POPULATION DYNAMICS AND ECOFRIENDLY MANAGEMENT OF TOMATO FRUIT BORER (*Helicoverpa armigera Hub.*)

THESIS

SUBMITTED TO THE

ACHARYA NARENDRA DEVA UNIVERSITY OF AGRICULTURE & TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE (AGRICULTURE)

IN

ENTOMOLOGY

BY

SHAILENDRA KUMAR PATEL

Id. No.-A-7804/14/18

DEPARTMENT OF ENTOMOLOGY

ACHARYA NARENDRA DEVA UNIVERSITY OF AGRICULTURE & TECHNOLOGY, NARENDRA NAGAR (KUMARGANJ), AYODHYA - 224229 (U.P.)

INDIA

आचार्य नरेन्द्र देव कृषि एवं प्रौद्योगिक विश्वविद्यालय, कुमारगंज, अयोध्या

ACHARYA NARENDRA DEVA UNIVERSITY OF AGRICULTURE & TECHNOLOGY, KUMARGANJ

• AYODHYA •

U.P. INDIA

उत्तर प्रदेश भारत

अन्नं हि जीवानां ज्येष्ठम्

DEDICATED

TO

MY BELOVED

PARENTS & FAMILY MEMBERS..

SHAILENDRA…✍

DR. UMESH CHANDRA
FESI, FSSDAT, FSPPS
Assistant Professor &
Incharge Head

DEPARTMENT OF ENTOMOLOGY
ACHARYA NARENDRA DEVA UNIVERSITY OF AGRICULTURE & TECHNOLOGY, NARENDRA NAGAR (KUMARGANJ), AYODHYA (U.P.) INDIA

CERTIFICATE-I

This is to certify that the thesis entitled **"Population Dynamics and Ecofriendly Management of Tomato Fruit Borer (*Helicoverpa armigera Hub.*)"** submitted for the degree of **Master of Science (Agriculture)** in the subject of Entomology to the Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.), is a bonafied research work carried out by **Mr. Shailendra Kumar Patel, Id. No.- A-7804/14/18,** under my supervision and that no part of this thesis has been submitted for any other degree.

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

Narendra Nagar
July, 2020

(Umesh Chandra)
Major Advisor & Chairman

CERTIFICATE-II

This is to certify that the thesis entitled **"Population Dynamics and Eco-friendly Management of Tomato Fruit Borer (*Helicoverpa armigera* Hub"** submitted by **Mr. Shailendra Kumar Patel, Id. No.- A-7804/14/18** to the Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.), in partial fulfillment of the requirement for the degree of **Master of Science (Agriculture)** in subject of **Entomology** has been evaluated satisfactory by external examiner and approved by student's advisory committee after an oral examination.

Advisory Committee	**External Examiner**
Major Advisor & Chairman	**(Umesh Chandra)** Assistant Professor *& In-charge Head* Department of Entomology
Member (Major)	**(Sameer Kumar Singh)** Assistant Professor Department of Entomology
Member (Minor)	**(S. K. Singh)** Associate Professor Department of Plant Pathology
Member (Related Field)	**(D. K. Dwivedi)** Professor Department of Biotechnology
Dean's Nominee	**(R. S. Singh)** Assistant Professor Department of Agronomy
Dean, College of Agriculture	**Head of Department**

ACKNOWLEDGEMENT

I bow my head with great reverence to him who is omnipresent, omnipotent & omniscient and cause behind every effort.

It is uniquely proud privilege to me for expressing my deep emotion & immense gratitude to ***Dr. Umesh Chandra*** *(Incharge Head), Assistant Professor, Department of Entomology and Chairman of my Advisory Committee for his meticulous guidance, constant inspiration and encouragement, incessant, forbearance, peerless criticism coupled with befitting counsels throughout the investigation and preparation of this manuscript. I simply felt myself blessed being provided with an academic advisor like him.*

I express my profound sense of gratitude and regard to the members of my advisory committee, ***Dr. Sameer Kumar Singh,*** *Assistant Professor, Department of Entomology,* ***Dr. S.K. Singh****, Associate Professor, Department of Plant Pathology,* ***Dr. D.K. Dwivedi,*** *Professor, Department of Biotechnolog and* ***Dr. R.S. Singh,*** *Associate Professor, Department of Agronomy and for their expert guidance and valuable suggestions during the course of investigation.*

I am immensely rejoiced to owe my gratitude to ***Dr. V.N. Rai,*** *Dean, College of Agriculture & Head, department of Entomology and Hon'ble Vice-Chancellor* ***Prof. Brijendra Singh*** *for providing all sorts of facilities and amenities required during my study and research work.*

A word of appreciation goes to the faculty members of Department of Entomology, Dr. Sweta Patel, Sri. Subal Singh, Sri. Anil Singh, Sri. K.D. Singh, and Ram Pragat for their generous help and encouragement at various stages of research.

"Next to god, thy parents" all that I am and hope to be I owe my angel parents ***Shri. Ram pal*** *and* ***Smt. Sharada devi*** *I admire confidence bestowed on me by my parents. The untiring pains taking dedicated help, affection, silent wishes and*

blessings received from them to bring me to this level to do good deeds. It is beyond my capacity to express in words.

I am overwhelmed with rejoice to avail this rare opportunity to evince my profound sense of indebtness to my best and loving friend for the untried help, inspiration, love affection, criticism, encouragement, constructive suggestions even under stress condition has created an impact that will form edifice to my bright future.

I would like to thanks my batchmates ***Mr. Sarvesh yadav, Mr. Suryabhan, Mr. Dhirendra singh, Mr. Ajay Yadav, Mr. Sailendra, Mr. Aman Patel, Mr. Prashant Verma, Mr.Pawan singh, Mr.Vishal yadav*** *for their nice support and cooperation.*

Many more people helped me, if I do not listed them all, it is not of lack of gratitude but lack of space. To all of them I give my thanks.

Last but not the least I express my sincere thanks for having typed this manuscript with grateful skill and patience.

Many more deserve special thanks but time and space being limiting factors complied me to part the pen down.

NARENDRA NAGAR (KUMARGANJ) (SHAILENDRA KUMAR PATEL)

JULY, 2019

CONTENTS

S. No.	CHAPTERS	Page No.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-13
III	MATERIALS AND METHODS	14-20
IV	EXPERIMENTAL FINDINGS	21-32
V	DISCUSSION	33-35
VI	SUMMARY AND CONCLUSIONS	36-37
VII	BIBLIOGRAPHY	38-42

LIST OF TABLES

Table No.	DESCRIPTION	Page No.
3.1	Weekly meteorological data during cropping period (November, 2019 to March, 2020).	14-15
3.2	Treatments for testing effectiveness against tomato fruit borer under field conditions.	20
4.1	Occurrence of tomato fruit borer along with weather parameters during *Rabi,* 2019-20	21-22
4.2	Relationship of abiotic factor with population buildup of tomato fruit borer during *Rabi* 2019-20.	22
4.3	Duration of biology of *Helicoverpa armigera.*	24
4.4	Effectiveness of botanicals and biological insecticides against tomato fruit borer during *Rabi* 2019-20.	27
4.5	Effectiveness of botanicals and biological insecticides against tomato fruit borer during *Rabi* 2019-20.	30
4.6	Effect of botanical and biological insecticides on yield of tomato var. Narendra-6 during *Rabi* 2019-20.	32

LIST OF FIGURES

Fig. No.	DESCRIPTION
3.1	Layout plan of experiment
4.1	Effectiveness of botanicals and biological against tomato fruit borer during *Rabi* 2019-20.(First spraying)
4.2	Effectiveness of botanicals and biological against tomato fruit borer during *Rabi* 2019-20.(Second spraying)

ABBREVIATIONS USED

@	:	At the rate of
CD	:	Critical Difference
cm	:	Centimeter
DAS	:	Days after spraying
^{0}C	:	Degree of celcious
Fig.	:	Figure
g	:	Gram
ha.	:	Hectare
i.e.	:	Id east (that is)
Int.	:	International
J.	:	Journal
kg	:	Kilo gram
l	:	Liter
m	:	Meter
Max.	:	Maximum
Min.	:	Minimum
ml	:	Milliliter
mm	:	Millimeter
Mt	:	Million tonnes
N	:	Nitrogen
No.	:	Number
NS	:	Non-significant

%	:	Percent
qha^{-1}	:	Quintal per hectare
Rh	:	Relative humidity
S. No.	:	Serial number
Sci.	:	Science
SEm±	:	Standard error of mean
Spp.	:	Species
Vit.	:	Vitamin
Wt.	:	Weight

Chapter-I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.)is the one of the world'smost consumed vegetable crop. According to statistics of the Food & Agriculture Organization (FAO), around 340 billion pounds (170 million tons) of fresh and processed tomatoes were produced globally(FAO, 2018). The harvested area covered 5 million hectares of farmland. The world production of tomatoes has consistently increased since 2000, growing more than 54 percentfrom 2000 to 2014 (FAO, 2018). China is the largest producer of tomatoes, followed by the United States (US) and India. Other major producers in the tomato market are the European Union and Turkey. Together, these top five tomato producers supply around 70 percent of the global production. Mexico is the largest exporter of tomatoes in the world, followed by the Netherlands and Spain (CIA, 2017). In 2016, Mexico, the Netherlands, and Spain accounted for 25.1 percent ($2.1 billion), 19 percent ($1.6 billion), and 12.6 percent ($1.1 billion) of the world's total tomato exports, respectively (CIA, 2017).

In India, it occupies an area of 778,000 hectares with an annual production of 193, 970, 00MT (2018-19). The major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal (NHB 2015).

The cultivated tomato is a member of the genus *Solanum* within the family Solanaceae. The Solanaceae, commonly known as the nightshade family, also includes other notable cultivated plants such as tobacco, chilli pepper, potato and eggplant. Tomato classification has been the subject of much discussion andthe diversity of the genus has lead to reassessment of earlier taxonomic treatments. Tomato was originally named *Solanum lycopersicum* by Linnaeus in 1753; *Lycopersicon lycop*ersicum (L.) Karsten has also been used (Valdes and Gray, 1998). Miller (1768) in The Gardener's Dictionary used *Lycopersicon esculentum*. Rick (1979) included nine species in the *Lycopersicon* genus. For a long time tomatoes were known as *L. esculentum*, but recent research has shown that they are part of the genus Solanum and are now again broadly referred to as *Solanum lycopersicum* (Spooner, Anderson and Jansen, 1993; Bohs and Olmstead, 1997; Olmstead and Palmer, 1997; Knapp, 2002; Spooner *et al.*, 2005, 2003; Peralta *et al.*, 2008).

The genus Solanum consists of approximately 1500 species. The tomato clade (section *Lycopersicon*, formerly recognised as the genus *Lycopersicon*) includes the cultivated tomato (*Solanum lycopersicum*) and 12 wild relatives, all natives to western South America. Tomato (*Solanum lycopersicum*) is derived from two wild ancestor species, *Solanum pimpinellifolium* and *Solanum cerasiforme*. Other wild species are useful for breeding disease resistance, colour improvement and desirable quality traits (Ranc *et al*., 2008).

Tomatoes contain a variety of phytochemicals, the most well-known beinglycopene. In addition, other carotenoids (e.g. β-carotene, phytoene, phytofluene), phenolics (e.g. coumaric and chlorogenic acids, quercetin, rutin and naringenin), moderate amounts of the antioxidant vitamin C (ascorbicacid) and a little vitamin E (tocopherol) are present. Carotenoids are presentin many vegetables and fruit but lycopene is more restricted in its distribution,being concentrated in tomatoes, guava, rosehip, watermelon and pinkgrapefruit. Lycopene imparts the red colour to these fruit.Tomato is known for its outstanding nutritive value being a good source of vitamin-C. It contains 93.10 gm moisture, 0.90 gm protein, 0.1 gm fat, 0.60 gm mineral, 0.70gm fibre, 3.60 gm carbohydrate, 45.80 mg sodium, 0.19 mg of copper, 24 mg sulphur, 38 mg chlorine, 114 mg potassium, 320 IU vitamin-A, 0.07 mg thiamine, 0.01 mg riboflavin, 0.40 mg nicotine acid, 31 mg vitamin-C, 20 mg calcium, 15 mg magnesium, 2 gm oxalic acid, 36 mg phosphorus and 1.80 mg iron per 100 gm of fresh fruit (Aykroyd, 1963). In addition to its high nutritive value, it also has medicinal values. The pulp and juice are digestible and a mild aperient, promoter of gastric secretion, blood purifier. It is reported to have antiseptic properties against intestinal infections. It is said to be useful against cancer of the mouth, sore mouth, etc. Dried tomato juice retains vitamin C. It stimulates torpid liver and is good in chronic dyspepsia. It is one of the best vegetables which keep our stomach and intestine in good order (Bose *et al*., 2002).

