. 2015.** Fitness Cost of Methoxyfenozide and the Effects of Its Sublethal Doses on Development, Reproduction, and Survival of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *Pest Management*, **44**(5): 513-520

- Rehan, A., Saleem, M. A. and Freed, S. 2011.** Baseline susceptibility and stability of insecticide resistance of *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) in the absence of selection pressure. *Pakistan Journal of Zoology*, **43**(5): 973-978.
- Rehana, A. and Baig, M. M. H. 1983.** Persistence of the insecticide monocrotophos in pumpkin plants. *Pakistan Journal of Agricultural Research*, **4**(1): 68-70
- Rekha, Ranjan, R., Misbahuddin, S. and Ehteshammuddin, S.2000.** Effect of phosphomidon on protein and free amino acids concentration in the haemolymph of three sap feeding insect pests *Aspongopus janus*, *Chrysocoris stollii* and *Dysdercus cingulatus*. *Journal of Eco-Physiology*, **3**(3/4): 107-110.
- Sabry, H. M. and Khedr, M. A. 2014.** Biochemical and histological variations induced by IGRs in *Spodoptera littoralis* (Boisd.). *Glob. Journal of Environmental Science and Toxicology*, **1**(2): 163:178.
- Saeed, Q., Saleem, M. A., and Ahmad, M. 2012.** Toxicity of some commonly used synthetic insecticides against *Spodoptera exigua* (Fab) (Lepidoptera: Noctuidae). *Pakistan J. Zool.*, **44**(5): 1197-1201.
- Sahoo, S. K., Kapoor, S. K. and Singh, B. 2007.** Insecticide resistance management in *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) in Punjab, India. *Pesticide Research Journal* **19**(2): 226-230
- Saini, R. K., Pala, R. and Saharan, H. S. 2010.** Laboratory and field evaluation of novaluron (Rimon 10 EC) against *Spodoptera litura* (Fab.) on cotton. *Journal of Cotton Research and Development*, **24**(1): 91-94.
- Saini, R. K., Sarwan Kumar, Sharma, S. S. 2005.** Evaluation of insecticides against *Spodoptera litura* (Fab.) attacking cotton. *Journal of Cotton Research and Development*, **19**(2): 273-276.
- Saleem, M. A., Ahmad, M., Ahmad, M., Aslam, M. and Sayyed, A. H. 2008.** Resistance to selected organochlorine, organophosphate, carbamate and pyrethroid, in *Spodoptera litura* (Lepidoptera: Noctuidae) from *Pakistan Journal Economic Entomology*, 101: 1667-1675.

- Saleem, M. A., Ahmad, M., Aslam, M., and Sayyed, A. H. 2008.** Resistance to selected organochlorin, organophosphate, carbamate and pyrethroid, in *Spodoptera litura* (Lepidoptera: Noctuidae) from Pakistan. *Journal of Economic Entomology*, **101**(5): 1667–1675
- Saljoqi Ahmad-Ur-Rahman, RiazulHaq, Ehsan-ul-Haq, Javed Khan and Ghulam Ali. 2015.** Rearing of *Spodoptera litura* (Fabricius) on Different Artificial Diets and its Parasitization with *Trichogramma chilonis* (Ishii). *Pakistan Journal of Zoology*, vol. 47(1), pp. 169-175.
- Sammour, E. A., Kandil, M. A. and Abdel-Aziz, N. F. 2008.** The reproductive potential and fate of chlorfluazuron and lufenuron against cotton leafworm *Spodoptera littoralis* (Boisd.). *American-Eurasian Journal of Agricultural and Environmental Sciences*, **4**(1): 62-67.
- Santharam, G. and Balasubramanian, M. 1980.** Note on the control of *Spodoptera litura*, Fabricius (Lepidoptera: Noctuidae) on tobacco with nuclear polyhedrosis virus and diflubenzuron. *Indian Journal of Agricultural Sciences*, **50**(9): 726-727.
- Sastawa, B. M., Lawan, M and Maina, Y. T. (2004).** Management of insect pests of soybean: effects of sowing date and intercropping on damage and grain yield in the Nigerian Sudan savanna. *Crop Prot.*, 23 (2): 155-161.
- Saxena, D. K. (1972).** Arthropod pests of soybean in Madhya Pradesh and their control. *Pesticides*, 6 (4): 17-19.
- Selvaraj, K., Babu, V. R., Gotyal, B. S. and Satpathy, S. 2015.** Toxicity and bioefficacy of individual and combination of diversified insecticides against jute hairy caterpillar, *Spilarctia obliqua*. *Journal of Environmental Biology*, **36**:1409-1414.
- Serghiou, C.S. 1982.** The effectiveness of synthetic pyrethroids against *Spodoptera littoralis* (Boisd.) larvae. *Technical Bulletin, Agricultural Research Institute, Cyprus*. **42**: 5.
- Shad, S. A., Sayyed, A. H. and Saleem, M. A., 2010,** Cross-resistance, mode of inheritance and stability of resistance to emamectin in *Spodoptera litura* (Lepidoptera: Noctuidae). *Pest Management Science*, 66: 839-846.

