

BIOLOGY AND SEASONAL INCIDENCE OF SHOOT
BORER, *CHILO INFUSCATELLUS* SNELLEN IN
SUGARCANE

BY

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MASTER OF SCIENCE (AGRICULTURE)
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

RAJENDRA AGRICULTURAL UNIVERSITY, BIHAR
PUSA (SAMASTIPUR) – 848 125, INDIA

2015

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SUGARCANE

BY

INGLE DIPAK SHYAMRAO



**A THESIS SUBMITTED TO
THE RAJENDRA AGRICULTURAL UNIVERSITY, BIHAR,
PUSA**

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

**MASTER OF SCIENCE (AGRICULTURE)
ENTOMOLOGY**

DEPARTMENT OF ENTOMOLOGY

**RAJENDRA AGRICULTURAL UNIVERSITY, BIHAR
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2015

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Dated : 19 / 06 / 2015



Certificate

This is to certify that the thesis entitled **Biology and Seasonal Incidence of sugarcane borer, *Chilo infuscatellus* Snellen in Sugarcane** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) ENTOMOLOGY** of the Faculty of Agriculture, Rajendra Agricultural University, Bihar, Pusa is the faithful record of *bonafide* research work carried out by **MR INGLE DIPAK SHYAMRAO** under my supervision and guidance. No part of this thesis has so far been submitted for any other degree or diploma.

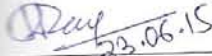
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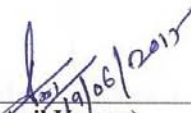
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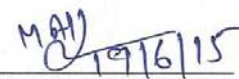

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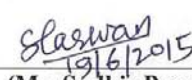
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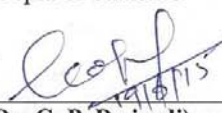
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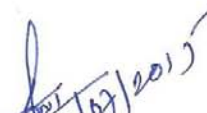
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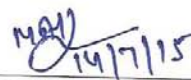
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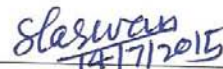
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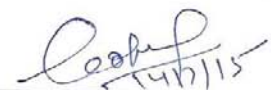
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ACKNOWLEDGEMENTS

First and foremost, I would like to thank my greatest teacher of all, God. I know that I am here and that I am able to write all of this for a reason. I will do my best in never forgetting what a great fortune I have in just being here, and that it comes with a lesson and a responsibility. I hope I am doing the work you have planned me to do.

First and foremost hartly humble thanks to my scholarly guide Dr. Hari Chand, (Junior Scientist-cum-Assist. Prof. Deptt. of Entomology, S.R.I., Pusa). Who has the attitude and substance of a genius, he continually and convincingly conveyed a spirit of adventure in regard to research work and shepherded me thought the bulk of the work, I am also thankful to him for his kind guidance by helping time to time giving valuable suggestion for motivating me for doing well in my future, painstaking efforts in checking this thesis and making it a reality. I would remain indebted forever to him and his family.

I express my special thanks and indebtedness to the Member of my Advisory Committee Mr. Anil Kumar (Junior Scientist-cum-Assist. Prof. Deptt. of Entomology, S.R.I., Pusa), Dr. Md. Minnatullah (Junior Scientist-cum-Assist. Prof. Department of Plant Pathology, S.R.I., Pusa), Mr. Sudhir Paswan (Junior Scientist-cum-Assist. Prof. Department of Statistics, S.R.I., Pusa)

I also express my sincere thanks to my Dean's Nominee Dr. G. P. Dwivedi (Senior Scientist-cum-Associate Prof. Deptt. of Entomology, S.R.I., Pusa) for his kind guidelines and involvement as Dean's Nominee in my Advisory board.

I am highly obliged to Dr. R Ray, Chairman, Deptt. of Entomology, RAU, Pusa, Bihar for his inspiration and encouragement during my investigation.

I am also grateful to the resource persons of the Department of Entomology Dr. M. L. Agrawal, Dr. S.P. Singh, Dr. A.K. Mishra, Dr. A. K. Rai, Dr. U. Mukharjee, Dr. S. P. N. Singh, Dr. Neeraj Kumar and Mr. Nagendar Kumar taking the classes at the time of course work and all others teachers and non-teaching staff for their sincere cooperations.

I am extremely thankful to honorable Vice-Chancellor, DRI-cum-Dean
Mr. Datta (Ag.), Registrar, Director Research and Director Student Welfare of
DRI, Bihar, Pusa (Samastipur) for providing necessary facilities during my study
period.

I owe a deep and endless sense of reverence towards my parents (Sri.
Shyamrao, Smt. Kaveribai), Sister (Bali Tai), brothers (Satish and Atish) and whole
family member whose immense patience and support enables me to achieve all my
ambitions.

Warmest thanks to my seniors Mr. Chaitanya Kumbhar, Mr. Paidi
Shyamrao, Mr. Jitendra Kumar, Mr. Indresen Kumar and Mr. Sashidhar for
their timely helps and with whom I spent every remembered day during my steady.
I am safely concealing their names in my heart forever.