Helicoverp aarmigera(Hub.) is a key pest as it infests fruits and makes them unfit for human consumption causing considerable (55%) crop loss. It has been estimated that crops worth Rs.1000 crore are lost annually by this pest.Over the years, the more common method for the control of this pest has been to have a film of a persistent effective insecticide over the foliage and fruiting bodies. However, the indiscriminate use of insecticides has eroded sustainability and resulted in build- up of pesticide residues, resistance to pesticides, resurgence and secondary outbreak of this pest. Therefore, switching from the use of insecticides alone to more bio-intensive methods of pest management such as the use of trap crops and farm scraping has become the trend. Trap cropping and planting of diversionary hosts have been widely applied and recommended in the past. Tomato fruit worm adults prefers marigold at flowering stage for oviposition as compared to tomato, which reduced *H. armigera* infestation of tomato. So, to have clear proven idea on the incidence of fruit borer and to find the population build-up of these pest attacking tomatoes and their relation with abiotic factors like temperature, rainfall and relative humidity, the present experiment was conducted for further understanding of the role played by the abiotic factors in the incidence of fruit borer which is harmful to tomato growers which ultimatelywill help tomato growers for better return in terms of yield as well as income generation.

The indiscriminate use of synthetic chemical pesticides to control this pest resulted in development of resistance (Armes *et. al.,* 1992, 1994) and harmful pesticide residues in fruits. The presence of residues of DDT, HCH, endosulfan, malathion and primisphos-methyl in market samples of tomato has been reported (Dikshit *et al.,* 1992; Chalal *et al.,* 1997). Microbials and neem formulations have been reported to reduce the *H. armigera*population and fruit damage in tomato (Praveen, 2000 and Thilagam, 2003). Hence, attempts were made to evaluate the efficacy of different sequential application of nucleo polyhe drosisvirus of *H. armigera* (Ha-NPV), *Bacillus thuringiensis* var. *Kurstaki* Berliner (Btk), neemazol and spinosad as the alternatives to the synthetic chemical pesticides for the sustainable management of *H. armigera* on tomato.

Keeping in view of aforesaid facts and knowing the seriousness of problems,the present study is undertaking with the following objectives:

1. To study population dynamics of tomato fruit borer.
2. Correlation between tomato fruit borer populations with abiotic factors.
3. To study the biology of tomato fruit borer.
4. Management of tomato fruit borer through Integrated Pest Management with inter cropping.

Chapter-II

REVIEW OF LITERATURE

The available information on the various aspects of tomato fruit borer, *Helicoverpa armigera* Hub. have been reviewed and given below.

2.1 Population dynamics of *Helicoverpa armigera*

Lal *et al.* (1985) used sex pheromone traps baited with 11- haxadecenal and (z) 9-haxadecenal for monitoring *H. armigera* population and reported effective catches in March-April. They also observed peak larval population densities preceded by a peak in moth catches.

Parihar and Singh (1985) noticed the incidence of fruit borer. *H. armigera* (Hubner) on tomato and found that maximum fruits were infected in 2 week of April (50-68 & 33.04 % in 1984 & 1985 respectively).

Walker and Cameron (1990) monitored adult population of *H. armigera* on tomato and maize with the help of pheromone traps and found increase in catches in tomatoes in late January, mid February and March coincided with increase in egg counts. Catches of adult in maize crops were low as compared with catches in tomatoes. However, the peak flights into tomato fields in mid February and early March coincided with flights into maize crops.

Fang *et al.* (1990) studied the occurrence of tomato fruit borer and reported peak population of *H.armigera* from late October to mid November.

Dubey *et al.* (1993) studied on population dynamics of *H. armigera* in Madhya Pradesh for over two consecutive years (1983-84 and 1984-85) showed its peak activity from February to March during both years.

Verma and Sankhyan (1993) monitored *H. armigera* population by using pheromones traps and worked out relationship between moth activity and larval infestation on important cash crops including tomato.They found that adult activity started during 10-11 standard week (SW (mid March). Chickpea was the first crop exploited by the over wintered population of *H. armigera* between 13-20 SW while tornado harboured a persistent larval population from 17-26 SW. They found negative correlation with maximum temperature and positive correlation with rainfall and adult activity.

Dwevedi *et al.* (1996) used sex pheromone traps for monitoring *H. armigera* and reported that maximum number of moths was trapped in April, March and May during 1988, 1989 and 1990, respectively. They found increase in its population between10.5 to 5.6 ^{0}C.

Pandey *et al.* (1996) reported that *H. armigera* is one of the major limiting factors of spring season tomato in the hills. They reported that pest was active from February to May with high incidence during March - April.

Chavan *et al.* (2013) investigated on the population dynamics and evaluation of pest management modules against major insect pests of tomato were carried out at Navsari Agricultural University, Navsari, south Gujarat in *Rabi*, 2007-08. Results revealed that aphid and whitefly population commenced from transplanting with 1.35 aphids leaf-1 and 0.37 whiteflies leaf-1, reached to peak level (7.31 aphids/leaf and 6.01 whiteflies/leaf) at 11 WAT. Peak level of percent infested leaves by leaf miner was 31.75 % at 10th WAT. The higher population of *Helicoverpa* on foliage (2.80-3.40 plant-1) was noticed during third week of January to end of February (10-16 WAT).

Bala *et al.* (2017) studied larval population of *H. armigera* first appeared in the field during 3rd standard metrological week (SMW) which gradually increased and reached its peak (7.37 larvae per plant) during 12th SMW. Correlation between various abiotic factors viz., maximum relative humidity (r = -0.38), minimum relative humidity (r = -0.21) and rainfall (r = -0.33) with fruit borer larval population was found to be negative where as maximum temperature (r = 0.88), minimum temperature (r = 0.86) and sunshine hour (r = 0.34) were positively correlated with *H. armigera* larval population. application of *Beauveria bassiana* 1.50% LF (Bio-Power) at three different doses along with neem and quinalphos revealed that upto 80% pest mortality over untreated control can be obtained when *Beauveria bassiana* 1.50% LF was applied @ 4000 ml/ha.

Kharia *et al.* (2018) reported the population of *H. armigera* and *Bemisia tabaci* were recorded starting from the 4th standard week at crop establishment stage and till 18th standard week at the crop maturity stage. The first appearance of the fruit borer was noticed during 11th standard week (12th -18th March) and it reached maximum in 16th standard week (16 - 22April), while the population decreased up to crop maturity. A negligible population of whitefly was first observed during 16th standard week which remained below ETL ranging from 0.1 to 0.2 adults per plant till crop maturity (18th standard week).

2.2 Correlation between populationof *H. armigera*with abiotic factors

Kekati *et al.* (2005) conducted an field experiment in Jorhat, Assam, India, up during the 2001-02 *Rabi* season to study some seasonal history and population build aspects of the tomato fruit borer. The pest population increased commencement from the first week of November and touched its peak during the first week of December. The Population build-up ofthe pest revealed significant negative correlation with low temperature and non-significant correlation with high temperature.

Singh *et al.* (2006) conducted field experiment and studies to calculate the larval population of *H.armigera* and its damage on tomato in Ranipur.

Kurl *et al.* (2008) carried out an experiment for the study to determine the impact of tomato-based cropping systems (tomato-sugarcane, tomato-maize-potato and tomato-vegetables) on the population build-up of *H. armigera*in Meerut, Uttar Pradesh, India during 2004-06. The larval population and per cent of fruit damage caused by *H. armigera* were significantly different in all the three patterns and was highest in the tomato-vegetables pattern. It was followed by the larval population and fruit damage percentage of the tomato-maize-potato pattern. Tomato-sugarcane noted the lowest *H. armigera* incidence.

Chatar *et al.* (2010) reported that the pest was active during the last week of December to 3rd week of January. Later on, the pest population declined gradually towards the maturity of the crops. Correlation of *H. armigera*with different weather parameters indicated that maximum temperature exhibited highly significant negative correlation (r= - 0.7514) with larval population of *H. armigera*, whereas minimum temperature (r= - 0.5771) and mean temperature (r= - 0.6836) exhibited significant negative correlation.

Chakravarthy *et al.* (2011)studied the effects of sowing date (at the 44th, 46th, 48th and 50th standard meteorological week, corresponding to early, moderately early, late and very late sowing) on the population density of *H.armigera* were studied in Uttar Pradesh , West Bengal, India, during 2007-09. The average pest occurrence on tomato was highest under very late sowing (17th) and lowest tender early sowing (7.65%).

Sharma *et al.* (2012) observed that maximum temperature and minimum temperature had positive correlation with male moth catches and larval population of *H. armigera* while, relative humidity had negative correlation with male moth catches and larval population of *H. armigera* .

Bisht *et al.* (2014) carried out an experiment for study the incidence of *Helicoverpa armigera* Hub, on tomato (*Solanum lycopersicum* L.) at Pantnagar during the cropping season

2011-12 and 2012-13 revealed that the pest presented its incidence almost throughout the crop season marked its first presence in 7^{th} and 9^{th}SMW i.e. (February and March), attain peak population in 16th and 15th SMW (April), respectively.

Renu *et al.* (2017) conducted under field conditions at Central Research Farm, SHUATS, Naini, Allahabad during Rabi, 2014-15, studied seasonal incidence of the fruit borer, *Helicoverpa armigera* (Hubner) on tomato. The incidence of fruit borer started in 8^{th} standard week (third week of February) with a normal population of 22 larvae per plant.

Meena *et al.*(2017)conducted the field experiment to study the fluctuation of pest population of tomato fruit borer, *Helicoverpa armigera* (Hub.) and their relation with the prevailing weather conditions in kharif season during 2012-13. The results shown that borer incidence commenced in the 4th week of October 2012 with intensity (0.67 larvae 5 plants).

Singh *et al*. (2017) study was conducted to ascertain the effect of weather i.e. temperature on fruit borer, *Heicoverpa armigera* (Hub.) activity, major insect-pest of Tomato in northern plains of India. Initial fruit infestation by *H. armigera* was recorded in November in the years of study i.e. 2012-13 and 2013-14 which declined during December-January and touched the peak i.e. 11.93 and 14.78 percent in the month of March. The correlation of *H. armigera* fruit damage (%) with maximum temperature was strongly positive (r= 0.5082 and 0.5393) and similarly with minimum temperature (r= 0.5880 and 0.6866) as well.

Saini *et al.* (2017) studied Seasonal Incidence of fruit borer (*Helicoverpa armigera* Hubner) of chilli (*Capsicum annum* L.) during June to December 2014, at Horticulture farm, Rajasthan College of Agriculture, Udaipur. The study revealed that the occurrence of fruit borer, *H.armigera* (1.00 larvae plant-1) was started in the fourth week of August (34 SMW) and touched it's highest in the first week (40 SMW) of October (2.80 larvae plant-1).

Kumar *et al.* (2017) field experiment was conducted to study the seasonal incidence of tomato fruit borer, *H. armigera* (Hub.) on tomato with and without marigold as a trap crop. The incidence of *H. armigera* on tomato without marigold as a trap crop was first noticed in the first week of February. The pest touched the peak with a mean of 4.40 larvae / plants during third week of March. Similarly, the incidence of *H. armigera* on tomato with marigold as a trap crop was first noticed in the fourth week of January. The pest touched the peak with a mean of 1.20 larvae/plant during third week of March. The correlation between fruit borer population and mean atmospheric temperature was positive and significant in with and without marigold (r= 0.633 and 0.677, respectively). The significantly positive correlation were found between *H. armigera* larvae and damaged fruits in tomato with and without marigold (r = 0.878 and 0.929, respectively).

Kumar *et al.* (2017) conducted to have a look at the seasonal occurrence of tomato fruit borer, *H. armigera* (hub.) on tomato with and without marigold aa lure crop. The prevalence of *H. armigera* on tomato without marigold as a trap crop become first visible within the first week of February.

Bhati *et al.* (2017) the fruit borer larva was first observed during the 2nd SW and reached at its peak (1.4 larvae / plant) during 4th SW. During this period the maximum and minimum temperature were 21.5 and 90C, respectively, whereas morning and evening relative humidity were 89 and 57 per cent, respectively. Further sunshine, wind speed, morning and evening vapour pressure and evaporation were 6.8 hrs, 3.5 km / hr, 8.7 mm, 10.2 mm and 1.9 mm, respectively. After 10th SW, there was a gradual decline in the larval population and was available up to $_{16}{}^{th}$ SW.

Mushtaq *et al*. (2019) studies were carried out at Experimental Farm, Faculty of Agriculture, Wadura, Sopore, SKUAST-K, during the year, 2016-2017. The larval infestation of *H. armigera* started a month and half (22 SW) after transplanting of the crop in all the tomato genotypes. A negative and nonsignificant correlation was computed between *H. armigera* larval population and maximum temperature (r = -0.032), whereas sunshine hours had negative and significant association (r = -0.566) with fruit borer larvae. The other abiotic factors such as minimum temperature, rainfall, maximum and minimum humidity had significant and positive correlation with r values of 0.874, 0.734, 0.543 and 0.593, respectively.

2.3. Biology of tomato fruit borer

Vaishampayan and Veda (1980) observed population dynamics of gram pod borer *H. armigera* (Hubner) and it's out break situation on gram. *H. armigera* has completed 5 generations in the laboratory as well as in field. The seasonal variation in generation time was largely due to extreme variation in ecological factors, temperature (10-45°C). photoperiod (10 -14 hours), relative humidity (15-95%) and rainfall. These factors also affected the percent age of population emergence and fecundity of the female, males out numbered the females in the 19 and 5th generations and female lives longer than males in all generations Tripathi and Singh 1993).