- Shalaby, F. F., Hafez, A. A., Mohamed, S. A. and El Aziz, M. F. A. 2013.** Comparative efficacy of certain plant extracts alone and combination with profenofos against *Spodoptera littoralis* (Boisd.) (Lepidoptera : Noctuidae). *Toxicological and Environmental Chemistry* **95**(5): 778-789
- Shankarganesgh, K., Subrahmanyam, B., Gopalakrishnan, Dhingra, S. and Bhandari, J. K. S. 2009.** Susceptibility of *Spodoptera litura* (Fab.) from tarai region to insecticides and its esterase profile. *Indian Journal of Entomology*, **71** (2): 120-124
- Shankarganesh, K., Walia, S., Dhingra, S. and Bhandari, J. K. S., 2009,** Effect of pretreatment of synergists on the toxicity of insecticides to *Spodoptera litura* (Fabricius). *Indian Journal of Entomology*, 71(2): 113-119.
- Shankarganesh, K., Dhingra, S. and Rao, G. R. 2007.** Relative toxicity of some synthetic insecticides against different populations of *Spodoptera litura* (Fabricius). *Pesticide Research Journal*, **19**(2): 172- 175.
- Sharma, P. 2011.** Effect of some plant natural products and insecticides against *Spodoptera litura* (Fab.) and *Bombyx mori* (Linn.). Thesis, M.Sc. (Ag.), Department Of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p.103.
- Sharma, P. C. and Pathania, A. K. 2014.** Comparative toxicity of insecticides and biopesticides against *Spodoptera litura* (F.). *Indian Journal of Entomology*, **76**(4): 269-272.
- Sharma, P. C. and Pathania, A. K. 2015.** Toxicity of some insecticides and biopesticides to *Spodoptera litura* (Fabricius). *Ind. J. Sci. Res. and Tech.*, **3**(4):43-50.
- Sharma, P. K. and Srivastava, A. 2009.** Field evaluation of new insecticides and combinations against rice whorl maggot, *Hydrellia philippina* and leaf folder, *Cnaphalocrocis medinalis*. *Oryza*, **46**(4): 335-336
- Sharma, R. N. 1990.** Observations on mating and oviposition in *Aspongopus janus* (Fab.) (Heteroptera: Pentatomidae). *Environment and Ecology*, **8**(4):1329-1330

- ShuiJin, H., JunFeng, X. and ZhaoJun, H. 2006.** Baseline toxicity data of insecticides against the common cutworm *Spodoptera litura* (Fabricius) and a comparison of resistance monitoring methods. *International Journal of Pest Management*, **52**(3): 209-213.
- Sidhu, A. S. and Dhawan, A. K. 1980.** Chemical control of Bihar hairy caterpillar infesting cotton. *Entomon*, **5**(4): 295-300
- Singh, D. S. and Singh, J. P. 1997.** Evaluation of susceptibility level of synthetic pyrethroids and non-pyrethroids against larvae of *Spodoptera litura*. *Indian Journal of Entomology*, **59**(3): 245-247.
- Singh, D. S. and Singh, J. P. 1998.** Relative susceptibility and development of resistance in *Spodoptera litura* larvae against some pyrethroid and non pyrethroid insecticides, *Indian Journal of Entomology*, **60**(2): 177-180.
- Singh, D. S. and Singh, J. P. 2000a.** Status of pyrethroid and non pyrethroid insecticides to the larvae of Bihar hairy caterpillar, *Spilarctia obliqua*. *Indian Journal of Entomology*, **62** (2): 141-145
- Singh, D. S. and Singh, J. P. 2000b.** Relative susceptibility of *Spilarctia obliqua* larvae against some pyrethroid and non-pyrethroid insecticides. *Indian Journal of Entomology*, **62** (3): 289-294.
- Singh, D. S., Sircar, P. and Dhingra, S. 1985.** Status of Bihar hairy caterpillar, *Diacrisia obliqua* (Walker) (Arctiidae: Lepidoptera) in the context of susceptibility to pyrethroid and non-pyrethroid insecticides evaluated during the last two decades. *Journal of Entomological Research*, **9**(1): 15-18.
- Singh, G., Grewal, G. S. and Singh, G. 1982.** Chemical control of the Bihar hairy caterpillar *Diacrisia obliqua* (Walker) on castor and sesame. *International Journal of Entomology*, **1**(1): 69-71.
- Singh, J. P. 1970.** Elements of vegetable pests. Vora & Co. Publisher Pvt. Ltd., Bombay, 275p.
- Singh, J. P., 1973,** Pests of soybean. *Pesticide.*, **7** (9): 24-27.

- Singh, O. P. 1991.** Efficacy of some new insecticides against the Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) and estimation of losses to soyabean in Madhya Pradesh. *Indian Journal of Agricultural Research*, **25**(4): 189-193.
- Singh, O. P. and Singh, K. J. (1990a).** Efficacy and economics of some emulsifiable concentrate insecticides against *Melanagromyza sojae* (Zehntner) and *Chrysedexis acuta* (Walk) on soybean. *Journal of Insect Science* 3(1): 77-82.
- Singh, O. P., Singh, K. J and Singh, P. P. 1988.** Effect of dates of sowing and varieties on the of major insect pests of soybean in Madhya pradesh. *Bharatiya Krishi Anusandhana Patrika*, 3(1): 47-57.
- Singh, O. P., Singh, K. J. and Nema, K. K., 2000,** Efficacy of some seed dressing and granule insecticides against major insect pests of soybean. *Pestology*, 24 (1): 8- 11.
- Singh, S. and Beri, S. K. 1973.** Studies on the immature stages of Agromyzidae from India: Notes on the biology and description of immature stages of *Melanagromyza*. *Journal of Natural History*, 5: 241-250.
- Sitaramaiah, S., Sreedhar, U., Ramaprasad, G. and Satyanarayana, S. V. V. 2001.** Management of tobacco leaf eating caterpillar, *Spodoptera litura* (Fab.) with insecticide baits in NLS tobacco. *Tobacco Research*, **27**(1): 7-11.
- Snodgras, G. L., Adamczyk, J. J. and Gore, J. 2005.** Toxicity of insecticides in a glass-vial bioassay to adult brown, green and southern green stink bugs (Heteroptera: Pentatomidae). *Journal of Economic Entomology*, **98**: 177-181.
- Somchoudhury, A. K., Jana, S. K., Nair, N., Samanta, A. and Sarkar, P. K. 2008.** Studies on the effect of different abiotic factors and bioefficacy of different chemicals on yellow mite, *Polyphagotarsonemus latus* (Banks) infesting jute. *Journal of Entomological Research*, **32** (2): 105-107
- Sontakke, B. K. and Mishra, P. R. 1994.** Impact of different sowing dates/seasons on the incidence of insect pests and yield losses in soybean. *Journal of Insect Science* 7 (1): 84-87.
- Sontakke, B. K. and Patro, B. 1991.** Occurrence of insect pests of Soybean in Western Orissa. *Environmental Entomology*. 9 (1):173-175.