I would like to special thanks to my dear batchmates Mr. Nitish Kumar,
Mr. Shantanu Kumar, Mr. Ravikant Kumar, Mr. Hansraj Hans, Mr. Monu, Mr.
Rajul Kumar, and Miss. Monika, Miss. Smita Kumari and Miss. Ashwini
Jadhav with whom I studied and spent so many valuable times during the
course of my study.

I wish to offer my thanks to my juniors who were always with me during
the course of study.

I their pray to "GANPATI BAPPA" and "MAA SARSAWATI" for
blessings in my life.

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Sugarcane.**

ABSTRACT

The study on biology and seasonal incidence of shoot borer, *Chilo infuscatellus* Snell. experiments were conducted during 2014-15. The study on biology of *Chilo infuscatellus* was conducted in laboratory at Department of Entomology, whereas a field experiment was laid out at Research Farm of S. R. I., Pusa to assess the seasonal incidence of *Chilo infuscatellus*.

The study on biology of sugarcane shoot borer under laboratory conditions revealed that the eggs were oval in shape, dorsoventrally flattened, looked like a scale of fish and were laid in masses on the under surface near to midrib of the leaf. Freshly laid eggs were creamy white in colour, which gradually changed to yellowish. The incubation period varied from 4.35 to 4.45 days (4.4 ± 0.02). The larvae passed through five larval instars to complete the larval period. The total larval period varied from 16.66 to 17.23 days (16.94 ± 0.12). The pupa was obtect type, brownish in colour and its period varied from 6.92 to 7.5 days (7.21 ± 0.13). The male and adult period varied from 3.62 to 3.80 and 4.31 to 4.45 days, respectively. The per cent hatching of *Chilo infuscatellus* ranges from 78.3 to 92.4 per cent (85.35 ± 3.15). Total life cycle *C. infuscatellus* from egg to adult emergence varied from 31.95 to 32.82 days (32.28 ± 0.20).

The absolute population of shoot borer (larvae) was noticed in the field from 1st fortnight of March, 2014 to 2nd fortnight of August. The peak population was recorded in the 1st fortnight of May. The relationship between population of insect and weather parameters showed significant positive correlation with maximum temperature i.e., as the temperature increased the corresponding population of insect also increased.

The mean per cent incidence of shoot borer was recorded from March to (month), harvest of the crop. The maximum (9.32 %) incidence was recorded in the first fortnight of May, 2014 and lowest (1.2 %) incidence recorded in the second fortnight of August, 2014. The maximum temperature showed significant positive correlation with incidence whereas, relative humidity and rainfall were showed negative role.

Extent of parasitization on shoot borer eggs by *Trichogramma chilonis* Ishii. was recorded the peak parasitization in the month of May which ranged from 12.3 to 15.6 per cent. The correlation analysis between parasitization and weather parameters, revealed that maximum temperature showed significant positive correlation whereas, relative humidity at 07 00 hrs and rainfall showed significant negative correlation.



INTRODUCTION

Sugarcane (*Saccharum officinarum* L.), one of the most important cash crops grown in all tropical and subtropical countries of world, is world's most efficient harvester of solar energy, storing this energy as huge quantity of biomass in the form of fibre and fermentable sugars. This crop is of great importance in the agricultural sector and in general economy of many of the tropical developing countries relies on it. It provides employment not only to agricultural labours in the fields but also to industrial labours in the sugar factories. It is also an important source of foreign exchange. It was cultivated an about 23.8 million hectares in more than 90 countries with the worldwide harvest of 1.69 billion tones (Anonymous, 2014). India occupies an important position among the sugarcane producing countries and has a neck to neck race with Brazil for the first position.

In India, it is cultivated in about 50.12 lakh hectares of land with an annual production of 350.02 million tonnes and productivity 69.8 tonnes per hectare during 2013-14 (Anonymous, 2014). Sugarcane crop and its products contribute about 1.1% to the national GDP which is significant considering that the crop is grown only in 3% of the gross cropped area. The contribution of sugarcane to the agricultural GDP has steadily increased from 5% (1990-91) to 10% (2010-11). During the last two decades, the average annual growth of sugarcane agriculture sector was 2.6% as against overall growth of 3% in agriculture sector in the country (Solomon, 2014). It is grown under varied soil and climatic conditions. India has significant potential to expand sugarcane production by increasing both planting area and yield. However, the relatively higher demands on water will make expansion in area more difficult. Indian states namely: Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Haryana and Punjab are leading in sugarcane production.

In Bihar, sugarcane is cultivated in an area of 2.66 lakh hectares with production of cane about 15.08 million tonnes and productivity of sugarcane is 56.8 tonnes per hectare during 2013-14 (Anonymuos, 2014). The poor yield of sugarcane is attributed to the attack of pests and diseases, inadequate irrigation facilities, short supply of manures and fertilizers, lack of high yielding varieties, resistant varieties,

lack of knowledge of actual time of incidence of pests and multi-ratooning. This is facilitated by the uninterrupted cropping pattern and favourable canopy structure of the crop offering conducive microclimate for pests build up. The sugarcane yield loss is also increasing day by day due to monoculture and negligence towards plant protection measures.