Choudhary and Sharma (1981) reported that the pest had complete 4 generation from September to April. A minimum period of 29.7 days to complete 4 generation during

November December and maximum of 98.5 days from mid-December to mid April. The second generation was completed from first week of November to second week of December, a total 33.2 days.

Mathur and Upadhyay (1992) documented that single female of *H. armigera* can lays 500 to 1000 eggs. The egg period lasts from 3 to 7 days. The newly hatched larva measures 2 to 2.5 mm long while full grown larva was reported to he 35mm in length and very variable in length. The caterpillar moults lour times and become full grown in 20 to 25 days. The pupal period generally lasts from 10 to 24 days depending upon the environmental conditions.

Shekhar *et al.* (1995) studies the life table of *H. armigera* on 13 food plants in Krishna-Godavari, Andhra Pradesh and found that mortality was high mostly in the egg and 1. 2 instar larvae stages on okra and mung bean .The influence of weather factors and natural enemies on population of *H. armigera* on different food plants was qualified.

Izquierdo *et al.* (1996) collected the eggs and larvae of noctuid *H. armigera* weekly from 27 commercial tomato crops in Spain, during 1990-92 and the parasitoids and predators were determined in the laboratory at 25 C. 70 % relative humidity and LD 16:8. Species from the *Trichogramma* and *Telenomow* were found parasitizing eggs, with *Trichogramma evanescens* and *Telenomus*vti being the most common.

Prakash and Fenemore (2000) reviewed that oviposition of *H. armigera*starts about four days after emergence and may continue for about ten days. Eggs are deposited on tender leaves singly and they hatch in 3-7 days. They reported six larval instars with total larval period of 14-38 days depending upon the climate. The full grown larva was reported as 3.5 cm long while pupa was 1.6 cm in length. Moths emerged after a week or so.

Nigam and Kumar (2000) reviewed that egg stage of *H. armigera* occupies 3-4 days. A ful grown larva is about 34 mm long. Pupal period varied from 6-12 days. The total life cycle from egg laying to adult emergence takes about 21-49 days during summer and autumn. There are about eight generations of pest in a year.

Sharma and Singh (2000) documented that egg of *H. armigera* is laid singly and about 0.5mm in length. A single female can lay 3-4 thousand eggs. The incubation period lasts from 2 to 4 days. Newly emerged larva is about 2 mm in length and greenish in colour. The total larval period is about 25 to 30 days. Full grown larva is 30-35 mm long. The length of pupa is about 16mm while it is 6.0 mm in breadth. Total life cycle lasts for 3 t0 7 weeks.

Borah and Dutta (2002) studied the biology of gram pod borer, *H. armigera* in the laboratory and observed that the eggs of *H. armigera* hatch in 3,39 days. The pod borer has six larval instars and the larvae take 19.77 days to complete its development. Thepre-pupal and pupal periods are 2.28 and 14.27 days, respectively. The female mothlives comparatively longer (8.66 days) than the male (6.38 days) and the male to femalesex ratio are 1:1.45.

Thakor and Patel (2008) studied the biology of *H.armigera* (Hubner) under laboratory conditions on cabbage and they found that the egg incubation period was 4.04 days and the larval stage passes through sixinstars. The average development period of the respective instar was 3.66, 4.90, 5.22 and 6.30 days and the total larval period averaged 25.04 days. The pupal period averaged 10.72 days.

Sharma *et.al.* (2011) studied on life history and infestation done by *Helicoverpa armigera* (Hubner) on tomato in semi-arid region of Rajasthan. They observed that the fecundity female ranged from 256.60-490.66 eggs and percentage hatchability ranged between 77.80-89.0 per cent in different generations. The longevity of male and female moths was 2.44-5.89 and 8.79-11.33 days, respectively. In the first two generations the ratio of male was higher than female (1:0.76 and 1:0.67) but in the next generation the ratio of female was higher than males (1:1.22). The incubation period was 5-7, 5-6 and 4-6 days in the 1", 2 and 3 generation. The larvae passed through five instars with 21,25-38.24 days of total larval period in different generations. The mean pre-pupal pernod and pupal period ranged from 4.04-4.75 and 13.78-24.38 days in different generations. *H. armigera* completed three generations in semi-arid region of Rajasthan from October to May.

Lakshmi *et al.* (2011) studied the comparative biology of *Helicoverpa armigera* (Hubner) on different medicinal plants under laboratory conditions revealed that thespherical, ribbed eggs were laid singly on leaves, flowers and spikes and on or near the fruiting bodies. The fecundity of female moth was, on an average, 12.34 to 0.60 eggs on Coleus, eggs on Ashwagandha, 1212.4 to 0.85 eggs on Kalmegh and 1480.2 to 0.90 eggs on Musk mallow.

Baikar and Naik (2016) reported that longevity of adult ranged from 6 to 8 days with an average of 6.9 ± 0.74 days in males, while the longevity of female moths ranged from 8 to 10 days with an average of 9.0 ± 0.66 days.

Herald and Tayde (2018) the *Helicoverpa armigera* (Hubner) recorded that the mean pre-oviposition, oviposition and post-oviposition period on tomato lasted for 2.90 ± 0.73 days, 5.50 ± 0.52 and 1.60 ± 0.51 days, respectively. A female laid on an average 412.0 ± 5.24 eggs. The incubation period was observed to be 3.50 ± 0.52 and their size varied from 0.40 to 0.62 mm in length and 0.37 to 0.56 mm in breadth.

2.4. Management of tomato fruit borer through I.P.M. With inter cropping

Kumari and Reddy (1992) studied the relative trap efficiency of ICRISAT standard trap and sleeve trap for trapping male of *H. armigera* & *S. litura* using synthetic traps. Sinha and Jain (1992) carried out the monitoring of male *H. armigera* at IARI regional station, Karnal (Haryana) India from January 1986 to May 1986 using sex pheromone baited traps. Maximum activity was recorded during the spring summer season (6-28 SW) while a minor peak activity was observed in autumn (42^{th} to 50^{th} SW). Pattern of trap catches indicated oceans of 4-5 generations in a year Moth catches in summer were tiund to he positively correlated with larvae count of *H. armigera.*

Sinha and Mehrotra (1993) studied the effects of trap design, trap elevation, pheromone quality and loading and ageing in the pheromone dispenser on the catch efficiency of traps baited with synthetic sex pheromone of *H.armigera* were investigated in ticids of chickpea in Karnal, Haryana, India in 1987.90. Final conclusion is with increasing the numbers por trap of rubber septa, each with 5 mg lure, had no effect on trap catch: A rubber septum was as effective as 6 rubbers or septum with 30mg lure. The pheromone dispensers lost their attraction power after weeks.

Prasad *et al.* (1993) worked in the field trials in A.P., India, catches of 22 adult in *H. armigera*. Trap per night in sleeve pheromone traps corresponded to 10 percent damage to the reproductive part in cotton by *H. armigera*.

Chhabra and Kooner (1993) studied pheromone trap in chickpea and pigeonpea in Ludhiana (Punjab) India between 1981 and 1990. Thy revealed that there were population peaks of *H. armigera* per year.

Dhanorkar and Puri (1993) Investigated peak catches of adults of *H. armigera* and Pectinophoragossypiella in pheromone traps in color field in Maharashtra. (India) were observed in September and February and September. November and March 1987-88 respectively.

Verma and Sankhyan (1993) studied the adult activity of *H. armigera.* They monitored *H.armigera* pheromone baited traps and catch data and larval activities. They reported that maximum temperature and rainfall were negatively and positively correlated with population build up of insect.

Dubey *et al.* (1995) studied the population dynamics of *H. armigera* over two years (1983-84 & 1984-85). The pest showed peak activity in February and March during both years.

Somnuk *et al.* (1995) conducted the experiment on pheromone trapping and during the week without pheromone trapping, the numbers of eggs were more than those found during the week with pheromone traps, nevertheless data showed no significant difference. The level of abundance of *H. armigera* math was monitored by pheromone trapping, the highest number was averaged at 4.5 moths per trap at sixth to seventh week after tomatoes transplanting.

Pandey *et al.* (1997) studied monitoring and management of tomato fruit borer (*H. armigera*) and its egg.parasite (*Trichogrammaishi*) in western hills Nepal found that monitoring of *H.armigera* for several seasons across the agro climatic zones, indicated that March - April is the peak activity period of the Moth.

Bhadauria and Bhadauria (1997) used synthetic pheromone traps to study *H.armigera*population fluctuations in Indore, Madhya Pradesh in 1995-96. Moths were trump throughout the year during the period (7 to 27 May) of high temperature (40^0C) and RH (<50%). Five population peaks were observed during the study.

Ge.Shaokui *et al.* (1997) studied the effects of sex pheromone was behaviors of adult *Heliothis* and its field control. A field experiment was carried out in China and found that sex-pheromone not only affected the counting and copulation of adult of *H.armigera*, but also disturbed flying behavior in the course of feeding, dispersal und concealment and the male population was reduced by half. The copulation of cuch female was reduced by 0.6 times and the incubation rate in the laboratory and field was reduced by 19 and 13.5 percent, respectively.

Patil and Kulkarni (1997) analyzed light and pheromone trap catch for seven years from 1987 to 1993 and compared with 1994 and 1995 data that Indicated maximum activity of *H. armigera* From October to December in Raichur, India. There was a significant negative correlation with temperature and rainfall; whereas morning relative humidity showed a positive significant correlation with trap catches.

Satpathy and Rai (2000) evaluated the potentiality of NPV (crude and formulated). endosulfan and neem products under field conditions on tomato cv. sel-7.The treatment viz., crude NPV (200 or 300 LE/ ha), formulated NPV (100 LE/ha),endosulfan + crude NPV (350g ai.+ 100 or 200 LE/ha), formulated NPV + Neemagold(100 LE + 2.5 ml/), formulated NPV + Econeem (100 LE/ha + 2.5 ml/l) and endosulfan(700 g ai ha). They reported that an application of crude NPV + endosulfan (100 LE/ha + 350 g a.l. ha) which resulted in mean fruit damage of 720 per cent is recommended and crude NPV at 300 LE/ha performed equally well (7.79 per cent damage).

Mehta *et al*. (2001) studied on the management of tomato fruit borer, *H. armigera*(Hubner) with nine insecticidal treatment at Palampur (Himachal Pradesh) and observed that among the bio-pesticides tested, B.t. treated plots had lowest fruit infestation(10.68%) as compared to HaNPV (11.959) and azadirachtin (14.68%). A mixture of deltamethrin + *B.t.* application revealed afruit damage of 5.58 per cent while untreated control had 24.2 per cent fruit damage.

Praveen, (2000) and Thilagam(2003) microbials and neem formulations have been reported to reduce the *H. armigera* population and fruit damage in tomato.

Hussain and Bilal (2007) the use of marigold as a trap crop for the management of tomato fruit borer in tomato was evaluated. The proportion of larvae counted on trap row increased with increasing rate and on main crop decreased with decreasing rate at 65 and 80 days after transplanting. All the treatment combinations recorded lowest fruit damage, larval population on tomato but trapped higher larvae on marigold. Moreover, 3:1 combination observed (81.0-88.89%) larval reduction than sole crop and was significantly better than other treatments.

Rijaland Dahal (2019)studied themanagement of *Helicoverpa spp.*requires an integrated pest management method which aims in producing healthy crops and maintaining better sustainable agro ecosystem.Integrated pest management aims to maintain pest population below economic injury level. It is an integration of appropriate measure that inhibits the development of pest population. Integrated pest management aims to grow healthy crops with least damage to agro-ecosystem. *Helicoverpa* can damage 90% of fruit and reduce yield by 30-40%. Resent research have been made in biological and cultural management of *Helicoverpa* but development of resistant variety is best option. Flubendiamide 40SC@0.21ml/ltr and Emamectin benzoate are best chemical whereas *Trichogramma* @30cards/ha, Helio nucleo polyhedrosis and neem based pesticide are best biological method for the pest management. Lowest percentage of fruit damages and the yield highest of marketable fruits damage with NPV @ 300 LE/ha (Mohan *et al*., 1996).

Vaidya *et al*. (1997) reported thatthe larval mortality of *H. armigera* up to 50-66 percent after 48 hrs and 83 percent at 72 hrs of treatment at 0.05 percent and 0.1 percent concentration of *Bacillus thuringiensis* subsp. *aizawai*.

Reddy and Divakar (1997) reported 90 per cent kill of *H. armigera*in tomato with Delfin treatment.

Chapter-III

MATERIAL AND METHOD

The thesis entitled "**Population dynamics and eco–friendly management of tomato fruit borer (*Helicoverpa armigera* Hub.)"** on tomato were carried at Student's Instructional Farm,Acharya Narendra Deva University of Agriculture & Technology Kumarganj, Ayodhya,(U.P.) and nearby farmers field during *Rabi*,2019-2020 . The details of materials used, experimental procedures followed and techniques adopted have described below.