- Sreelakshmi Pattapu and Mathew Thomas Biju. 2017.** Development of castor based oligidic diet for tobacco caterpillar, *Spodoptera litura* (Fabricius) and its comparative study with other artificial and natural diets. *Journal of Entomology and Zoology Studies*. 5(3): 1040-1044.
- Sreenivasulu, B., Naidu, V. G. and Prasad, P. R. 2002.** Integrated pest management in groundnut against *Spodoptera litura* (Fab.) and other sucking pests. *Pest Management and Economic Zoology*, 10(2): 193-196.
- Sridhar, Y. and Sharma, A. N. 2013.** Field efficacy of thiamethoxam and lambdacyhalothrin ready mix formulation, Alike 247 against major insect pest of soybean. *Indian Journal of Plant Protection*, 41(30): 202-205
- Srivastava, B. and Kushwaha, K. S. 1991.** Specificity of insecticides to *Spodoptera litura* (Fab.) and its parasite, *Peribaea orbata* (W.). *Indian Journal of Plant Protection*, 19(2): 194-196.
- Srivastava, B. K. and Joshi, H. C. 1965.** Occurrence of resistance to BHC 'In' *Prodenia litura* (Fab.)(Lepidoptera: Noctuidae). *Indian Journal of Entomology*, 27: 102-104.
- Srivastava, B. K. and Joshi, H. C. 1965.** Occurrence of resistance to BHC in *Prodenia litura*. *Pest Management Economic Zoology*, 10(1): 93-95.
- Srivastava, K. P. 1993.** A text book of Applied Entomology, Vol-II. *Kalyani Pub.*, p. 266
- Srivastava, N. C. and Srivastava, B. B. L. 1990.** Bioefficacy of moulting disruptor penfluron on the growth of *Spilosoma obliqua* (Wlk.) and *Spodoptera litura* (Fab.) (Lepidoptera Arctiidae). *Annals of Agricultural Science Cairo*, 35(2): 1025-1031.
- Srivastava, N. C. and Srivastava, B. B. L. 1991.** Effect of chitin inhibitor penfluron on the growth of *Spilosoma obliqua* (Wlk.) and *Spodoptera litura* (Fab.). *Journal of Insect Science*, 4(2): 123-126.
- Stanley, J., Chandrasekaran, S., Regupathy, A. and Sheeba Jasmine, R. 2006.** Base line toxicity of emamectin and spinosad to *Spodoptera litura* (Fabr.). *Annals of Plant Protection Science*, 14(2): 346-349.

- Stanley, J., Chandrasekaran, S., Regupathy, A. and Jasmine, R. S. 2006.** Baseline toxicity of emamectin and spinosad to *Spodoptera litura*. *Annals of Plant Protection Sciences*, **14**: 346-349.
- Su, J., Lai, T. and Li, J. 2012,** Susceptibility of field population of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in China to chlorantraniliprole and the activities of detoxification enzymes. *Crop Protection*. 42: 217-222.
- Suby, S. B., Brijesh Singh and Gupta, G. P. 2008,** Efficacy of certain newer insecticides with novel modes of action on tobacco caterpillar, *Spodoptera litura* (Fabricius). *Indian Journal of Entomology*, 70(2): 95-99.
- Sudhakar, K. and Dhingra, S. 2004.** Susceptibility of different instars of *Spodoptera litura* (Fabricius) to chemical and microbial insecticides. *Indian Journal of Entomology*, **66**(2): 111-113.
- Suenaga, H. 1953.** On the soybean stem miner (*Melanagromyza sojae*) *Shokubutsu Boeki*, 7: 264- 266 (In Japanese).
- Tabashnik, B. E. 1989.** Managing resistance with multiple pesticide tactics: theory, evidence and recommendations. *Journal of Economic Entomology*, **82**: 1263-1269
- Talekar, N. S. and Chen, B. S. 1983.** Seasonality of insect pests of soybean and Mung bean. *Journal of Economic Entomology* 76:34-37.
- Talikoti, L. S., Sridevi, D. and Ratnasudhakar, T. 2009,** Relative toxicity of selected novel insecticides against tobacco caterpillar, *Spodoptera litura* (Fab.). *Indian Journal Plant Protection*, 37(1&2): 183-185.
- Talikoti, L. S., Sridevi, D. and Ratnasudhakar, T. 2012.** Relative toxicity of insect growth regulators against tobacco caterpillar, *Spodoptera litura* (Fabricius). *Journal of Entomological Research*, 36(1): 31-34.
- Tandi, B. L. and Narayanan, K. 2002.** Susceptibility of different larval instars of *Spodoptera litura* to its nuclear polyhydrosis virus. *Indian Journal of Applied Entomology*, **16**(1): 40 -43
- Temple, J. H. 2011.** Red banded stink bug, *Piezodorus guildinii* (Westwood): pest status, control strategies and management in Louisiana soybean. Ph.D. dissertation

Temple, J. H., Pommireddy, P. L., Cook, D. R., Marçon, P. and Leonard, B. R. 2009. Susceptibility of selected lepidopteran pests to rynaxypyr®, a novel insecticide. *Journal Cotton Science*, 13: 23-31.

Temple, J. H., Davis, J. A., Hardke, J., Price, P., Micinski, S., Cookson, C., Richter, A. and Leonard, B. R. 2011. Seasonal abundance and occurrence of the red banded stink bug in Louisiana soybeans. *Louisiana Agriculture*, 54: 20-22.

Temple, J. H., Leonard, B. R., Davis, J. A. and Fontenot, K. 2009. Insecticide efficacy against red banded stink bug, *Piezodorus guildinii* (Westwood), a new stink bug pest of Louisiana soybean. *Midsouth Entomologist*, 2: 68-69.

Thakur, A. K. and Kaistha, S. 2001. Chemical control of Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) damaging sesamum. *Himanchal Journal of Agricultural Research*, 27: 51-58.

Thippaiah, M. 1997. Bio-ecology of semilooper, *Trichoplusia orichalcea* (Fab.) (Noctuidae : Lepidoptera) with observation on other pest complex of soybean and their management. *M. Sc. (Agri.) Thesis*, Univ of Agric Sci, Bangalore (India).

Thippaiah, M. 1997. Bioecology of semilooper, *Thysanoplusia orichalcea* (Fabricius) (Noctuidae: Lepidoptera) with observation on other pest complex of soybean and their management. Thesis, M.Sc. (Ag.), Univesity of Agricultural Sciences, Bangalore, India.