Insect pests like termites, borers, pyrilla, whiteflies, bugs, mites, etc. attack this crop and cause heavy losses in terms of yield and sugar recovery. Sugarcane borers make holes, tunnels in internodes due to which food supply to aerial parts of stem and leaves stops and also pave ways for certain diseases. The control of borers is still a serious problem due to their concealed feeding behavior. Mohyuddin *et al.* (1997) stated that sugarcane borers are hidden pests, therefore approach of pesticides and limited use of biological agents were found less effective. Borers resistant varieties provide the additional control needed in the IPM programme.

The Crambid moth borer, *Chilo infuscatellus* Snell.(Crambidae: Lepidoptera) is commonly known as shoot borer in the north Indian sugarcane belts and as early shoot borer in peninsular India. The borer was described as *Dhosah* from Bengal by Mukerji (1857). The moth borer sketched and named by Cotes (1889) as *Diatrea saccharalis* Fabr., was really *Argyria sticticrapsis* Hmps. Kapur placed the borer under a genus *Chilotrea* and named it as *Chilotraea infuscatellus* Snell. In 1965, Bleszynski merged *Chilotraea* under genus *Chilo* Zck. The shoot borer is widely distributed in all sugarcane growing areas in India. *Chilo infuscatellus* is the most notorious and destructive one. The shoot borer damages crop mainly at cane formative phase. The young larvae bore down the spindles and also upwards destroying the apical meristem. Consequently, the cut of spindle dries up and develops into a conspicuous dead heart that can be pulled out easily emit the rancid odour. The damage due to *Chilo infuscatellus* ranges from 30-75 per cent in early stage of the crop (May-June) in subtropical India (Krishnamurty Rao, 1954).

A number of researchers have estimated the loss due to the infestation of this pest in terms of yield at harvest. Shoot borer, *Chilo infuscatellus* Snellen is a key pest in early stages of crop causing economic loss up to 6 per cent (Avasty and Tiwari, 1986). It causes about 22-33 per cent loss in cane yield, 12 per cent in sugar recovery, 2 per cent in CCS and 27 per cent in jaggery (Patil and Hapse, 1981).

David (1979) reported that 9 species of borers regularly damage sugarcane. Of these, the shoot borer, *Chilo infuscatellus* is posing serious threat to sugarcane production all over India.

It has cosmopolitan distribution and infests the crop at the shoot stage both in tropical as well as subtropical India. Seshagiri Rao and Krishnamurthy (1973) reported the economic threshold level of shoot borer to be 15 per cent incidence.

Keeping the above facts in consideration, the present investigation is therefore, proposed to be conducted in order to study the biology and seasonal incidence of shoot borer, *Chilo infuscatellus* Snellen with the following objectives;

1. To study the biology of sugarcane shoot borer, *Chilo infuscatellus* Snellen.
2. To study the seasonal incidence of *Chilo infuscatellus* Snellen and its bio-agents in sugarcane agro-ecosystem with respect to weather parameters.



REVIEW OF LITERATURE

Literature revealed scantiness on information on the biology and seasonal incidence of shoot borer, *C. infuscatellus* Snellen in sugarcane pertaining to Bihar agro-ecosystem. A review on *Chilo infuscatellus* regard to the present study is described in this chapter.

2.1 Nomenclature:

The crambid moth borer, *Chilo infuscatellus* Snell. (Crambidae: Lepidoptera) is commonly known as shoot borer in north Indian sugarcane belt and as early shoot borer in Peninsular India. The first attempt to give a specific name to the moth borer of sugarcane was made by Cotes (1889) in India. He named all the borers as *Diatrea saccharalis* Fb. But due to unsatisfactory systemic position, he consulted with Dr. C.V. Riely, who identified these as a species of *Chilo* and not as *Diatrea*. According to him, these *Chilo* were identical with *Chilo infuscatellus* Snellen. Kapur (1950) placed this borer under genus *Chilotraea* and named as *Chilotraea infuscatella*. Gupta (1959) suggested this Indian species belongs to genus *Chilo* as it resembled *Chilo infuscatellus* Snell.

The shoot borer has a wide range of occurrence from Afghanistan through central Asia, India to Korea, Taiwan, Indonesia, Malaysia as well as Philipines (Kapur, 1950 & Bleszynski, 1969).

2.2 Biology:

Saikia *et al.* (1996) studied in laboratory observations, adults of *Chilo infuscatellus* mated within 24 hours of emergence, usually between 20:00 and 24:00. Gravid females oviposited on ventral leaf surfaces of sugarcane. The largest number of eggs was laid on the first day of oviposition and the fecundity varied from 201.2 to 252.0 eggs/female. The pest passed through five generations in a year. The incubation period ranged from 5 to 9 days. Egg viability was 79.35 to 93.75%. The total larval period varied from 26.2 to 145.4 days. The pupal stage covered 7.7 to 19.2 days. Pre-oviposition, oviposition and post-oviposition periods were 1.5-1.8, 1.8-2.9 and 4.0-5.4 days, respectively. The average sex ratio (male: female) was 1:1.47.