3.1 Topography and climatic condition

The experimental site lies between 26.47̊ N latitude, 82.12̊ E longitude and 113 m above from the sea level in the sub-tropical belt of the country with alkaline to normal soil. Mostly the rainfall is confined from July to September months. The weekly meteorological data obtained from the Department of Agro-meteorology of the University (Table 3.1).

Table 3.1: Weekly meteorological data during cropping period

Standard Week	**Rainfall (mm)**	**Temperature (^oC)**		**RH (%)**	
		Min.	**Max.**	**Min.**	**Max.**
47	0	12.5	27.2	59.1	91.8
48	0	14.2	26.8	61.5	93.5
49	0	9.7	24.9	47.2	94.2
50	2.2	11.2	23.9	57.1	91.7
51	0	8.5	17.6	73.8	91.7
52	0	5.3	14	79.7	89.8
1	7.8	9.1	19.3	62.7	88.7
2	6.6	8.2	16.5	77.4	93.4
3	21	10.2	18.6	76.8	95.4
4	0	6.4	20.5	76.2	90.2
5	0	7.3	21.8	57.1	91.4
6	0	6.2	22.5	48.5	92.2

7	0	8.8	22.8	49.2	85.5
8	5.3	12.4	25.4	61.8	91.3
9	0	14.0	26.8	52.4	92.8
10	6.8	13.9	26.2	59.1	88.8
11	9	14.7	26.8	57.4	87.2

3.2 Plan of experiments

A field experiments were conducted at Students Instructional Farm, A.N.D.U.A. &T., Kumarganj, Ayodhya, during *Rabi* 2019-2020. To evaluate planting combination of tomato (Narendra-6) intercropped with marigold in a Randomized Block Design (RBD) with three replications. Twenty day old tomato Narendra-6 variety taken and 40 day old marigold (Pusa Basanti Gainda) was taken Main Experimental Station, Horticulture farm. For tomato row to row spacing 60 cm. and plant to plant distance 45 cm. whereas, marigold seedling were planted 25 cm. apart. During the present studies, three row of tomato with one row of marigold.

3.2.1 Field preparation and transplantation of seedlings

The experimental plots were prepared by one deep ploughing with mould board plough followed by two cross harrowing. The whole fields were cleaned by removing weeds and plant debris manually. Entire field was marked with rope to have sowing in rows at 60 cm spacing between row to rows and 45 cm between plant to plant. Field was divided in 3 blocks, 27 plots and a big plot for incidence by providing channels for irrigation and drainage.

3.2.2 Fertilizers application

At the time of field preparation 1.5 ton F.Y.M. are mix in soil. At sowing time the recommended dose of fertilizers like nitrogen @ 75 Kg/ha in the form of urea, phosphorous @ 100 Kg/ha in the form of single super phosphate and potassium @ 50 Kg/ha in the form of murate of potash, half dose of nitrogenous fertilizer and full dose of phosphorus and potash were applied in soil as basal application. The remaining half quantity of N is top dressed four weeks after transplanting.

3.2.3 Crop Management

To remove all the weeds from plots one hand weeding was given. For irrigations purpose; first to four given by hazara. After established the plant irrigation done at 30 days after transplanting and second at 60 days after sowing were given. Weeding and hoeing were done after irrigation with the help of hand hoe as an inter-culture operation.

3.3 To work out the incidence of tomato fruit borer

3.3.1 Population dynamics of tomato fruit borer

The experiment was laid out in RBD with thrice replication with growing a variety, Narendra-6 during *Rabi* 2019-20. The recommended agronomic practices were followed to raise the crop. Bulk plot of 40×3 m^2 with three replication of tomato variety Narendra-6 was raised and maintained without any insecticidal application to study the seasonal incidence of *H. armigera* in relation to abiotic factors viz., maximum and minimum temperatures, morning and evening relative humidity and rainfall. The bulk plot area was divided into ridges and furrows with 60 × 45 cm spacing. The crop was transplanted on 20/11/2019 and all the recommended package of agronomic practices viz. fertilizer application, irrigation, inter-cultivation and disease management were followed.

3.3.2 Observations on seasonal incidence of tomato fruit borer, *H. armigera*

The incidence of the tomato fruit borer was recorded at weekly interval on 5 randomly selected plants from each plot. From initiation stage and continued till the crop maturity. The observations were taken by counting the number of larvae per plant.

3.3.3 Record of weather variables

The data on weather variables such as temperature, relative humidity and rainfall of the crop season *Rabi* 2019-20 were obtained from department of Agro-meteorology of the University to correlate the incidence of insect with abiotic factors.

3.4 Correlation between *H. armigera* population with weather variables

The data recorded on the incidence of insects were statistically analyzed in order to determine the correlation coefficients between *H. armigera* population with weather variables.

3.4.1 Correlation studies

The correlation between population *H. armigera* and abiotic factors *i.e.* minimum temperature, maximum temperature, relative humidity and rainfall were worked out by using following formula:

$$r = \frac{Edn.dy}{\sqrt[N]{\frac{\sum d^2\ xi}{N} \times \frac{\sum d^2\ y}{N}}}$$

Where,

r= Correlation coefficient

y=Population

xi=Weather parameter

n=Number of observations

∑=Summation

3.5 Biology of *H. armigera*

The investigations on the biology of *Helicoverpa armigera* was carried at laboratory of the Department of Entomology, Acharya Narendra Deva University of Agricultural & Technology Kumarganj, Ayodhya during 2019-20. Full-grown caterpillars of *H. armigera* were collected from tomato crop grown in the Student Instructional Farm. These larvae were reared separately in clean *H. armigera* rearing trays in the laboratory at room temperature during January to March. Fresh leaves of tomato plants were kept in the jars to serve as food for the larvae, fresh food was provided daily in the jars about 5 cm thick layer of dry soil was provided at the bottom of the rearing jars to help the grown up larvae to pupate The pupae were transferred into jars for the emergence of adults. Only one pupa was kept in each rearing jars. The newly emerged moths were released in pairs in rearing jars of one litre capacity. The female moth was slightly bigger than male moth and possessed the tuft of hair on tip of abdomen (Bhatt and Patel 2001). Cotton swabs soaked in 10 percent sucrose solution were provided to serve as food for the adults. The eggs laid by each female on the leaves, walls of the rearing jar and on the muslin cloth were removed daily with the help of moist camel hair brush. Count the number of eggs and transferred in petri- plates for studying the incubation period and rest of the twenty specimens were observed to study the other parameters like incubation period, number of larval instar, duration of the larval instar, total larval period, pre-pupal period, pupal duration, longevity of male and female.

3.5.1 Incubation Period

Eggs were observed at 12 hours interval to determine the incubation period (days). The change in colour from yellowish white to light grey (black lead) was taken as a mark for egg hatching.

3.5.2 Number of larval instars

To ascertain the number of instars, observations on moulting were recorded daily The size of the head capsules of 1^{st} and 2nd instar were collected by detecting it with the help of handlens (20x) while in later instars it was visible with naked eye.

3.5.3 Duration of larval instars and total larval period

To record the duration of each larval instars and total larval period, observations were taken after each 12 hours.

3.5.4 Pre-pupal period

The sixth instar larvae in the later part of its life became sluggish, suspended feeding and stopped movements and then got reduced in size before the initiation of pupal formation. The time interval between inactivation and pupal formation was recorded as pre-pupal period. The observations were recorded after each 12 hours.

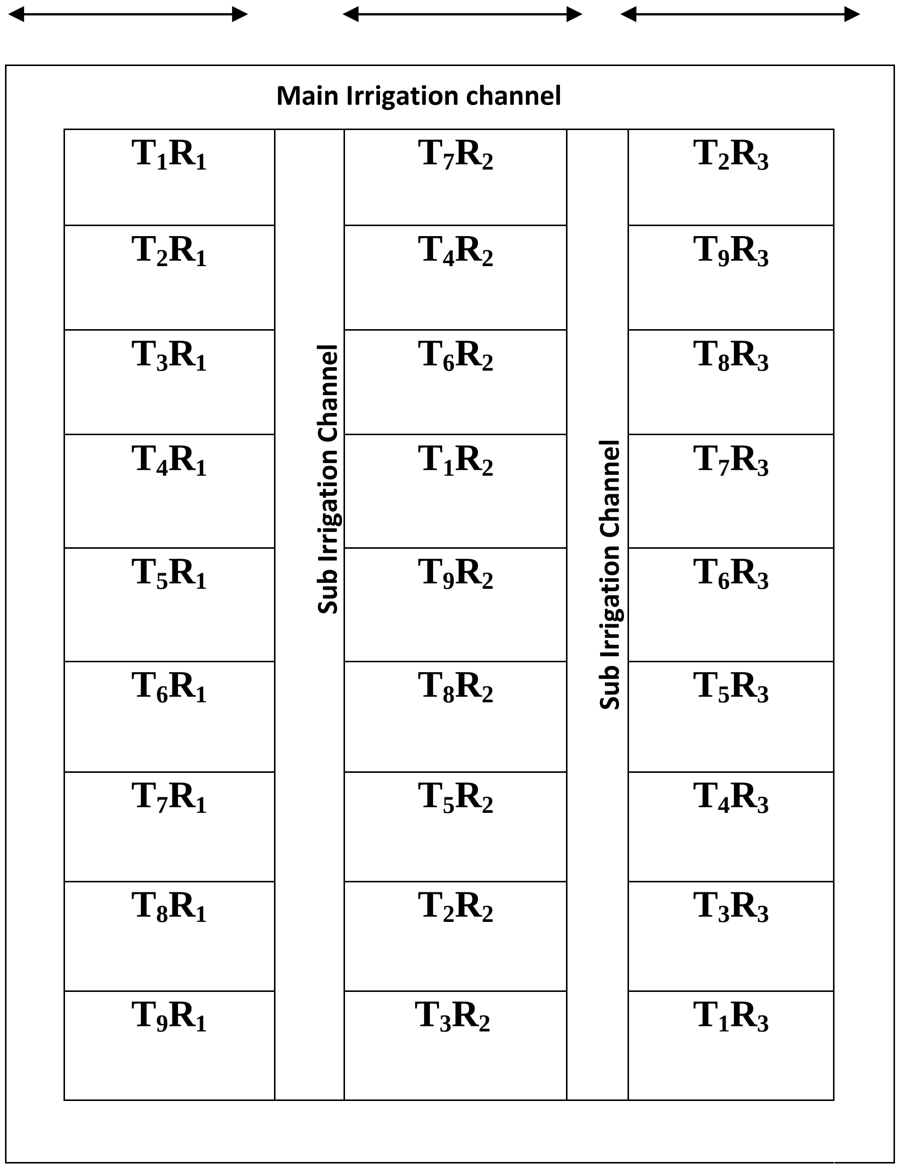
3.5.5 Pupal period

The duration between pupation and emergence of the adults was recordedas the pupal period.

3.5.6 Adult longevity and total life period

The total duration (days) of adult male and female from emergence till death and total life period of *H. armigera* from egg to the mortality of adult male and female was recorded. The individuals were the same on which the earlier parameters were recorded.

3:1 Layout plan of experiment



Details of experiment

Design	-	RBD
Plot size	-	4 x 3 m
Spacing	-	60 x 45 cm
Replications	-	3
Treatments	-	9 (8+ control)
Variety	-	Narendra 6

3.6 Management of *H. armigera* with IPM techniques

Table 3.2: Treatments for testing effectiveness against tomato fruit borer under field conditions.

Tr. No.	Insecticide name	Rate /Dose	Source
T^1	Pheromone trap (Helilure) + Inter cropping (marigold)	10 trap/ha.	PCI
T^2	Ha-NPV+ Inter cropping (marigold)	300 LE	Entomology Dept.
T^3	*Trichogramma chilonis* + Inter cropping(marigold)	1,25,000 eggs/ha	Entomology Dept.
T^4	*Bacillus thruringensis* + Inter cropping(marigold)	2g /lit.	CIMAP(Lucknow)
T^5	Neem oil + Inter cropping(marigold)	5%	Self- made
T^6	Neem Seed Kernel Extract (NSKE) + Inter cropping (marigold)	5%	Self- made
T^7	Neem Leaf Extract (NLE) + Inter cropping(marigold)	5%	Self –made
T^8	Karanj Seed Extract + Inter cropping(marigold)	5%	Self –made
T^9	Control + Inter cropping (marigold)	--	--

Larval population of tomato fruit borer was recorded at weekly interval on 5 randomly selected plants to record the larval population of *H. armigera.* The treatments were applied when infestation reached above ETL (1.0 larvae/ plant).

3.6.1 Yield

The yield of healthy fruits of each plot (kg./plot) was recorded at each picking and converted into q/ha.

3.6.2 Cost-benefit ratio

The economics of each treatment was worked out on the basis of expenditure incurred on fruit borer management and value of additional yield over control by using the following formula

$$\textbf{Cost} - \textbf{benefit ratio} = \frac{\textbf{Net monetry return of additional cost (Rs./ha)}}{\textbf{Cost of treatment (Rs./ha)}}$$

Chapter-IV

EXPERIMENTAL FINDINGS

The present investigations entitled "**Population dynamics of fruit borer (*Helicoverpa armigera* Hub.) in tomato and management through Integrated Pest Management (IPM)**" were carried out at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during *Rabi*, 2019-20. The results obtained from different studies have been presented here under different sections as follows.