Thodsare, N. H. 2014. Manifestation of biological attributes in *Spilosoma obliqua* (Wlk.), *Spodoptera litura* (Fab.) and *Dysdercus cingulatus* (Fab.) in response to essential oils and insecticides. Thesis, Ph.D., G. B. Pant University of Agriculture and Technology, Pantnagar, p-128-146

Thodsare, N. H. and Srivastava, R. P. 2014. Efficacy of indoxacarb and emamectin benzoate against Bihar hairy caterpillar, *Spilosoma obliqua* (Walker). *Journal of Entomological Research*, 38(2): 115-120.

Thodsare, N. H. and Srivastava, R. P. 2015. Contact and stomach toxicity of four combination insecticides against *Spodoptera litura*. *Indian Journal of Plant Protection*, 43(1): 22-27.

- Tomlin, C. D. S. 2009.** A world compendium The Pesticide Manual. Fifteenth edition. *British Crop Production Council*. p. 1457
- Tong Hong, Qi Su, Xiaomao Zhou, Lianyang Bai. 2013.** Field resistance of *Spodoptera litura* (Lepidoptera: Noctuidae) to organophosphates, pyrethroids, carbamates and four newer chemistry insecticides in Hunan, China. *Journal of Pest Science*. **86**:599–609
- Tong, H., Qi Su, Zhou, X. and Bai, L. 2013.** Field resistance of *Spodoptera litura* (Lepidoptera: Noctuidae) to organophosphates, pyrethroids, carbamates and four newer chemistry insecticides in Hunan, China, *J Pest Sci*, **86**: 599–609.
- Toscano, L. C., Calado Filho, G. C, Cardoso, A. M., Maruyama,W. I. and Tomquelski, G. V. 2012.** Impact of insecticides on *Spodoptera frugiperda* (Lepidoptera, Noctuidae) and its natural enemies on off-season maize in Cassilandia and Chapadao. *do Sul, State of Mato Grosso do Sul, Brazil. Arquivos do Instituto Biologico Sao Paulo*, **79**(2): 223-231.
- Tugwell, P., Rouse, E. P. and Thompson, R. C. 1973.** Insects in soybeans and a weed host (*Desmodium* sp) *Ask. Agric. Expet. Stn., Report Service*, 214: 3-18.
- Umopathy, G. and Baskaran, P. 1991.** Insecticidal control of major pests of radish. *Madras Agricultural Journal*, **78**(1/4): 94-96.
- Vaitheeswaran, A. 2009.** Bioefficacy of some insecticides and insecticide mixture against *Spilarctia obliqua* (Walker) and *Spodoptera litura* (Fabricius). Thesis, M.Sc. (Ag.), Department Of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, p.104.
- Vastrad, A. S. 2003.** Neonicotinoids current success and future outlook. *Pestology*, **27** (7): 60-63
- Venkataravanappa, B. 1996.** Development of integrated pest management strategies for pest complex on soybean. *M. Sc. (Agri). Thesis*, Uni. Agric. Sci., Bangalore (India).
- Venkateswarlu, U., Madhumathi, T. and Arjuna Rao, P. 2005.** Relative toxicity of novel insecticides against insecticide resistant Guntur strain of *Spodoptera litura* (Fab.) on cotton in Andhra Pradesh. *Pesticide Research Journal*, **17**(1): 33-35.

- Venkateswarlu, U., Madhumathi, T., Arjuna Rao, P. and Srinivas Rao, V. 2006.** Status of insecticide resistance in *Spodoptera litura* on cotton in Guntur and Praakasam districts of Andhra Pradesh. *Indian Journal of Plant Protection*, **34** (1): 26- 32.
- Verma, G. and Singh, K. K. 2000.** Organophosphorous pesticides and their environmental impact. *Pest Information*, **25** (2): 6-10
- Vinod Kumar, Manglik, V. P. and Bhattacharya, A. K. 1998.** Estimation of population density of some insect pests of soybean. *Journal Insect Science*, **11** (1): 14-18.
- Vinoth Kumar, B., Boomathi, N. , Kumaran, N. and Kuttalam, S. 2010.** Non target effect of ethiprole + imidacloprid 80 WG on predators of rice planthoppers. *Madras Agricultural Journal*, **97**(4-6): 153-156
- Waddill, V. H. 1986.** Insecticidal control of several insect pests of tomatoes. Proceedings of the Tropical-Region, American Society for Horticultural Science. Unda, **23**: 258-262.
- Wang, D., Wang, Y., Liu, H., Xin, Z. and Xue, M. 2013.** Lethal and sublethal effects of spinosad on *Spodoptera exigua* (Lepidoptera: Noctuidae). *Journal of Economic Entomology*, **106**(4): 1825-1831
- Willrich, M. M., Leonard, B. R. and Cook, D. R. 2003.** Laboratory and field evaluations of insecticide toxicity to stink bugs (Heteroptera: Pentatomidae). *Journal of Cotton Science*, **7**: 156-163.
- *Wu, S., Gu, D. and Wang, D., 1995,** Resistance of the tobacco armyworm (*Prodenia litura*) to insecticides and its control. *Acta Agric. Shanghai*, **11**: 39-43.
- Yadav, J. S., Valli, M. Y. and Prasad, A. R. 2001.** Isolation, identification, synthesis, and bioefficacy of female *Diacrisia obliqua* (Arctiidae) sex pheromone blend. An Indian agricultural pest. *Journal of Pure Applied Chemistry*, **73**(7): 1157-1162.
- Yadav, R. P., Kumar, N., Yazdani, S. S. and Goel, S. C. 1992.** Effect of insecticides on field populations of Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) and its naturally occurring parasitoids in Bihar. Bioecology and control of insect pests: Proceedings of the National Symposium on Growth, Development & Control Technology of Insect Pests, pp.192-199.

Yadav, R. P., Singh, R. and Sinha, P. K. 1984. Stomach and contact toxicity of some important insecticides to Bihar hairy caterpillar, *Diacrisia obliqua* (Walker) infesting sweet potato, *Ipomoea batata*. Poir. *Journal of Entomological Research*, **8**(1): 42-45.