Mehla *et al.* (2003) studied the bionomics of gurdaspur borer *Acigona steniellus* at CCSHAU Regional Research Station, Karnal. The incubation, larval and pupal periods ranged from 7-9, 17-46 and 6-13 days, respectively. The per cent pupation and adults emergence were 13.2-17.57 and 64.28-70.83 per cent respectively, during different generations, while the longevity of males and females was 2-5 days. The sex ratio recorded as 55.5-60.7 per cent (Male) 39.3-45.5 per cent (Female) during different generation of the pest. The fecundity per female varied from 14-121 eggs during July-October.

Kumar *et al.* (2004) carried out investigations during 2003 on biology and seasonal incidence of sugarcane early shoot borer, *Chilo infuscatellus* at Tirupati, Andhra Pradesh, India, revealed that the insect laid eggs on the ventral surface of the leaf, close to the midrib. The egg laying capacity of female was approximately 320-350 and the incubation period ranged from 4.36 to 4.44 days. The larva passed through five instars and the total larval period ranged from 16.68 to 17.10 days. Pupation took place in the outermost leaf sheath in a silken cocoon and the pupal period varied from 6.94 to 7.16 days. Longevity of male and female moths varied from 3.60 to 3.82 and 4.32 to 4.46 days, respectively. The sex ratio of male: female was 1:1.92. The total life period from egg to adult was completed in 31.96 to 32.63 days. The peak period of activity of the pest was observed in May.

Chelvi *et al.* (2010) reported that the study undertaken to formulate an artificial diet for the sugarcane shoot borer (*Chilo infuscatellus*) larvae. The efficacy of granulosis virus obtained from the larvae reared on the artificial diet. Four diet combinations were prepared containing various concentrations of gram dal, casein, yeast, sorbic acid, ascorbic acid, salt, multivitaplex, vitamin E, castor oil, formaldehyde, glucose, shoot bits, agar and water. The most important abiotic factor responsible for the borer multiplication was temperature and during summer the population of shoot borer larvae increased to a maximum level.

Muhammad *et al.*(2012) studied the population dynamics of *Chilo infuscatellus* Snellen emerge from over wintering larvae during fourth week of February and population of adults occurs in early vegetative growth stage of sugarcane crop and maximum population of 37.4 ± 2.20 was recorded during August. The population of *C. infuscatellus* was declined after August and 18.6 ± 2.42 , 14.6 ± 1.74 moths were captured/trapped in month of September and October, respectively.

Bhavani (2013) studied on the biology of sugarcane early shoot borer, *Chilo infuscatellus* Snellen on bean shaped artificial diet (in vitro) under laboratory conditions at R. A. R. S., Anakapalle, Andhra Pradesh, India revealed that the ESB moth laid eggs on the ventral surface of the leaf, close to the midrib. The fecundity of female ranged from 368 to 384 and the incubation period ranged from 4.0 to 4.1 days. The larva passed through four moults with five instars and the total larval period ranged from 16.0 to 16.3 days. Pupation occurred in the outermost leaf sheath in a silken cocoon and the pupal period varied from 6.3 to 6.6 days. Longevity of male and female moths varied from 3.5 to 3.6 and 4.0 to 4.2 days, respectively. The sex ratio of male and female was 1:2.28. The total life cycle was completed in 30.2 to 30.7 days.

2.3 Seasonal incidence:

Mashih *et al.* (1988) conducted the field experiment at Takhat Bhai tehsil of Mardan dist. (Pakistan) from March to November revealed that the highest incidence of borer infestation was observed in sugarcane as sole crop and wheat intercropped with sugarcane showed minimum pyrilla and borer infestation.

Mali (1990) carried out field studies in Vidarbha, Maharashtra, India, showed that there are two population peaks of *Chilo infuscatellus* in sugarcane, one in May and another one in October, under conditions of high temperature and low humidity.

Singla and Duhra (1990) conducted the experiment to determine the effect of plant density and irrigation schedule on the incidence of *Scirpophaga excerptalis* and *Chilo infuscatellus* on the sugarcane variety CoJ 64. The incidence of *C. infuscatellus* was greater at the higher seed rate compared to that at the normal rate (20000 three budded sets) when the crop was irrigated at and after, an interval of 8-10 days.

Singla and Duhra (1992) studied on the effect of planting row direction on the incidence of *Scirpophaga excerptalis* and *Chilo infuscatellus* on sugarcane in the pre-monsoon period revealed that the shoot damage by *C. infuscatellus* was lower in east-west planted sugarcane, whereas this trend was reversed for *S. excerptalis*.

Jena and Patnaik (1996) studied the effect of planting dates on the incidence of *C. infuscatellus* on sugarcane in Orissa. They observed that the planting of sugarcane from January to April resulted in 13.04-24.84 per cent dead hearts at 105 days after planting. Planting during June-October reduced the pest infestation to 1.54-5.45 per cent, while planting during November-December resulted increase in infestation (5.08-10.56 per cent).