4.1 Population dynamics of tomato fruit borer (*Helicoverpa armigera* Hub.)

The weekly observation of ***H***. *armigera* on tomato starting from germination to harvest. The incidence of insect was fluctuating under varying weather conditions. The data of population recorded tomato during experimental period were analyzed statistically as under condition.

The occurrence of fruit borer was started from 2nd standard week (Second week of January, 2020) to 11th standard week (Second week of March, 2020) with varying population ranging from 0.12 to 0.89 larvae. The peak period of occurrence of this insect was observed in 6th standard week (Second week of February, 2020). he maximum population of this insect was recorded as 2.65 larvae /plant. The maximum infestation of fruit borer larvae was recorded at minimum temperature 6.2°C, maximum temperature of 22.5°C, minimum relative humidity 48.5, maximum relative humidity 92.2 per cent and rainfall 0 mm.The minimum 0.12 larvae per plant population was recorded at 2nd standard week with minimum temperature 8.2°C, maximum temperature of 16.5°C, maximum relative humidity of 93.4 and minimum relative humidity 77.4 per cent and rainfall 6.6 mm.

Table 4.1: Occurrence of fruit borer on tomato along with weather parameters during *Rabi*, 2019-20

Standard Week	No. of larvae/plant	Rainfall (mm)	Temperature (^{o}C)		RH (%)	
			Min.	Max.	Min.	Max.
47	0.00	0	12.5	27.2	59.1	91.8
48	0.00	0	14.2	26.8	61.5	93.5
49	0.00	0	9.7	24.9	47.2	94.2
50	0.00	2.2	11.2	23.9	57.1	91.7
51	0.00	0	8.5	17.6	73.8	91.7
52	0.00	0	5.3	14	79.7	89.8

1	0.00	7.8	9.1	19.3	62.7	88.7
2	0.12	6.6	8.2	16.5	77.4	93.4
3	0.68	21	10.2	18.6	76.8	95.4
4	1.16	0	6.4	20.5	76.2	90.2
5	1.73	0	7.3	21.8	57.1	91.4
6	2.65	0	6.2	22.5	48.5	92.2
7	2.43	0	8.8	22.8	49.2	85.5
8	2.11	5.3	12.4	25.4	61.8	91.3
9	1.58	0	14.0	26.8	52.4	92.8
10	1.43	6.8	13.9	26.2	59.1	88.8
11	0.89	9	14.7	26.8	57.4	87.2

4.2 Effect of abiotic factor on population buildup of fruit borer on tomato.

The occurrence of fruit borer larvae was correlated with abiotic factors by determining correlation coefficients. The fluctuating trend in incidence of *H.armigera* population was found mainly due to change in weather conditions.

The correlation coefficient with rainfall (r = -0.12) negatively non significant, positively significant with maximum temperature (r = 0.38), negatively non significant with minimum temperature (r = -0.17), negatively non significant with maximum relative humidity (r = -0.34) and negatively significant with minimum relative humidity (r = -0.48) given in Table 4.2

Table 4.2: Relationship of abiotic factors with population buildup of fruit borer on tomato during *Rabi* 2019-20

Correlation (r)	**Rainfall (mm)**	**Temperature (℃)**		**Relative humidity (%)**	
		Min.	**Max.**	**Min.**	**Max.**
	-0.12	-0.17	0.38*	-0.48*	-0.34

***Correlation is significant at the 0.05 level**

4.3 Biology of fruit borer (*Helicoverpa armigera* Hub.)

The investigation on the biological parameters of *H. armigera* was studied under laboratory conditions during January to March, 2019-2020 in the Post Graduate Research laboratory, Department of Entomology, A.N.D.U.A. &T. Kumarganj, Ayodhya. The average temperature during the study was 27.2°C with relative humidity of 75± 5 per cent. The results obtained are presented under following heads-

4.3.1 Incubation period

The freshly laid eggs were hemispherical, shiny and greenish yellow in colour which changed to deep yellow after a day and then changed to dark or grey black a day before hatching In due course of time a depression occurred on the upper portion of egg which became apparent with the advancement of time. The emergence cf larva from egg shell took place through a fire hole made by emerging larva. After emergence eggshell became transparent. Further, the data Revealed that incubation period and find 3-4 days (mean 3.50±0.52 days).

4.3.2 Larval period

4.3.2.1 Fisrt larval instar

Freshly emerged first instar larva was smaller (1.42 mm) in size and cream coloured with yellowish orange longitudinal lines on the dorsal surface of the body with brown to black head. The legs and thorax were of brown coloured. The duration of this instar lasted for 2-3 days (mean of 2.5±0.52 days).

4.3.2.2 Second larval instar

The second instar larva was yellowish brown in colour. The head capsule was prominent and dark. The duration of this instar lasted for 2-3 days (mean of 2.6 ±0.51 days). The body length of this instar was 3.38 mm.

4.3.2.3 Third larval instar

The body colour of third instar was yellowish white with many black spots from anterior to posterior end Head capsule was dark and proportionate to the body: The third instar larvae is 9.46 mm in length and the duration of this instar ranged from 3-4 days (mean of 3.60±0.51).

4.3.2.4 Fourth larval instar

The fourth instar larva was yellowish brown or reddish brown in colour with lateral stripes yellowish white but dorsal stripes were black This instar measuring (178 mm) lasted for 4-5 days (mean 4.40±0.52 days).

4.3.2.5 Fifth larval instar

The fifth instar measuring 293 mm is yellowish brown to reddish brown in colour (Plate-3) with broker Lateral stripes having black colour. Head, thoracic shield and legs were reddish brown. This instar lasted for 4-5 days (mean 4.70 ±0.48 days).

4.3.2.6 Sixth larval instar

The full-grown larva of the sixth instar (32.2 mm in size) was brownish with brown lateral stripes and distinct dorsal stripe It was long and ventrally flattened but convex dorsally. The duration of the last instar ranged from 4-5 days (mean of 4.20 ± 0.42 days). So the larva passed through six instars. The total larval period lasted for 23-25 day with mean 9.50 ±1.79 day.

Table 4.3 Biology of *Helicoverpa armigera* on natural diet (tomato) under lab condition

Biological parameters		**Range**	**Av ± S.D.**
Incubation period (days)		3 – 4	3.50 ± 0.52
Larval period (days)	**First**	2 – 3	2.50 ± 0.52
	Second	2 – 3	2.60 ± 0.51
	Third	3 – 4	3.60 ± 0.51
	Fourth	4 – 5	4.40 ± 0.52
	Fifth	4–5	4.70 ± 0.48
	Sixth	4–5	4.20 ± 0.42
	Total larval period	23 – 25	9.50 ± 1.79
Pre-pupal period (days)		1 – 3	2.10 ± 0.73
Pupal period (days)		13 – 15	13.80 ± 0.91
Adult period (days)		8 – 10	8.90 ± 0.87
Total Life cycle (days)		40 - 47	-

4.3.3 Pre-pupal period

The sixth instar larva in the later part of its life became sluggish, suspended feeding and stopped movements and then got reduced in size before the initiation of pupal formation. The time interval between inactivation and pupal formation was recorded as pre-pupal period. The range of pre-pupal period was 1-3 days and mean (2.10±0.73).

4.3.4 Pupal period

Freshly formed pupa was light green yellowish in colour but later on turned into dark brown prior to emergence of moth. The mean duration of this stage was 13.80 ±0 .91 days and ranged from 13-15 days.

4.3.5 Adult Longevity

The duration from the date of emergence to death of adults was considered as the adult longevity. The results presented in Table 4.4 indicated that the adults lived for 8 to 10 days with an average of 8.90 ± 0.87 days.

4.3.6 Total development period

The duration of total life cycle was considered as the period between the dates of egg laying to the dates of death of adults. Data presented in Table 4.4 revealed that the entire life span of *H. armigera* on tomato under laboratory conditions varied from 40 to 47 days.

4.4 Management of tomato fruit borer through Integrated Pest Management with inter-cropping

The field tests were carried out for crop season *(Rabi* 2019-20) to find out the effectiveness of treatments against tomato fruit borer. Total Nine treatments viz**.,** Pheromone trap @ 10 trap/ha, H-NPV @ 300LE, *Trichogramma chilonis* @ 150000 eggs/ha, *Bacillus thuringensis var. kurustaki* @ 2g/lit, 5 per cent Neem oil, 5 per cent NSKE, 5 per cent Neem leaf extract, 5 per cent Karanj seed extract, and control (water spray) were tested against tomato fruit borer. For application of treatments, the incidence of tomato fruit borer was regularly monitored to see the tomato fruit borer reaching at ETL (1 larva / plant). The population of tomato fruit borer was recorded one day before spray at 1, 3, 7 and 14 days after spray.

4.4.1 First spray

Based on the population of tomato fruit borer recorded at 1 day after spray, it was found that the treatments differed significantly from each other. The significantly lower population (1.17 larvae/plant) was recorded in H-NPV @300LE with highest reduction which differed significantly from the remaining 8 treatments at 1 day after spray. Based on these observations, H-NPV @ 300LE was found as a most effective insecticide against tomato fruit borer at 1 day after spray during *Rabi*, 2019-20.

The effectiveness of the treatments was further compared at 3 days after spray and it was found that all the treatments were superior over control in controlling tomato fruit borer. Significantly lowest population (0.83 larvae /plant) of tomato fruit borer was observed in H-NPV @ 300LE with reduction as compared with other treatments. All botanical and biological treatments are found significantly more effective to decrease the population of tomato fruit borer from 3 days after spray in compression to control during *Rabi* season 2019-20.

The effectiveness of the treatments was further compared at 7 days after spray and it was found that all the treatments were superior over control in controlling tomato fruit borer. Significantly lowest population (0.53 larvae /plant) of tomato fruit borer was observed in H-NPV @ 300LE with reduction as compared with other treatments. All botanical and biological treatments are found significantly more effective to decrease the population of tomato fruit borer from 7 days after spray in compression to control during *Rabi* season 2019-20.

The population of tomato fruit borer was further recorded at 14 days after spray, which showed almost similar trend in the effectiveness of treatments against tomato fruit borer with some differences as Pheromone trap @ 10 trap/ha, H-NPV @ 300LE, *Trichogramma chilonis* @ 150000 eggs/ha, *Bacillus thuringensis var kurustaki* @ 2g/lit, 5 per cent Neem oil, 5 per cent NSKE, 5 per cent Neem leaf extrcact, 5 per cent Karanj seed extract and differed significantly from all the treatments at 14 days after spray during crop season of 2019-20. Based on post treatment observations at 1, 3, 7, and 14 days after spray, it was found that both botanical as well as biological insecticides were effective against tomato fruit borer. However, biological insecticides were more effective than botanicals insecticides.

Table 4.4 : Efficacy of different treatments against larval population of tomato fruit borer (*H. armigera*.) during *Rabi*, 2019-2020

	Treatments	**First spray**				
		Tomato fruit borer/plant				
		1 DBS	**1 DAS**	**3 DAS**	**7 DAS**	**14 DAS**
T_1	Pheromone trap (Helilure) + inter cropping(Marigold)	1.29 (1.34)	1.26 (1.33)	0.95 (1.21)	0.73 (1.11)	1.03 (1.24)
T_2	H-NPV + inter cropping(Marigold)	1.31 (1.35)	1.17 (1.29)	0.83 (1.15)	0.53 (1.01)	0.81 (1.14)
T_3	*Trichogramma chilonis* + inter cropping (Marigold)	1.28 (1.33)	1.21 (1.31)	0.95 (1.20)	0.78 (1.13)	1.03 (1.24)
T_4	*Bacillus thruringensis* + inter cropping (Marigold)	1.29 (1.34)	1.26 (1.33)	0.89 (1.18)	0.68 (1.09)	0.86 (1.16)
T_5	Neem Oil + inter cropping (Marigold)	1.30 (1.34)	1.27 (1.33)	0.95 (1.21)	0.78 (1.13)	0.98 (1.22)
T_6	Neem Seed Kernel Extract (NSKE) + inter cropping (Marigold)	1.32 (1.35)	1.29 (1.34)	1.05 (1.24)	0.90 (1.18)	1.08 (1.26)
T_7	Neem Leaf Extract (NLE) + inter cropping(Marigold)	1.31 (1.34)	1.28 (1.34)	1.09 (1.26)	0.96 (1.21)	1.11 (1.27)
T_8	Karanj Seed Extract+ inter cropping (Marigold)	1.33 (1.35)	1.32 (1.35)	1.12 (1.27)	1.03 (1.24)	1.17 (1.29)
T_9	Control + inter cropping (Marigold)	1.30 (1.34)	1.50 (1.41)	1.70 (1.48)	1.88 (1.54)	2.03 (1.59)
	SEm±	**0.01**	**0.07**	**0.01**	**0.02**	**0.01**
	C.D.@5%	**NS**	**0.03**	**0.02**	**0.05**	**0.02**