***Zhou, T. 1984.** Monitoring of the resistance in common cutworm, *Spodoptera litura* (Lepidoptera : Noctuidae) to four classes of insecticides. *Agricultural Research Journal*, 35(1): 325-332

The author, Rukesh Pramod K. N. of this manuscript was born on 26th May 1991 at Koratagere, Tumakuru dist. (Karnataka). He passed his High School examination from Don Bosco High School, Tumakuru (Karnataka) and Intermediate examination from Vidya Vahini Pre-University College, Tumakuru (Karnataka) in the year 2007 and 2009, respectively. He graduated from College of Agriculture, Mandya, University of Agriculture Sciences (UAS), GKVK, Bengaluru in 2013. Then, by qualifying AIEA-JRF ICAR Exam, he joined College Agriculture, of Junagadh Agricultural University (JAU), Junagadh (Gujarat) in 2013 for the degree of Master of Science in Agriculture with major in Entomology. Thereafter, he qualified All India Entrance Examination (AIEEA-SRF, 2015) conducted by Indian Council of Agricultural Research and got admission for the degree of Ph.D. (Entomology) in College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar in the year 2015-2016.

Permanent Address

*Rukesh Pramod K. N.
S/o Shri Nagarajaiah S.
Mathrushri Krupa 1st C Cross
Krishna Nagar, Vidya Vahini College Road
Tumakuru, Karnataka-572103
Mobile: +91 7252027208
E-mail: rukesh26@ gmail.com*

Name : Rukesh Pramod K. N. **Id. No.** : 49652
Sem. & year of admission: 1st sem, 2015-16 **Degree** : Ph. D.
Major : Entomology **Department** : Entomology
Minor : Plant Pathology
Thesis Title : “STUDIES ON PEST INCIDENCE, BIOLOGY AND FIELD RESISTANCE OF TOBACCO CATERPILLAR *Spodoptera litura* (Fabricius) ON SOYBEAN IN MAJOR DISTRICTS OF UTTARAKHAND”.
Advisor : Dr. Neeta Gaur

ABSTRACT

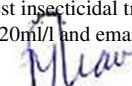
The field and laboratory studies were carried out during 2016-17 and 2017-18 at G.B.P.U.A & T. Pantnagar, Uttarakhand, India, to study “pest incidence, biology and field resistance of tobacco caterpillar *Spodoptera litura* (Fab.) on soybean in major districts of Uttarakhand”. The survey was carried out in the major districts like U. S. Nagar, Nainital, Almora, Champawat, Pithoragarh, Paruri Garhwal, Tehri Garhwal, Uttarakashi, Haridwar and Dehradun. Incidence of major pest defoliators (*S. litura*, *S. obliqua* and *T. orchalcea*) was highest in Nainital, followed by Almora and U. S. Nagar. Whereas, the highest incidence of the chrysomelid beetle, *Hispinae spp.* was found highest in Tehri Garhwal, followed by Almora and Uttarkashi. The highest incidence of sucking pests *i.e.*, whitefly (*B. tabaci*) and jassids (*E. kerri*) was found in the district Nainital, followed by U. S. Nagar and Haridwar. Stem fly infestation was highest with 29.65% in U.S. Nagar being followed by Haridwar (19.07%) and Nainital (16.34%). Girdle beetle damage was more in Tehri Garhwal followed by Nainital, Dehradun and U.S. Nagar. The three different natural enemies' viz. Coccinellid beetles, Eucanthecona bugs and spiders were found most abundant in three hilly districts of Uttarakhand, namely Nainital (11.7/mrl), followed by Almora (11.5/mrl) and Uttarkashi (10.3/mrl).

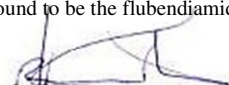
The biology of *S. litura* on soybean and different natural host based artificial diet was evaluated in laboratory conditions. Among the different diets tested the soybean leaves based artificial diet (Diet II) proved to be best and recorded least total larval period of 16.3 days, highest larval growth index of 5.47 and total developmental index 2.28. The second best artificial diet was found to be chickpea flour based artificial diet (Diet-I) with total larval period of 15.5 days, larval growth index of 4.74 and total developmental index was 2.0.

The experiment was conducted on field collected population of *S. litura* to evaluate the LC50 and field resistance against major insecticides, the results revealed that U. S. Nagar population when subjected to leaf dip bioassay method at 48 HAF, recorded 8.58 fold resistant towards chlorantraniliprole 20 SC, 2.09 fold for indoxacarb 15.8 EC, 3.26 fold for lambda cyhalothrin 5 EC, 2.15 fold for spinosad 45 SC, 2.71 fold for dichlorvos 46 SC, 5.23 fold for emamectin benzoate 5G, 23.26 fold for imidacloprid 17.5 SC, 3.92 fold for flubendiamide 480 SC and 2.54 fold for lufenuron 5 EC.