Rachappa and Naik (2000) evaluated the post release movement of *Trichogramma chilonis*, the impact of intercrops and *T. chilonis* on the incidence of the early shoot borer (*Chilo infuscatellus*) and the efficacy of different IPM modules against the early shoot borer in sugarcane planted on 10th January revealed that the *Chilo infuscatellus* incidence was significantly less (2.6 to 7.2%) in module I (sevidol [carbaryl + lindane], endosulfan and *T. chilonis*) followed by module II (granular virus and *T. chilonis*), however, the highest per centage of incidence was observed in module III (endosulfan sprays). Module I recorded the highest cost-benefit ratio of 1:2.8, followed by module II.

Rachappa and Naik (2000) studied on the effect of intercrops (coriander, soybean, frenchbean, and bhendi) and release of *T. chilonis* (50,000 parasitized eggs/ha) on early shoot borer (*Chilo infuscatellus*) incidence on sugarcane variety (cv. CoC-671). Highest per cent parasitism of *T. chilonis* on *C. infuscatellus* was recorded from coriander with sugarcane (2:1) intercroppings. Moreover, sugarcane intercropped with bhendi recorded the highest infestation and lowest *T. chilonis* activity than any of the other treatments.

Sardana (2000) studied sugarcane intercrop with green gram, cow pea, pigeon pea, sunflower, maize, sorghum, okra, mint (mentha), black gram and sunhemp, revealed that the *Chilo infuscatellus* incidence was higher in the sugarcane monoculture (13.7%) as compared to sugarcane + intercrops (7.5-13.0%). Whereas, the green gram, black gram and sunhemp treatments recorded significantly lower incidences of *Chilo infuscatellus* (1.4-1.8%), compared to the monoculture (10.8%).

Saini *et al.* (2000) conducted the field experiment at eight sugar-mill zone of Haryana during 1993 to assess incidence of shoot borer (*Chilo infuscatellus* Snellen). On the basis of the presence of dead-hearts, the highest per centage of damaged tillers was found in Rohtak (7.7), followed by that in Karnal (5.9), Shahbad (5.0), Kaithal (4.9) and Sonipat (4.5). Damage in other zones was 3% or less. Over all incidence of the pest in the state was about 4.5%.

Thirumurugan *et al.* (2001) studied on the effect of the time of planting on the incidence of the shoot borer, (*Chilo infuscatellus*) and the yield and quality of sugarcane (cv. CoC. 92061), the treatments consisted of 12 monthly plantings in the first week of every month from April-March; harvesting took place in the twelfth month revealed that the January planted sugarcane recorded the highest cane yield (89.22 t/ha) and found the lowest shoot borer incidence (10.02%). The shoot borer mainly affected the sugarcane shoot stage from March to May.

Giri and Ray (2002) reported that the *C. infuscatellus* incidence was lower in intercropped than sole cropped sugarcane. Intercropping of potato with coriander and wheat resulted in the lowest and highest incidence of *C. infuscatellus*, respectively, during both the years.

Madan *et al.* (2002) studied on the 30 genotypes as tolerant, 48 as moderately tolerant, 52 as susceptible and one as highly susceptible having pest incidence of 0.0-5.0, 5.1-10.0, 10.1-20.0 and above 20.0, respectively. The highest incidence of early shoot borer was recorded in genotypes S-90- 337 (15.9%), CoS 90269 (18.7%) and CoH 98 (32.09%) during 1994-95, 1995-96 and 1996-97 respectively.

Srikanth *et al.* (2002) studied on effect of selection of agronomical practices on the incidence of sugarcane shoot borer, *Chilo infuscatellus* at Coimbatore, Tamil Nadu, India. In an experiment on critical periods of crop-weed competition, wherein sugarcane crop was maintained with different weed regimes, the incidence of borer was significantly lower in weed-infested crop than in weed-free crop.

Thirumurugan *et al.* (2004) studied the effect on different parameters of losses due to shoot borer as well as its effect on compensatory ability of sugarcane varieties, viz. CoC 771, CoC 85061, CoC 92061, CoG 93076, CoG 94077 and CoG 95076 and Co740 against shoot borer attack in Tamil Nadu during 1999-2002. The results showed that the variety Co 740 produced the highest number of compensatory tillers and highest per centage loss in yield (21.04 per cent), followed by 16.65 per cent loss in CoC 771. The other varieties like CoC 771 showed highest cane weight loss (19.63 per cent), followed by 12.50 per cent in CoG 94077. The highest CCS per centage loss was observed in Co 740 which was found in the range of 1.72-8.02 per cent, while the lowest was found in variety CoC 92061 (1.61-3.00 per cent).

Mandal (2005) evaluated 10 sugarcane cv. for resistance against early shoot borer. Three varieties viz., CoC 671, Co 62175 and Co 7219 were found as resistant showing 1.2, 3.2 and 3.9 per cent dead hearts incidence, respectively.

The field trials conducted by Sable *et al.* (2005) aimed at developing a model for forecasting the incidence of pests and diseases in sugarcane under *suru* and preseasonal conditions were conducted at Pune and Padegaon in Maharashtra, during 2001-03.