Figures in the parentheses are $\sqrt{x+0.5}$ transformed values. DBS = Day before spray, DAS = Day after spray

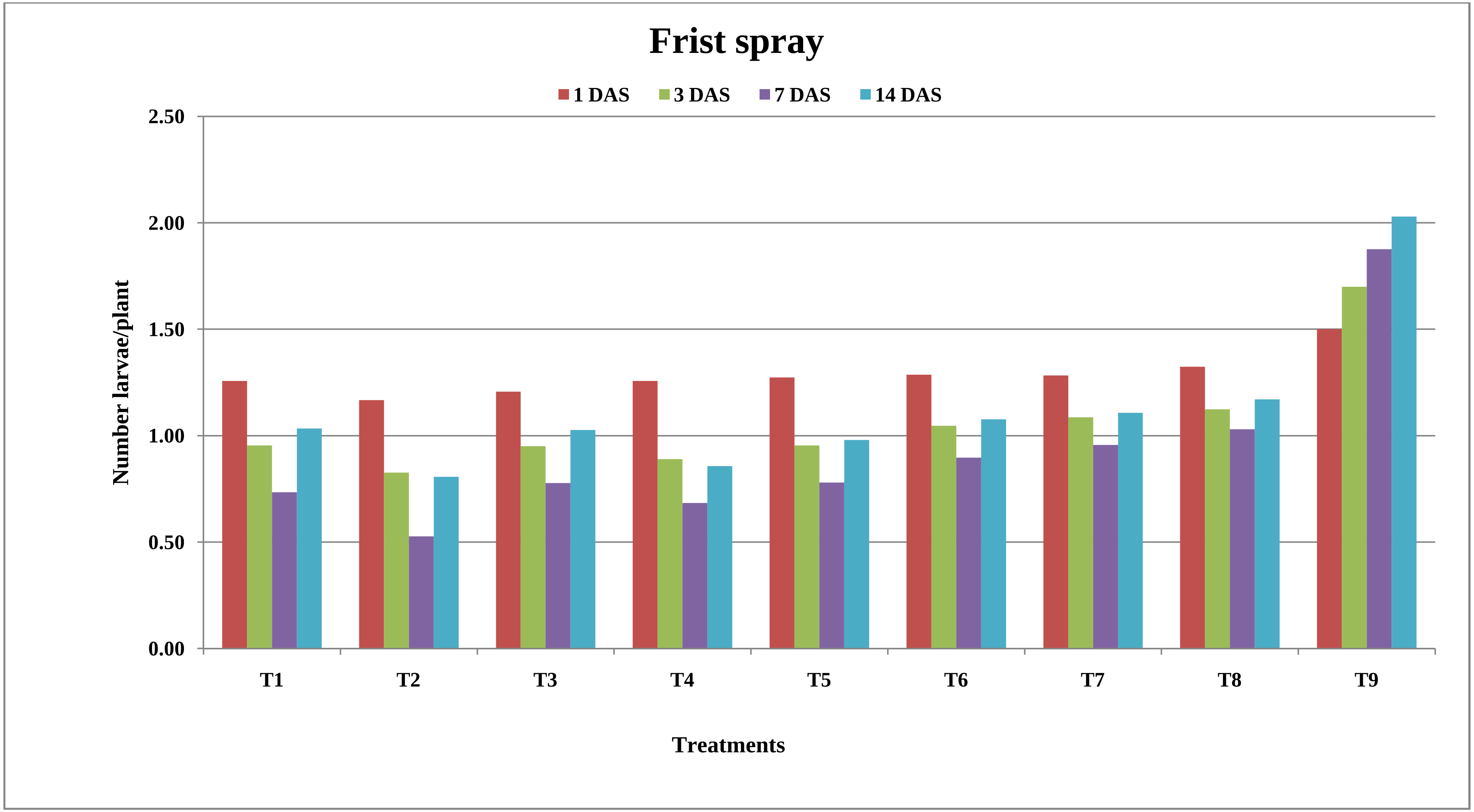


Fig 4.1: Efficacy of different treatments against larval population of fruit borer (*H. armigera*) during *Rabi*, 2019-2020

4.4.2 Second spray

Based on the population of fruit borer recorded at 1 days after spray, it was found that the treatments differed significantly from each other. The significantly lower population (1.04 larvae/plant) was recorded in H-NPV @ 300 LE/Ha. with highest reduction which differed significantly from the remaining 8 treatments at 1 days after spray. Based on these observations, H-NPV @ 300 LE/ha was found as a most effective insecticide against fruit borer. Among 4 botanical tested, 5 per cent Neem oil, 5 per cent NSKE, and 5 per cent Neem leaf Extract, found comparatively more effective than 5 per cent Karanj seed extract in controlling fruit borer at 1 days after spray during *Rabi*, 2019-20.

The effectiveness of the treatments were further compared at 3 days after spray and it was found that all the treatments were superior over control in controlling fruit borer. Significantly lowest population (0.77 larvae /plant) of fruit borer was observed in H-NPV @ 300 LE/Ha. with reduction as compared with other treatments. All botanicals and biologicals treatments are found significantly more effective to decrease the population of fruit borer from 3 days after spray in compression to control during *Rabi* season 2019-20.

The effectiveness of the treatments were further compared at 7 days after spray and it was found that all the treatments were superior over control in controlling fruit borer. Significantly lowest population (0.29 larvae /plant) of fruit borer was observed in H-NPV @ 300 LE/Ha. with reduction as compared with other treatments. All botanicals and biologicals treatments are found significantly more effective to decrease the population of fruit borer from 7 days after spray in compression to control during *Rabi* season 2019-20.

The population of fruit borer was further recorded at 14 days after spray, which showed almost similar trend in the effectiveness of treatments against fruit borer with some differences as Pheromone trap @ 10 trap/ha, H-NPV @ 300LE, *Trichogramma chilonis* @ 150000 eggs/ha, *Bacillus thuringensis var kurustaki* @ 2g/lit, 5 per cent Neem oil, 5 per cent NSKE, 5 per cent Neem leaf extrct, 5 per cent Karanj seed extract and differed significantly from all the treatments at 14 days after spray during crop season of 2019-20. Based on post treatment observations at 1, 3, 7, and 14 days after spray, it was found that both botanical as well as biological insecticides were effective against fruit borer. However, biological insecticides were more effective than botanical insecticides.

Table 4.5: Efficacy of different treatments against larval population of tomato fruit borer (*H. armigera*.) during Rabi, 2019-2020

	Treatments	**Second Spray**				
		Tomato fruit borer/plant				
		1 DBS	**1 DAS**	**3 DAS**	**7 DAS**	**14 DAS**
T_1	**Pheromone trap (Helilure) + inter cropping(Marigold)**	1.17 (1.29)	1.05 (1.25)	0.90 (1.60)	0.33 (0.91)	0.40 (0.95)
T_2	**H-NPV + inter cropping(Marigold)**	1.24 (1.33)	1.12 (1.27)	0.77 (1.13)	0.29 (0.89)	0.37 (0.93)
T_3	***Trichogramma chilonis* + inter cropping(Marigold)**	1.15 (1.32)	1.13 (1.28)	1.03 (1.24)	0.77 (1.13)	0.83 (1.15)
T_4	***Bacillus thruringensis* + inter cropping(Marigold)**	1.26 (1.33)	1.27 (1.33)	0.97 (1.21)	0.45 (0.97)	0.54 (1.02)
T_5	**Neem Oil + inter cropping(Marigold)**	1.23 (1.32)	1.36 (1.37)	1.06 (1.25)	0.80 (1.14)	0.87 (1.17)
T_6	**NSKE + inter cropping(Marigold)**	1.21 (1.32)	1.15 (1.28)	0.96 (1.21)	0.76 (1.12)	0.82 (1.15)
T7	**Neem leaf extract+ Inter cropping(Marigold)**	1.15 (1.30)	1.11 (1.27)	0.97 (1.21)	0.81 (1.15)	0.87 (1.17)
T8	**Karanj seed extract + Inter cropping(Marigold)**	1.20 (1.32)	1.16 (1.29)	1.03 (1.24)	0.87 (1.17)	0.92 (1.19)
T9	**Control + Inter cropping(Marigold)**	1.35 (1.35)	2.27 (1.66)	2.22 (1.65)	2.17 (1.63)	1.45 (1.40)
	SEm±	**0.14**	**0.01**	**0.01**	**0.02**	**0.02**
	C.D.@5%	**NS**	**0.02**	**0.03**	**0.05**	**0.02**

Figures in the parentheses are $\sqrt{x+0.5}$ **transformed values, DBS = Day before spray, DAS = Day after spray**

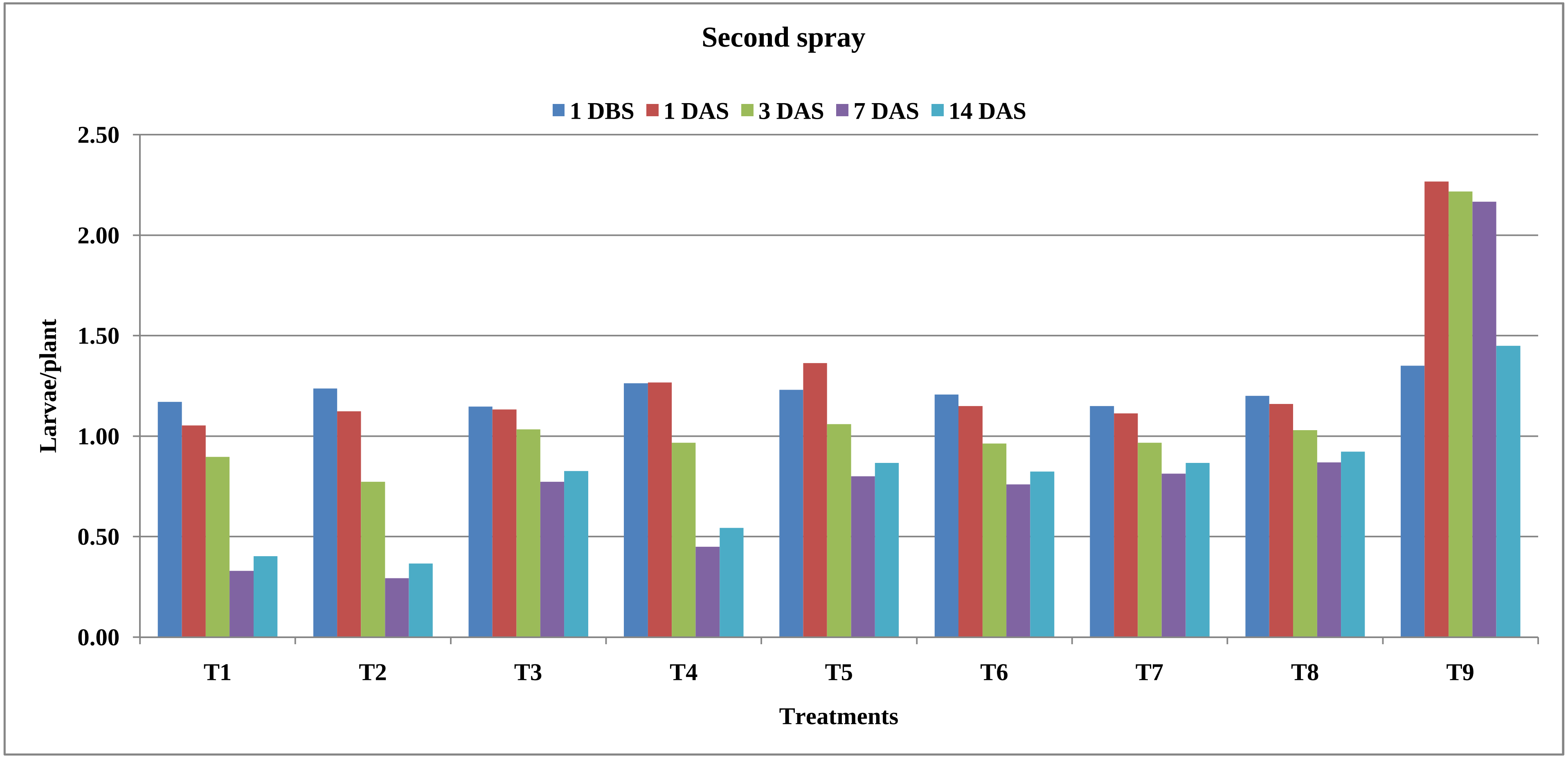


Fig 4.2: Efficacy of different treatments against larval population of tomato fruit borer (*H. armigera*) during *Rabi* 2019-20

4.5 Effect of treatments on yield

All the treatments gave significantly higher yield range 197.43-173.65 q/ha over control 171.34 q/ha. The effect of treatment on yield was found higher yield 197.43q/ha in H-NPV@ 300LE. As compare to other tested treatments. The result showed that all treatments had better yield in compression to control.