The Nainital population revealed Spinosad 45 SC to be most toxic with resistance ratio (RR) 1.86 and followed by Indoxacarb 15.8 EC with 2.93 RR, Emamectin benzoate 5G with 14.10 RR, Lambda cyhalothrin 5 EC with 4.16 RR, Dichlorvos 45SC with 2.38 RR, Chlorantraniliprole 18.5 SC with 5.44 RR and Flubendiamide 480 SC with 4.81 RR. Lufenuron 5 EC was found to be least lethal with 2.72 RR. Haridwar population recorded resistance to Emamectin benzoate 5 G with (RR) 7.54 was found to be more toxic followed by Spinosad 45 EC with 5.63 RR, Chlorantraniliprole 18.5 SC with 2.36 RR. Indoxacarb 15.8 EC with 3.29 RR, Dichlorvos 45 SC with 3.00 RR, Lambda cyhalothrin 5 EC with 6.69 RR, Imidacloprid 17.5 SC with 16.29 RR and Flubendiamide 480 SC with 3.47 RR. But, the larvae were found to be least mortal with Lufenuron 5 EC with 2.39 RR. *S. litura* population collected from Tehri Garhwal district Spinosad 45 SC reported highly toxic and with resistant ratio (RR) 2.68 followed by Emamectin benzoate 5 G with RR 9.62, Chlorantraniliprole 18.5 SC with RR 2.37, Lambda cyhalothrin 5 EC with RR 4.5, Dichlorvos 45 SC with RR 2.46, Flubendiamide 480 SC with RR 3.49 and Imidacloprid 17.5 SC with RR 42.88. The lowest larval mortality was reported by Lufenuron 5 EC with RR 3.01. Pithoragarh, the results revealed that *S. litura* high mortality to Emamectin benzoate 5 G with Resistant Ratio (RR) of 5.28 followed by Indoxacarb 15.8 EC, Spinosad 45 EC Chlorantraniliprole 18.5 SC, Dichlorvos 45 SC, Lambda cyhalothrin 5 EC, Flubendiamide 480 SC and Lufenuron 5 EC with values of RR 2.14, 3.16, 2.92, 2.81, 5.86, 3.92, 2.79 respectively. The least toxicity was recorded by Imidacloprid 17.5 SC with RR 107.06. Dehradun population among the various insecticides tested, Emamectin benzoate 5 G was found to highly toxic against third instar larvae with Resistant Ratio (RR) of 2.48 followed by Spinosad 45 EC with RR 2.10, Chlorantraniliprole 18.5 SC with RR 2.36, Indoxacarb 15.8 EC with RR 2.71, Lambda cyhalothrin 5 EC with RR 3.01, Dichlorvos 45 SC with RR 2.21, Flubendiamide 480 SC with RR 3.13 and Lufenuron 5 EC with RR 2.63. The least toxicity was recorded by Imidacloprid 17.5 SC with RR 133.23. Champawat population Emamectin benzoate 5 G was found to be highly lethal with Resistant Ratio (RR) of 5.59 followed by spinosad 45 EC with RR 2.20, indoxacarb 15.8 EC with RR 2.27, chlorantraniliprole 18.5 SC with RR 2.07, lambda cyhalothrin 5 EC with RR 4.24, dichlorvos 45 SC with RR 2.69, flubendiamide 480 SC with RR 3.51 and lufenuron 5 EC with RR 2.84. Imidacloprid 17.5 SC with RR 193.21 was reported as least lethal insecticide. Population of *S. litura* collected from Almora district at 48 HAF, indoxacarb 15.8 EC was found to most toxic with and Resistant Ratio (RR) of 2.52 followed by chlorantraniliprole 18.5 SC with RR 3.05, emamectin benzoate 5 G with RR 9.18, spinosad 45 EC with RR 4.56, lambda cyhalothrin 5 EC with RR 3.24, dichlorvos 45 SC with RR 3.73, flubendiamide 480 SC with RR 3.92 and lufenuron 5 EC with RR 2.40. Imidacloprid 17.5 SC with RR 188.72 was found to be most lethal. Pauri Garhwal population emamectin benzoate 5 G showed to highest toxicity with Resistant Ratio (RR) 5.23, followed by spinosad 45 EC with RR 2.15, indoxacarb 15.8 EC with RR 2.09, chlorantraniliprole 18.5 SC with RR 2.44, lambda cyhalothrin 5 EC with RR 3.26, Dichlorvos 45 SC with RR 2.71, lufenuron 5 EC with RR 2.54, and flubendiamide 480 SC with RR 4.35. Imidacloprid 17.5 SC was found to be least toxic with RR 11.07. Uttarakashi population indoxacarb 15.8 EC was found most toxic Resistant Ratio (RR) of 2.35, followed by chlorantraniliprole 18.5 SC with RR 2.36, spinosad 45 EC with RR 3.61, emamectin benzoate 5 G with RR 3.55, lambda cyhalothrin 5 EC with RR 2.55, dichlorvos 45 SC with RR 2.46, flubendiamide 480 SC with RR 3.29 and imidacloprid 17.5 SC with RR 26.14. Lufenuron 5 EC with RR 2.13 was found to be least toxic.

Field trials were conducted to evaluate the field efficacy and economics of newer insecticides in *kharif* seasons of 2016 and 2017. The best insecticidal treatments to control *S. litura* with a highest yield and cost benefit ratio were found to be the flubendiamide 480SC @ 0.20ml/l and emamectin benzoate 5G @ 0.30g/l.


 (Neeta Gaur)
 Advisor


 (Rukesh Pramod K. N.)
 Author

नाम : रूकेश प्रमोद के. एन.
सत्र एवं प्रवेश का वर्ष : प्रथम सत्र, 2015-16
प्रमुख विषय : कीट विज्ञान
गौण विषय : पादप रोग विज्ञान
शोध का शीर्षक : "उत्तराखंड के प्रमुख जनपदों में सोयाबीन की फसल पर कीटों के जीव विज्ञान, और टोबैको कैटरपिलर स्पोडोप्टेरा लिटुरा (फैब्रिसियस) के जीव विज्ञान संरक्षण का परिणाम"
सलाहकार : डॉ. नीता गौड़

परिचयांक सं. : 49652
उपाधि : पीएच.डी.
विभाग : कीट विज्ञान

सारांश

फील्ड और प्रयोगशाला अध्ययन 2016-17 और 2017-18 के दौरान गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय पंतनगर, उत्तराखंड, भारत में किए गए, जिसमें प्रमुख रूप से सोयाबीन पर तंबाकू के कैटरपिलर स्पोडोप्टेरा लिटुरा (फैब) के "कीट घटना, जीव विज्ञान और क्षेत्र प्रतिरोध" का अध्ययन किया गया। सर्वेक्षण उत्तराखंड के जिले में यू.एस. नगर, नैनीताल, अल्मोड़ा, चंपावत, पिथौरागढ़, परूरी गढ़वाल, टिहरी गढ़वाल, उत्तरकाशी, हरिद्वार और देहरादून जैसे प्रमुख जिलों में किया गया था। प्रमुख कीट पत्तिजालक (एसा लिटुरा, एसा ओब्रीका और टी। ऑर्केलेसिया) की छती नैनीताल में सबसे अधिक थी, इसके बाद अल्मोड़ा और उत्तरकाशी में, जिला नैनीताल में चूसने वाले कीटों यानि सफेद मखी (बी। टैबसी) और जसिड्स (ई। केरी) की सबसे ज्यादा क्षति हुई, इसके बाद यू.एस. नगर और हरिद्वार का स्थान रहा। हरिद्वार (19.07%) और नैनीताल (16.34%) के बाद अमेरिकी नगर में तना मखी की घुसपैठ 29.65% के साथ उच्चतम थी। टिहरी गढ़वाल में गर्डल बीटल की क्षति अधिक थी, उसके बाद नैनीताल, देहरादून और यू.एस. नगर। तीन अलग-अलग प्राकृतिक दुश्मना उत्तराखंड के तीन पहाड़ी जिलों, अर्थात् नैनीताल (11.7 / mrl), अल्मोड़ा (11.5 / mrl) और उत्तरकाशी (10.3 / mrl) के बाद कोकिनेलिड बीटल, यूकांथेकोना कीड़े और मकड़ियों सबसे अधिक प्रचुर मात्रा में पाए गए।