Rao *et al.* (2006) evaluated sugarcane genotypes for resistance to early shoot borer revealed that the genotype 2000 A62 was found promising by recording significantly less incidence of early shoot borer (15.90 per cent).

Thirumurugan *et al.* (2006) reported that the cane crop was sprayed with 5% tomato extracts+ release of *T. chilonis* at 2.5 cc/ha at fortnightly interval, recorded the lowest cumulative shoot borer incidence of 8.08% with the highest shoot borer reduction of 70.83% and 43.30%, respectively, over the untreated control.

Abdullah *et al.* (2006) evaluated some insect pest resistant promising sugarcane clones, i.e. I 137-96, I 131-97, I 202-97 and standard varieties like Isd 20, Isd 28 and Isd 29 against shoot borer. They reported that these clones encountered very low infestation by early shoot borer (*Chilo infuscatellus*) which ranged from 0.00 to 0.53% at Ishurdi and 0.52 to 1.87% at Thakurgaon (Bangladesh)

Kumar *et al.* (2007) studied the factors influencing incidence of early shoot borer in sugarcane revealed that the January planted crop recorded low cumulative incidence (34.73%) of early shoot borer than February and March planted crop. Low incidence (23.79 and 18.23%) of the pest was noticed when wider spacings of planting (120 cm and 150 cm) and that of higher incidence (41.50 and 34.89%) was noticed when narrow spacings of planting (60 cm and 90 cm).

Bhatti *et al.* (2008) evaluated 46 sugarcane genotypes in 3rd cycle to determine the incidence and intensity of borer infestation revealed that the stem borer appeared in April and infestation increased gradually up to 21.44 per cent in September.

Hole *et al.* (2009) evaluated 17 genotypes for their reactions to early shoot borer indicated significantly lowest (9.8 per cent) infestation of the pest in variety Co 93021 on second year plant cane and first ratoon crop. However, it was found at par with the varieties, viz. Co 93009, Co 93016, Co 93010, Co 6304, CoG 93076, Co 93014, Co 7914, Co 93024, Co 86032, Co 7219, Co 93007 and Co 93008 in the range of 9.9-14.6 per cent.

Randhawa *et al.* (2009) reported the newly sugarcane crop, irrigation intervals of 08 days was very effective for decreasing the incidence of early shoot borer, followed by 16, 24 and 32 days irrigation interval. Higher cane yield per acre was also obtained under 08 days irrigation intervals as compared to longer period of irrigations intervals.

Abdullah (2009) observed the incidence of six promising sugarcane clones viz., I 24-00, I 80-00, I 124-00, I 133-00, I 149-00 and I 178-00 and two standard varieties Isd 32 and Isd 34 against some major insect pests of sugarcane at Ishurdi and Thakurgaon (Bangladesh) revealed that (pooled data) those clones encountered very low infestation by early shoot borer which ranged from 0.24 to 1.04 per cent at both locations.

Srikanth *et al.* (2009) studied the seasonal dynamics of sugarcane shoot borer *Chilo infuscatellus* Snell. (Lepidoptera: Crambidae) and its parasitoid *Sturmopsis inferens* Tns. (Diptera: Tachinidae) was examined and augmentative release of the parasitoid against the borer was evaluated at Coimbatore. The borer was active during the study period with overall range of 0.3-28.6 per cent fortnightly deadheart incidence. With considerable year to year variation, the borer attained its peak stage during July-August in high incidence but showed indistinct peak activity periods in years of low attack.

Chand *et al.* (2010) conducted a field trial to find out the comparative level of incidence among nine promising clone/varieties of sugarcane, viz. Bo 146, Bo 147, CoP 02181, CoP 02182, CoSe 02235, UP 01104 and UP 01105, and two standard varieties (Bo 91 and CoP 95422) against borer pests of sugarcane revealed that the shoot borer infestation in the range of 6.66 to 15.10 per cent.

Rao *et al.* (2010) observed that sugarcane intercropped with green gram registered less (4.15%) incidence of early shoot borer followed by sugarcane intercropped with blackgram (4.25%) and cowpea (4.85%) whereas in sole crop showed higher (16.35%) incidence was recorded.

Khan *et al.* (2011) reported that the infestation of *C. infuscatellus* on three selected varieties, i.e. SPF-234, CPF-237 and Thatta-10 during 2009-10 and found that there was significantly highest infestation as 1.28 ± 0.63 unit on SPF-234 and 1.24 ± 0.86 unit on Thatta-10 while infestation on CPF-237 was recorded insignificant. However, this infestation ratio was reported significantly highest on SPF-234, 1.55 ± 1.62 unit followed by CPF-237, 1.33 ± 2.54 unit while it was significantly lowest on Thatta-10 in the year 2010.

Chand *et al.* (2011) reported that the incidence of borer was significantly lower (2.98%) and significantly higher millable cane in the IAM (integrated approach for management) plot as compared with 11.27% in untreated control. IAM programme had increased the cane yield (64.94 tonnes/ha) over the untreated block (23.36 tonnes/ha).

Chand *et al.* (2011) reported the seasonal incidence of *Chilo tumidicostalis* Hampson on commercial varieties of sugarcane revealed that variety Bo-147 was relatively more infested showing 29 to 51 larvae per cane followed by CoP-9702 (23 to 42) and 25 to 41 larvae in CoP-9301 cultivar. Peak incidence was observed between August and October.

Rana *et al.* (2011) reported that minimum sugarcane borer infestation (4.00 and 3.18%) with maximum stripped cane yield (48.00 and 46.70 tonnes/acre) were in the treatment where Furadan 3G @ 15 kg/ acre + *Trichogramma* eggs @ 60000/acre followed by 4.36 and 4.30% bores infestation with 47.38 and 45.00 tons/ acre cane yield in the treatment.

Bhavani *et al.* (2012) studied on the effect of nitrogen, phosphorus, potassium and total sugars on the incidence of early shoot borer (ESB), *Chilo infuscatellus* Snell in four least susceptible, four moderately susceptible and four highly susceptible sugarcane genotypes. Least susceptible (LS) genotypes (98 A 125, Co 0110, Co 6806 & 98 A 165) had significantly lower N, higher P and K, and lower sugar contents in shoots at 60 days after planting compared with genotypes that were highly susceptible (HS) to ESB.

Pandey (2014) reported that the six chemicals namely; chlorantraniliprole (20 S.C. @ 0.05 Kg a.i./ha), chlothianidine (50% WDG @ 0.05 Kg a.i./ha), imidacloprid (200 S.L. @ 0.02 Kg a.i./ha), azadiractin (0.15 E.C. 0.03% a.i./ha) and cartap hydrochloride (50 W.S.P. 0.75 Kg a.i./ha) along with chlorpyrifos (20 E.C.

@ 1 Kg a.i./ha) as check insecticides were evaluated. chlorantraniliprole @ 0.04% was most effective as it exhibited least dead hearts of 2.85% with the decrease of 83.43% in the incidence over control and hence, it can be suggested that chlorantraniliprole @ 0-04% could be the most preferred option.

2.4 Weather parameters relationship:

Jabbar *et al.* (1986) studied population dynamics of *C. infuscatellus* at National Agricultural Research Centre, Islamabad and found that the stem borer appeared during early July and the infestation increased gradually up to 42 per cent.

Mali (1990) found there were two population peaks of *C. infuscatellus* in sugarcane, one in May and another in October under the conditions of high temperature and low humidity in Vidarbha (Maharashtra).

Rao *et al.* (1991) conducted a field trial to observe effect of physical factors on infestation at Anakapalle (A.P.) revealed that planting time, temperature, humidity, rainfall and variety had little influence on infestation by *C. infuscatellus* while soil type, moisture stress and moonlight had shown to definite influence on pyralid activity. Besides, plant physiological factors also appeared to have a prominent role in the population dynamics of *C. infuscatellus*.

Jena *et al.* (1997) conducted field studies on the sugarcane varieties Co 6907, Co 7219 and Co 62175 which showed the infestation level of *Chilo infuscatellus* was positively and significantly correlated with temperature (maximum, minimum and mean). Rainfall had no effect on the infestation level.

Rustamani *et al.* (1997) studied correlation between infestation of *Scirpophaga nivella* and *C. infuscatellus* and temperature as well as humidity revealed that there were positive, but non-significant correlation between the infestation, temperature and humidity.

Hapase *et al.* (1979) attempted to establish a correlation between borer infestation and weather parameter from the data collected at Padegaon (Maharashtra) during 1960-75. Individual years data analysis showed poor relationship, but from pooled analysis, revealed that maximum temperature had significant positive correlation with borer infestation, while relative humidity showed a negative relationship.

Rao *et al.* (2004) reported that peak period of infestation of sugarcane early shoot borer was in May and September. They also observed that maximum and

minimum temperatures had a significant effect (positive correlation) on light trap catches and relative humidity exerted a weak negative correlation. Multiple regression analysis showed that the number of rainy days exhibited significantly negative effect on light trap catches.

Khan *et al.* (2011) recorded significantly highest infestation of *C. infuscatellus* during the hottest months of year on three selected varieties, i.e. SPF-234, CPF-237 and Thatta-10.

Rao *et al.* (2013) suggested that relatively warmer (minimum temperature $>23.8^{\circ}\text{C}$) and dry nights (RH $< 77\%$) favoured the incidence. The rainfall events exceeding 50 mm/day controlled the pest during early stages of crop growth.

Pandey and Kumar (2014) recorded the highest incidence of *C. infuscatellus* was during 21st standard week (8.8 per cent) at 43.1°C maximum temperature, 28.4°C minimum temperature, 57.0 per cent maximum relative humidity, 21.0 per cent minimum relative humidity and 9.1 sun shine hours. Sugarcane variety CoS 8436 planted after wheat harvest significant positive correlated with minimum temperature and highly significant with minimum relative humidity.