Table 4.6: Effect of different treatments on yield of tomato var. Narendra-6 during *Rabi* 2019-20

Tr. No.	**Treatments**	**Dose**	**Yield (q/ha)**
T_1	Pheromone trap (Helilure) + inter cropping (Marigold)	10 trap/ha	182.52
T_2	H-NPV + inter cropping (Marigold)	300 LE	197.43
T_3	*Trichogramma chilonis* + inter cropping(Marigold)	150000 eggs/ha	189.12
T_4	*Bacillus thruringensis* + inter cropping(Marigold)	2 g/lit	192.93
T_5	Neem Oil + inter cropping(Marigold)	5%	192.39
T_6	Neem Seed Kernel Extract (NSKE) + inter cropping(Marigold)	5%	191.70
T_7	Neem Leaf Extract (NLE) + inter cropping(Marigold)	5%	189.63
T_8	Karanj Seed Extract+ inter cropping(Marigold)	5%	173.65
T_9	Untreated (Control) + inter cropping(Marigold)		171.34
S.Em.±		-	8.99
CD at 5%		-	26.97

Chapter-V

DISCUSSION

An attempt was made to record the seasonal occurrence of fruit borer and to observe efficacy of different treatments against fruit borer (*Helicoverpa armigera* Hub**.**) in tomato (Narendra 6) crop during *Rabi* 2019-20. The findings of experiments have been discussed in the light of available literature in the following sections.

5.1 Seasonal occurrence of fruit borerof tomato

The incidence of fruit borer recorded on periodic basis during crop season, revealed that the insect appeared at early stage (2nd standard week to 11th standard week) of crop growth. During *Rabi* 2019-20, the initial population of this insect (0.12 larvae/plant) was recorded in 2nd standard week (2nd week of January, 2019). This was increased to the level of 2.65 larvae/plant in 6th standard week (2nd week of February, 2020). The above findings were in confirmation with Chavan *et al*. (2016).

5.2 Correlation coefficient between abiotic factors and occurrence of fruit borer

The correlation coefficient determined between the occurrence of fruit borer and abiotic factorrevealed both positive and negative correlations.

Based on the correlation coefficients of fruit borer with abiotic parameters, the incidence of fruit borer was correlated at non significant level with minimum temperature; rainfall and maximum relative humidity.The above findings were similar with Kumar *et al*. (2018).

5.3 Biology of tomato fruit borer, *H. armigera*

5.3.1 Incubation period

The mean incubation period was 3.50 ± 0.52 days which ranged from 3-4 days at room temperature. These results are in conformity with the findings of Singh and Singh 1975). However, Verma and Kakar (1996) Chaudhary and Sharma (1981) and Multani *et al.* (2000) reported variations in the incubation period.

These work also reported by Kumar and Mishra (2012) reported that the incubation period varied from 4-5 days. Liu *et al*. (2004) reported that the incubation period of *H.*

armigera on tomato was 3 days. Baikar and Naik (2016) reported that the incubation period was observed to be 3.2±0.79 days.

5.3.2 Larval period

In the present investigations, the average larval duration was 9.50±1.79 days and ranged from 23-25 days. These findings are in conformity with Saraf and Makhija (2015) who reported larval period was 17-24 days. Baikar and Naik (2016) reported that the larval development was completed within 21.8±0.79 days.

5.3.3 Pre-pupal period

The mean duration of this stage was 2.10±0.73 days and ranged from 1-3 days.Baikar and Naik (2016) reported that the mean pre-pupal period lasted for 2.2±0.45 days.

5.3.4 Pupal period

The mean duration of this stage 13.80±0.91and ranged from 13-15 days. However Saraf and Makhija (2015) who reported that the pupal period ranged from 14-17 days.

5.3.5 Total life span

The longevity of adult male was ranged from 6-8 days while 8-10 for female adult. The total life spanwas 19.10 ± 2.95 days and ranged from 40-47 days.

5.4.1 Effectiveness of treatments against fruit borer

H. armigera is one of the most destructive pest, causes huge yield losses by bore into tomato fruits. The yield losses range from 5 to 80 percent across the country (Singh and Chahal, 1978; Kakar *et al*., 1980 and Lal and Lal 1996). The concept of trap cropping fits into the ecological framework of habitat manipulation of an agro-ecosystem for the purpose of pest management. Inherent characteristics of a trap crop may include not only differential attractiveness for feeding but also other attributes that enable the trap crop plants to serve as a sink for insects or the pathogens they vector (Shelton and Badenes, 2006).

Population of tomato fruit borer (larval population) was also significantly reduced in various treatment combinations of tomato and marigold when they were compared with sole crops of tomato in the years. Consistently low larval population was recorded in 3:1 combination. These observations draw their support from the findings of Torres-Villa *et al*. (2003) who reported higher tolerance to similar larval densities at advanced growth stages. Moreover, larval population at early crop stage was surely higher because larvae had a convenient environment in terms of abundance of flowers, fresh leaves and green fruits which promoted better larval performance.

The Effectiveness of treatments was determined based on the population of fruit borer was recorded one day before spray as pre-treatment observation, while post treatment observations were taken at 1, 3, 7, and 14 days after spray. The most effective biological insecticide Ha-NPV 300LE/ha reduce the population of tomato fruit borer.

5.4.2 Effect of treatments on yield

All the treatments gave significantly higher yield (197.43-173.65 q/ha) over control (171.34 q/ha). The higher yield was found in (197.43q/ha) in Ha-NPV@ 300LE as compare to other tested treatments. The result showed that all the treatments had better yield in comparison to control. Among biological control, Ha-NPV@ 300LE gave highest yield which over other biological and botanical control.

Chapter-VI

SUMMARY AND CONCLUSION

The experiments conducted on "Population dynamics and eco-friendly management of tomato fruit borer (*Helicoverpa armigera*)" during *Rabi* 2019-2020.The data obtained from experiments was compiled and analysed statistically. The summary and conclusion of the present experiments are presented below.

The weekly observation was recorded of *H. armigera* on tomato starting from germination to harvest. The incidenceof fruit borerpopulation was fluctuating under varying weather conditions. Theoccurrence of fruit borerwas started from 2^{nd} SW (January, 2020) to 11^{th} standard week (March, 2020) with varying population ranging from 0.12 to 0.89 larvae per plant in different standard weeks, the maximum population of this insect was recorded as 2.65 larvae/plant during 6^{th} SW (February, 2020) .

The correlation coefficients of fruit borer with abiotic parameters, the incidence of fruit borerwas correlated at non significant level with rainfall,minimum temperature and maximum relative humidity. However, fruit borerwas correlated significantly positive with minimum relative humidityand significantly negative with maximum temperature.

Looking at the biology of fruit borer on tomato, the egg period varies from 3 to 4 days (Av. 3.5 ± 0.52 days). The larva of *H. armigera* passed through sixth different instars. The first, second, third, fourth, fifth and sixth instar larva lived for 2 to 3 days (Av. 2.5± 0.52 days), 2-3 days (Av. 2.60 ±0.51 days), 3 to 4 days (Av. 3.60 ± 0.51 days), 4 to 5 days (Av. 4.40 ± 0.52), 4-5 day (Av. 4.70± 0.48) and 4-5 days(Av. 4.20± 0.42), respectively with a total larval period of 23-25 day and average mean 9.50±1.79. The pre-pupal and pupal stage lasted for 1 -3 days (Av. 2.10 ± 0.73 days) and 13 to 15 days (Av. 11.90 ± 1.44 days), respectively. The adults lived for 8 to 10 days (Av. 8.90 ± 0.87 days) and the entire life span under laboratory conditions varied from 40 to 47 days.

The field tests were carried out for crop seasons *(Rabi* 2019-20) to find out the effectiveness of treatments comprising all the treatments against fruit borer. Nine treatments viz**.,** Pheromone trap @ 10 trap/ha, Ha-NPV @ 300LE,*Trichogrammachilonis*@ 150000 eggs/ha, *Bacillus thuringensis var. kurustaki* @ 2gram/lit, Neem oil @ 5%,NSKE @ 5%, Neem leaf extract @ 5%, Karanj seed extract 5%, and control (water spray) were tested against fruit borer. For application of treatments, the incidence offruit borerwas regularly monitored to see the moth reaching at ETL (1 larvae / plant). The population of fruit borerwas recorded one day before spray as pre-treatment observation, while post treatment observations were taken at 1,3, 7, and 14 days after spray. The population of fruit borer was observed ranging from 2.65 to 2.43 larvae/plant prior to application of treatments which were non-significant during *Rabi*2019-20. The population of fruit borerdecreased due to application of treatments with botanical and biological biocontrol agents.

The effectiveness of treatments was further determined on the basis of cumulativereduction in population of fruit borer for *Rabi* season 2019-20. Out of all treatments, Ha-NPV @ 300 LE/ha was found best for controlling the population of fruit borer. All the treatments gave significantly higher yield (197.43-173.65 q/ha) over control (171.34 q/ha). The result showed that all the treatments had better yield than control.

Conclusion

- The maximum population of this insect was recorded as 2.65 larvae/plant during 6^{th}SW (February, 2020).
- Population of *H. armigera* exhibited non -significant correlation with rainfall, minimum temperature and maximum relative humidity. However, population of fruit borershowed significantly positive correlation with minimum relative humidity while significantly negative with maximum temperature.
- The entire life span under laboratory conditions varied from 40 to 47 day and average mean 19.10±2.95.
- Out of all treatments, Ha-NPV@ 300LE/ha was found best for reduction of population of fruit borer at 1, 3,7, and 14 days.
- The effect of treatment on yield was found higher (197.43q/ha)in*Ha*-NPV@ 300LE/ha. As compared to other tested treatments. The result showed that all the treatments had better yield in control.

Chapter-VII

BIBILIOGRAPHY

Baikar, A. A. and Naik, K. V. (2016). Biology of fruit borer, *Helicoverpa armiger* (Hubner) on chilli under laboratory conditions. *Plant Archives*. **16**(2):761-769.

Bala, S. C. and Sarkar, A. (2017). Population abundance and eco-friendaly management of tomato fruit borer, *H. armigrera* Hb. On tomato under west Bengal conditions. *Journal of Entomological Research*.**41**(1) :39-43.

Bhadauria, N. K. S. and Bhadauria, N. S. (1998). Seasonal population fluctuation of gram pod borer, Heliothis armigera. *Advances in Plant Science*. **11** (2): 283-285.

Bhati, R., Singh, R., Singh, G. and Singh, D. V. (2017). Effect of abiotic and biotic factors on population of tomato fruit borer (*Helicoverpa armigera*) on tomato *Journal of Pharmacognosy and Phytochemistry* . SP1: 485-489.

Bisht, R. S., (2014). Seasonal incidence of *Helicoverpa armigera* (HUB.) on tomato at Pantnagar, Uttarakhand. *International Journal of Basic and Applied Agricultural Research.* **12**(3):351-355.

Borah, S. R. and Dutta, S. K. (2002). Biology of gram pod borer, *Helicoverpa armigera* Hubner on tomato. *Journal of the Agricultural Science Society of North-East India,* **15**(1): 34-37.

Chakraborty, K., Santosh, R. and Chakravarthy, A. K. (2011). Incidence and abundance of tomato fruit borer, *Helicoverpa armigera* (Hubner) in relation to the time of cultivation in the northern parts of West Bengal, *India. Current Biotica* **,** **5**(1): 91-97.

Chatar, V. P., Raghvani, K. L., Joshi, M. D., Ghadge, S. M., Deshmukh, S. G. and Dalav, S. K. (2010). Population dynamics of pod borer, *H. armigera* (Hubner) infesting chickpea *international journal of plant protection*. **(3)**1:65-67.

Chaudhary, J. P. and Sharma, S. K. (1981). Biology of fruit borer *H.armigera* (Hubner) in the Haryana state. *Bull Ent*, 22: 110-112.

Chaudhry, N., Deb, D. C. and Senapati, S. K. (2009). Evalution commonly grown tomato variety and words of West Bengal. *Environment and Ecology*. **18** (4). 933- 939.

Chavan, S. M., Kumar, S. and Arve, S. S. (2013). Population dynamics and development of suitable pest management module against major insect pests of tomato (*Solanum lycopersicum*). *Journal of Applied Horticulture*, **15**(2): 150-155.

Chhabra, K. S. and Kooner, B. S.(1993). Assessment of *Heliothis armigera* Hubner population through pheromone trap at Ludhiana, India. *Zeitschrift-fur Angewandte-Zoologie*. 79: 3309317.

Dey, M., Das, S., Kamal, M. M, and Sarkar, R. (2017). Performance of different management practices on tomato fruit borer (*Helicoverpa armigera* Hubner) abundance and infestation. *J. Bangladesh Agril. Univ.* **14**(2): 161–166, 2016 ISSN 1810-3030.

Dhanokar, B. K. and Puri, S. N. (1993). Monitoring of cotton bollworms using sex pheromone traps in Marathwada. *J. of Cotton-Res and develop.* **7**(1),171-173.

Dilbagh Singh: Narang. D. D. and Singh, D. (1990). Control Tomato fruit borer, *Heliothis armigera* (Hubner) with synthetic pyrethroids .*Indian Journal of Entomology*. **52** (4) 534-540.