सोयाबीन पर स्पोडोप्टेरा लिटुरा की जीव विज्ञान और प्रयोगशाला स्थितियों में विभिन्न प्राकृतिक मेजबान आधारित कृत्रिम आहार का मूल्यांकन किया गया था। विभिन्न आहारों में परीक्षण किया गया सोयाबीन के पत्तों पर आधारित कृत्रिम आहार (आहार II) 16.3 दिनों का सबसे अच्छा और कम से कम कुल सुंडी की कुल जीवन काल अवधि, 5.47 का उच्चतम सुंडी वृद्धि सूचकांक और कुल विकास सूचकांक 2.28 साबित हुआ। 15.5 दिनों की कुल लार्वा अवधि, 4.74 का लार्वा वृद्धि सूचकांक और कुल विकासात्मक सूचकांक 2.0 के साथ दूसरा सबसे अच्छा कृत्रिम आहार काले चने के आटे पर आधारित कृत्रिम आहार (आहार- I) पाया गया यह प्रयोग स्पोडोप्टेरा लिटुरा की क्षेत्र में एकत्रित आबादी पर LC50 और प्रमुख कीटनाशकों के खिलाफ क्षेत्र प्रतिरोध का मूल्यांकन करने के लिए किया गया था, जिसके परिणाम से पता चला कि यूएस नगर की जनसंख्या जब 48 HAF पर पत्ते भिगो कर लगाए गई विधि के अधीन थी, क्लोरिड्राइनिप्रोले 20 एससी के लिए 8.58 गुना प्रतिरोधी दर्ज की गई थी। इंडोक्साकार्ब 15.8 ईसी के लिए 2.09 गुना, लैम्बडा साइहलोलिनिन 5 ईसी के लिए 3.26 गुना, स्पिनोसेड 45 एससी के लिए 2.15 गुना, डिक्लोरोवोस 46 एससी के लिए 2.71 गुना, इमामेक्टीन बेंजोएट 5 जी के लिए 5.23 गुना, इमिडाक्लोप्रिड 17.5 एससी के लिए 23.26 गुना, फ्लुबेंडियम के लिए 3.92 गुना। लुफेनेयूरोन 5 ईसी के लिए 2.54 गुना। नैनीताल की आबादी ने स्पिनोसेड 45 एससी को प्रतिरोध अनुपात (आरआर) 1.86 के साथ सबसे अधिक विषैले होने का खुलासा किया गया और उसके बाद इंडोक्साकार्ब 15.8 ईसी के साथ 2.93 आरआर, 14.10 आरआर के साथ इमामेक्टीन बेंजोएट 5 जी, 4.16 आरआर के साथ लैम्बडा साइहलोलिनिन 5 ईसी, 2.38 आरआर के साथ डिक्लोरोवोस 45 एससी, क्लोरिड्राइनिप्रोएल 5.44 आरआर के साथ 18.5 एससी और 4.81 आरआर के साथ फ्लुबेंडियामाइड 480 एससी। 2.72 आरआर के साथ लुफेनेयूरोन 5 ईसी कम से कम घातक पाया गया। हरिद्वार की आबादी ने इमामेक्टीन बेंजोएट 5 जी (आरआर) 7.54 के साथ प्रतिरोध को अधिक विषाक्त पाया। इसके बाद स्पिनोसेड 45 ईसी 5.63 आरआर के साथ, क्लोरिड्राइनिप्रोएल 18.5 एससी 2.36 आरआर के साथ इंडोक्साकार्ब 15.8 EC के साथ 3.29 RR, डिक्लोरोवोस 45 SC के साथ 3.00 RR, लैम्बडा साइहलोलिनिन 5 ईसी के साथ 6.69 RR, इमिडाक्लोप्रिड 17.5 SC के साथ 16.29 RR और 480 SC के फ्लुबेंडियामाइड 3.47 RR। लेकिन, सुंडी को 2.39 आरआर के साथ लुफेनूरन 5 ईसी के साथ कम से कम नश्वर पाया गया। टिहरी गढ़वाल जिला से स्पिनोसाद 45 एससी से ली गई स्पोडोप्टेरा लिटुरा की जनसंख्या अत्यधिक जहरीली और प्रतिरोधी अनुपात (आरआर) 2.68 के बाद, इमामेक्टीन बेंजोएट 5 जी के साथ आरआर 9.62, प्रतिरोध अनुपात 2.37 के साथ क्लोरिड्राइनिप्रोएल 18.5 एससी, आरआर 4.5 के साथ लैम्बडा साइहलोलिनिन 5 ईसी, आरआर 2.46 के साथ डिक्लोरोवोस 45 एससी, प्रतिरोध अनुपात 3.49 के साथ फ्लुबेंडियामाइड 480 एससी और आरआर 42.88 के साथ इमिडाक्लोप्रिड 17.5 एससी। प्रतिरोध अनुपात 3.01 के साथ सबसे कम लार्वा मृत्यु दर लुफेनेयूरोन 5 ईसी द्वारा बताई गई थी। पिथौरागढ़ के परिणामों से पता चला कि स्पोडोप्टेरा लिटुरा से अधिकतम मृत्यु दर इमामेक्टीन बेंजोएट 5 जी के साथ प्रतिरोधी अनुपात (आरआर) 5.28 के बाद, इंडोक्साकार्ब 15.8 ईसी, स्पिनोसेड 45 ईसी क्लोरिड्राइनिप्रोइल 18.5 एससी, डिक्लोरोवोस 45 एससी, लैम्बडा साइथालोलिनिन 5 ईसी, फ्लुबेंडियम 480 एससी प्रतिरोध अनुपात 2.14, 3.16, 2.92, 2.81, 5.86, 3.92, 2.79 के मूल्यों के साथ 5 ईसी। सबसे कम विषाक्तता इमिडाक्लोप्रिड 17.5 एससी द्वारा RR 107.06 के साथ दर्ज की गई थी। परीक्षण किए गए विभिन्न कीटनाशकों के बीच देहरादून की कीट आबादी, इमामेक्टीन बेंजोएट 5 जी 2.48 के प्रतिरोधी अनुपात (आरआर) के साथ तीसरे इंस्टर लार्वा के खिलाफ अत्यधिक विषैले पाए गए, इसके बाद आरआर 2.10 के साथ स्पिनोसेड 45 ईसी, आरआर 2.36 के साथ क्लोरिड्राइनिप्रोएल 18.5 एससी, प्रतिरोध अनुपात 2.36 के साथ इंडोक्साकार्ब 15.8 ईसी, आरआर के साथ 2.71, आरएम 3.01 के साथ लैम्बडा साइहलोलिनिन 5 ईसी, आरएम 2.21 के साथ डिक्लोरोवोस 45 एससी, प्रतिरोध अनुपात 3.13 के साथ फ्लुबेंडियामाइड 480 एससी और आरआर 2.63 के साथ लुफेनूरन 5 ईसी। सबसे कम विषाक्तता इमिडाक्लोप्रिड 17.5 एससी द्वारा प्रतिरोधी अनुपात 133.23 के साथ दर्ज की गई थी। चंपावत की आबादी इमामेक्टीन बेंजोएट 5 जी 5.59 के प्रतिरोधी अनुपात (आरआर) के साथ अत्यधिक घातक पाई गई, जिसके बाद आरआर 2.20 के साथ स्पिनोसेड 45 ईसी, आरआर 2.27 के साथ इंडोक्साकार्ब 15.8 ईसी, आरआर 2.07 के साथ क्लोरिड्राइनिप्रोएल 18.5 एससी, प्रतिरोध अनुपात 2.07 के साथ लैम्बडा साइथालोलिनिन 5 ईसी 4.24 के साथ पाए गए, डिक्लोरोवोस 45 एससी के साथ RR 2.69, फ्लुबेंडियामाइड 480 एससी के साथ RR 3.51 और लुफेनूरन 5 ईसी के साथ RR 2.84। आरआर 193.21 के साथ इमिडाक्लोप्रिड 17.5 एससी को कम से कम घातक कीटनाशक बताया गया था। स्पोडोप्टेरा लिटुरा की आबादी अल्मोड़ा जिले से 48 HAF पर एकत्र की गई, इंडोक्साकार्ब 15.8 EC 2.52 के साथ सबसे अधिक विषैले और प्रतिरोधी अनुपात (RR) में पाया गया, इसके बाद क्लोरिड्राइनिप्रोएल 18.5 SC के साथ RR 3.05, इमामेक्टीन बेंजोएट 5 G के साथ RR 9.18, स्पिनोसेड 45 ईसी के साथ मिला। प्रतिरोधी अनुपात 4.56 के साथ, लैम्बडा साइहलोलिनिन 5 EC के साथ RR 3.24, डिक्लोरोवोस 45 एससी के साथ RR 3.73, फ्लुबेंडियामाइड 480 एससी के साथ प्रतिरोधी अनुपात 3.92 और लुफेनेयूरोन 5 ईसी के साथ प्रतिरोधी अनुपात 2.40। आरआर 188.72 के साथ इमिडाक्लोप्रिड 17.5 एससी सबसे घातक पाया गया। पौड़ी गढ़वाल की आबादी इमामेक्टीन बेंजोएट 5 जी प्रतिरोधक अनुपात (आरआर) 5.23 के साथ उच्चतम विषाक्तता को दर्शाती है, इसके बाद स्पिनोसेड 45 ईसी के साथ आरआर 2.15, इंडोक्साकार्ब 15.8 ईसी के साथ आरआर 2.09, क्लोरिड्राइनिप्रोएल 18.5 एससी के साथ आरआर 2.44, आरएम 2.44 के साथ लैम्बडा साइथोलिनिन 5 ईसी, 3.26 के साथ डिक्लोरोवोस 45 एससी के साथ RR 2.71, लुफेनेयूरोन 5 ईसी के साथ RR 2.54, और फ्लुबेंडियामाइड 480 एससी के साथ RR 4.35। इमिडाक्लोप्रिड 17.5 एससी आरआर 11.07 के साथ सबसे कम विषाक्त पाया गया। उत्तरकाशी की आबादी इंडोक्साकार्ब 15.8 ईसी में 2.35 का सबसे जहरीला प्रतिरोधी अनुपात (आरआर) पाया गया, इसके बाद आरआर 2.36 के साथ क्लोरिड्राइनिप्रोएल 18.5 एससी, आरआर 3.61 के साथ स्पिनोसेड 45 ईसी, आरएम 3.55 के साथ इमामिनिन बेंजोएट 5 जी, आरआर 3.55 के साथ, लैम्बडा साइहलोलिनिन 5 ईसी के साथ आरआर 2.55, डाईक्लोरोसेलेरोसोला आरआर 2.46 के साथ 45 एससी, आरआर 3.29 के साथ 4 with 0 एससी और 21.48 के साथ इमिडाक्लोप्रिड 17.5 एससी। RR13 के साथ लुफेनेयूरोन 5 ईसी कम से कम विषाक्त पाया गया।

2016 और 2017 के खरीफ मौसमों में नए कीटनाशकों के क्षेत्र की प्रभावकारिता और अर्थशास्त्र का मूल्यांकन करने के लिए खेत में कड़ी फसल में अनुप्रयोग किए गए थे। उच्चतम उपज और लागत लाभ अनुपात के साथ स्पोडोप्टेरा लिटुरा को नियंत्रित करने के लिए सबसे अच्छा कीटनाशक उपचार फ्लुबेंडियामाइड 480 एससी @ 0.20ml / लीटर और इमामेक्टीन बेंजोएट 5 जी @ 0.30 जी / लीटर पाया गया।

(नीता गौड़)
सलाहकार

(रूकेश प्रमोद के. एन.)
लेखक