Dubey, O. P: Odak ,S. C. and Gargav, V. P. (1993). Population dynamics of gram pod borer. *JNKVV Research Journal*. **27** (1):59-63.

Duwadi, V. R., Paneru, R. B. and Chand, S. P. (1996). Monitoring of chickpea pod borer *Helicoverpa armigera* (Hubner) by using male attractant pheromone trap at, *Pakhribas Agriculture Centre,* 9p.

Fang, H. S., Nee, H. H. Chu, C. and Hwang S. H. (1990). Occurrence and chemical control of tomato fruit worm, *Helicoverpa armigera* (Lepidoptera: Noctuidae) of flue-cured tobacco. *Bulletin of Taiwan Tobacco- Research Institute, Taiwan Tobacco and Wine Monopoly Bureau.* **33,**57-64.

Ge, Shaokin, and Li, DianMo (1997). Effect of sex pheromone on behaviour of adult Heliothis and its field control. *Chinese J. pf App. Eco***. 8**(3) 291-294.

Herland, K. P. and Tayde, A. R. (2018). Biology and morphology of tomato fruit borer, *Helicoverpa armigera* (Hubner) under Allahabad conditions. *Journal of Entomology and Zoology Studies***. 6**(4): 1734-1737.

Hussain, Barkat, bilal and sheikh. (2007). Marigold as a trap crop against tomato fruit borer(Lepidoptera : Noctuidae). *International Journal of Agricultural Research*.

Izquierdo, J. T. (1996). *Heliothis armigera* Hubner (1 lepidoptera : Noctuidae) relationship between capture pheromone traps and egg. counts in tomato and carnation crops, *J. of App. Ento*. 120:5, pp. 281-290.

Kakati, M., Saikia, D. K and Nath, R. K., (2005). Seasonal history and population buildup of tomato fruit borer, *Heliothis armigera* (Hb.) (Lepidoptera Noctuidae). *Research on Crops*, **(6)** 2 :371-373.

Kharia, P. M., Kumar, R., Jat, M. K. and Chhangani, G. (2018). Population dynamics of fruit borer, *Helicoverpa armigera* and whitefly, Bemisia tabaci on tomato. *Journal of Entomology and Zoology Studies*. **6**(6): 396-399.

Kumar, V, Mahla, M. Lal, J. and Singh B. (2017). Effect of abiotic factors on the seasonal incidence of fruit borer *Helicoverpa armigera* (Hub.) on tomato with and without marigold as a trap crop. *Journal of Entomology and Zoology Studies*, **5**(2), S03-807.

Kumari Lalita, V. L. and Reddy D. D. R. (1992). Evaluation of Pheromone trap design for traping Spodoptera litura and Heliothis armigera and their Reproduction behavior. *Indian J. Pl. Protec*. 20; 21 pp. 18-23.

Kurl, S. P. Anil K and Naval, S., (2008). Study on population build-up of *Helicoverpa armigera* (Hubner) in tomato based cropping systems in Meerut District. *Journal of Farming Systems Research and Development*, **(1)** 41: 148-149.

Lal, S. S., Sachan, J. N. and Yadav, C. P. (1985). Sex pheromone trap a novel tool for monitoring gram pod borer population. *Plant Protection Bulletin*. **37**(3-4):3-5.

Mathur, N. M., Qureshi, Q. G., Gupta, H. C. and Srivastava, R. C. (1996). Field evaluation of *Bacillus thuringiensis* var. Kurstaki for the management of *Helicoverpa armigera* Hubner on tomato in Rajasthan. *Pest management and Econ. Zoo***. 4**(1-2): 51-53.

Meena, N. K Kanwat, P. M and Sharma, J. K. (2010). Seasonal incidence of leafhopper and whitefly on okra Abelmoschus esculentus (L.) Monech. *Disease Reporter*, **6** (2): 259-262.

Mushtaq, A. and Pathania, S. S. (2019). Effect of Abiotic Factors on Larval Population Build Up of Tomato Fruit Borer, *Helicoverpa armigera* Infesting Different Tomato Germplasm. *International Journal of Current Microbiology and Applied Sciences.* ISSN: 2319-7706.

Nigam, P. M. and Kumar, A. (2000). Economic and Applied Entomology (Second Edition). *Emkay publications, Delhi*. Chapter 75-152-153 pp.

Pandey, P. R.; Gurung, T. B., Ghimire, S. R. and Gurung, R. S. (1996). Monitoring and Management of tomato fruit worm (*H. armigera*). Annual report, Pokhara, Kaski (Nepal). *Lumle Agricultural Research Centre*, 18 p.

Pandey, R. R.; Gurung. T. B., G. C., Y. D. and Gurung, G. (1997). Monitoring and management of tomato fruit worm (*Helicoverpa armigera*) and its egg. parasite (*Trichogramma Ishi*) in the Western hills. Working paper at Rawalpindi, Pakistan. *Pak. J. of Zool*. 272. pp.127-131.

Parihar, S. B.S. and Singh, B. R. (1985). Incident of *Helicoverpa armigera* (Hubner) a fruit borer on tomato. *Ind. J. of Pl protect*. 13:135-136.

Patil, B.V. and Kulkarni, N.S. (1997). Monitoring of *Helicoverpa armigera* Hubner with light pheromone traps. *In.In. Pl. Protec*. 13:pp. 135-136.

Prakash, A. and Fenemore, P. G. (2000). Applied Entomology (Second Edition). *New age international (P) limited. Publishers, New Delhi* Chapter 17.210 pp.

Prasad, V. D., Rambabu, L. and Reddy, G. P. V. (1993). An action threshold for *Helicoverpa armigera* (Hubner) bases on pheromone trap catches in cotton. *Ind J. of Pl. Protec*. 21:1, pp.17-18.

Praveen, P. M. (2000). Eco-friendly management of major pests of okra *Abelmoschus esculentus* (L.) Moench) and tomato (*Lycopersicon esculentum* Mill.) Unpublished M.Sc.,(Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore, India. 116 pp.

Reddy, N. A. and Kumar, C. T. A. (2004). A study on correlation between abiotic factors and incidence of tomato fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Asgore Journal of Agricultural Sciences*, **38**(3): 417 421.

Renu, C., Keshav, M. and Veer, S., (2017). Seasonal incidence of fruit borer, *Helicoverpa armigera* (Hubner) on tomato in trans Yamuna Region of Allahabad. *Journal of Experimental Zoology*, **2** (01): 85-87.

Rijal, S. And Dahal, B. R. (2019). Integrated Management of Fruit Borer (*Helicoverpa armigera*) of Tomato in Nepal. *Acta Scientific Agriculture* (ISSN: 2581-365X).

Saini, A., Ahir, K. C. and Rana, B. S., (2017). Seasonal Incidence of Fruit Borer (*Helicoverpa armigera* Hubner) Infesting Chilli (Capsicum c om L). - *International Journal of Pure and Applied Bioscience*, **5**(2): 272-276.

Sapkal, S. D., and Gaikwad, B. B. (2018). Seasonal incidence of tomato fruit borer , *H. armigera* Hb. On tomato under protected cultivation. *Journal of Entomology and Zoology Studies*; **6**(4): 1911-1914.

Sharma, M. C. and Singh. P. P. (2000). Agriculture Entomology (First Edition). *V. K. Publications*. Chapter **13**. 316-319 pp.

Sharma, P. K., Kumar , U., Vyas, S.,Sharma, S. and Shrivastava, S.(2012). Monitoring of *H. armigera* (Hubner) Through pheromone traps in Tomato *(Lycopersicon esculentum)* crop and influence of some Abiotic factors on insect population , *journal of environmental science, toxicology and food technology* **(1*),*** 44-46.

Shekhar, P. R., Venkataiah, M. and Rao. N. V. (1995). Life table studies on *Helicoverpa armigera* Hubner in the Krishna Godavari zone of Andhra Pradesh *J. of Ins. Sci*. 8:1, pp. 27-30.

Shukla, A., Sharma, T. R. and Shukia, A. (1993). Field evaluation of tomato cultivars against fruit borer (*Helicoverpa armigera* Hub.) in Satpura Plateau region of Madhya Pradesh. *INKVV Research Journal* **27** (1), 140-142.

Singh P. S. (2006). Effect of cropping system on the incidence of *Helicoverpa armigera* Hubner on tomato. *Journal of Entomological Research*, **30**(4), 317-320.

Singh, N., Dotasara, S.K., Kherwa, B. And Singh, S. (2017). Management of tomato fruit borer by incorporating newer and biorational insecticides. *Journal of Entomology and Zoology Studies*; **5**(2): 1403-1408.

Singh, N., Gupta, N. (2017). Effect of Weather on Fruit Borer, *Helicoverpa armigera* (Hub) Activity in Tomato. *Sch J Agric Vet Sci ;* **4**(10):414-417.

Singh, V. and Gupta, N. (2017). Effect of Weather on Fruit Borer, *Helicoverpa armigera* (Hub) Activity in Tomato. *Sch. J. Agri. Vet. Sci.* **4**(10):414-417.

Sinha, S. N and Mehrotra, K.N. (1993). Factors influencing pheromone trap catches of *Helicoverpa armigera* Hubner. *Ind. In. Pl. protec*. 21: 1, 1-6.

Somnuk, W., Pompranee, P. (1995). Response of American boll worm, *Heliothis armigera* (Hubner) to pheromone trap: Kasetsart university., Bangkok (Thailand) 33, Kasetsart university annual conference. Kan prachum thang wichakan khong mahawitthayalai kasetsart khrang sakha phuket. Bangkok (Thailand). 1995. 474 p. 467 -474.

Vaishampayan, S. M. and Veda, O. P. (1980). Population dynamics of gram pod borer, *Heliothis armigera* (Hubner) and its outbreak situation in gram. *Cicer arietinum* L. at *Jabalpur Indian J. Ent*. **42** (3): 453-459.

Verma, A. K. and Sankhyan, S. (1993). Pheromone monitoring of *Heliothis armigera* (Hubner) and relationship of Moth activity with Larvae. *Lumle-Regional Agricultural Research Centre* No. 97-24, i and 14pp.

Walker, G. P. and Cameron, P. J. (1990). Pheromone trapping and field scouting for tomato fruit worm in tomatoes and sweet corn. *Proceeding of the Forty Third New Zealand Weed and Pest Control Conference.* 17-20.

DEPARTMENT OF ENTOMOLOGY
A. N. D. University of Agriculture & Technology, Kumarganj,
Ayodhya-224 229 (U.P.) India

Title: "Population dynamics and eco–friendly management of tomato fruit borer (*Helicoverpa armigera* Hub.)"

Name of student	**Major Advisor and Chairman**
Shailendra Kumar Patel	**Dr. Umesh Chandra**
A-7804/14/18	Assistant Professor(Incharge head)
M.Sc. (Ag.) Entomology	Department of Entomology

ABSTRACT

The Present investigation was carried out to investigated entitled "**Population dynamics and eco–friendly management of tomato fruit borer (*Helicoverpa armigera* Hub.)"** on tomato were carried at Student's Instructional Farm,Acharya Narendra Deva University of Agriculture & Technology Kumarganj, Ayodhya,(U.P.) and nearby farmers field during *Rabi*,2019-2020. The experiment was conducted in randomized block design (RBD) with three replications, nine treatments The tomato fruit borer (*Helicoverpa armigera* Hub.) a key pest of tomato. The incidence of fruit borer recorded on periodic basis during crop season, revealed that the insect appeared at early stage (2^{nd} standard week to 11^{th} standard week) of crop growth. The correlation coefficients of fruit borer with abiotic parameters, the incidence of fruit borer was correlated at non significant level with rainfall, minimum temperature and maximum relative humidity. However, fruit borer was correlated significantly positive with minimum relative humidity and significantly negative with maximum temperature. The biology of fruit borer on tomato, the egg period varies from 3 to 4 days (Av. 3.5 ± 0.52 days). The larva of *H. armigera* passed through sixth different instars. The first, second, third, fourth, fifth and sixth instar larva lived for 2 to 3 days (Av. 2.5± 0.52 days), 2-3 days (Av. 2.60 ±0.51 days), 3 to 4 days (Av. 3.60 ± 0.51 days), 4 to 5 days (Av. 4.40 ± 0.52), 4-5 day (Av. 4.70± 0.48) and 4-5 days(Av. 4.20± 0.42), respectively with a total larval period of 23-25 day and average mean 9.50±1.79. The pre-pupal and pupal stage lasted for 1 -3 days (Av. 2.10 ± 0.73 days) and 13 to 15 days (Av. 11.90 ± 1.44 days), respectively. The adults lived for 8 to 10 days (Av. 8.90 ± 0.87 days) and the entire life span under laboratory conditions varied from 40 to 47 days. The Effectiveness of treatments was determined based on the population of fruit borer was recorded one day before spray as pre-treatment observation, while post treatment observations were taken at 1, 3, 7, and 14 days after spray. The most effective biological insecticide Ha-NPV 300LE/ha reduce the population of tomato fruit borer.

(Shailendra Kumar Patel)	**(Umesh Chandra)**
Author	Major advisor & Chairman