2.5 Natural enemies:

Ahmad *et al.* (2012) reported the role of egg parasitoid, *Trichogramma chilonis* Ishii (Hymenoptera; Trichogrammtiade) as a pest management tool for the control of sugarcane stem borer (*Chilo infuscatellus*) under natural field conditions. They observed that intensity of damage showed minimum infestation of 9.31% was recorded in treatment T1 followed by T2, T3 and T4 with infestation percentage of 13.60, 17.07 and 19.44, respectively. The highest infestation was recorded at 25.95 per cent in control treatment.

Ullah *et al.* (2012) reported that the relative effectiveness of egg parasitoid *Trichogramma chilonis* and two commonly used insecticides, Basudin 60 EC and Furadan 3G against sugarcane stem borer, *Chilo infuscatellus* was evaluated in sugarcane fields under RBD design. Results revealed that highest (50.46) mean per cent parasitism was observed in *Trichocard* released plot (T3) followed by check plot (T4) being 12.54 while, in Basudin treated plot (T1) mean per cent parasitism was 8.70 % and in Furadan treated plot (T2) was 7.91 %. All these treatments were

found effective for the management of sugarcane stem borer. However the cost and benefit analysis showed that maximum return (84.78) was obtained from *Trichocards* released (T3) plots so, *Trichocards* may be recommended for the management of sugarcane stem borer instead of insecticides. Moreover, this practice may have significant role to protect the soil and conserve the natural resources from insecticides contamination.

Muhammad *et al.* (2012) observed that the *Trichogramma chilonis* parasitoids was found higher (52.4 %) in the blocks where parasitoids were released to control *Chilo infuscatellus* at weekly interval as compared to fortnight (40.9%) and monthly intervals (32.7%). However, the mean infestation was below economic threshold levels ranging from 5.3 to 6.5 % in all the blocks where the parasitoids were released in variable numbers.

Nadeem and Hamed (2011) observed that an average borer damage decreased to 43.1% at Chak 496/JB, 42.3% at Chak 701/43-GB and 35.1% at Chak 411/JB in biological control plots in comparison to check plots. Comparison of borer damage between bio-control and check fields in different sites showed effectiveness of *T. chilonis* to suppress the borer damage below to economic threshold level.

Padmasri and Rani (2014) revealed that an average per cent intensity of inter node shoot borer damage decreased to 70.70 and 53.87 per cent in 2011 and 2012 respectively, and average per cent incidence of inter node shoot borer damage decreased to 64.92 and 49.66 per cent in 2011 and 2012, respectively. Population of *Chilo sacchariphagus indicus* showed negative correlation with increase in number of parasitized eggs of *T. chilonis*, which indicates that it can be successfully used for the suppression of sugarcane inter node shoot borer.



MATERIALS AND METHODS

To study the biology and seasonal incidence of shoot borer, *Chilo infuscatellus* Snell. laboratory as well as field experiments were conducted during 2014-15. The biology of *Chilo infuscatellus* was conducted in laboratory at Department of Entomology, whereas a field experiment was laid out at Pusa Farm of S. R. I., Pusa to assess the seasonal incidence of *Chilo infuscatellus*. The materials and methods employed to undertake the investigation are presented here under.

3.1 Physiographic situation of the experimental site

The experimental site is situated at bank of Burhi Gandak at altitude of 52-9 m MSL, 23^o 29'N latitude and 85^o 4' E longitude. It has a semi humid sub-tropical climate being hot humid during March to September. The maximum (270.2mm) rainfall was recorded during 2014 in the month of August, whereas 7.4 mm was recorded in the month of January 2015, while minimum (1.0 mm) rainfall being 2nd fortnight of same month of the year. The maximum and minimum temperature was 38.6 °C and 8.5 °C in the month of May and December 2014, respectively. The highest (92.9 %) relative humidity was recorded in the month of December 2014 and lowest (10.1 %) in the month of January 2015. The meteorological data were presented in the table 1 and fig. 1. The conditions, however, found congenial for planting of sugarcane cv. (CoP-2061) as well as development of sugarcane shoot borer, *Chilo infuscatellus* in the year (2014-15) of investigation.

3.2 Fortnightly meteorological observations

Meteorological observations with regard to ambient temperature (°C), relative humidity (%) and rainfall (mm) prevailing at Pusa Farm of SRI, RAU, Pusa, Samastipur were recorded daily during crop season from February, 2014 to February, 2015 during the course of investigation. The data so obtained were finally merged together to obtain the fortnightly average of weather parameter for the period under investigation.

Table 1. Prevailing meteorological observations during 2014-15.

Month/year		Temperature (⁰ C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	07 00 hrs	14 00 hrs	
February,2014	I	21.5	9.9	89.3	59.5	83.2
	II	23.0	11.6	89.7	60.1	56.2
March, 2014	I	26.9	13.2	88.8	46.6	10.6
	II	32.7	17.2	77.8	35.1	0.0
April, 2014	I	35.7	18.0	71.6	31.6	0.0
	II	38.4	21.0	65.6	25.0	0.0
May, 2014	I	38.6	24.2	67.0	35.8	1.3
	II	36.6	24.0	77.2	40.5	62.7
June, 2014	I	36.5	26.6	82.5	53.8	24.6
	II	35.9	26.1	83.4	63.7	68.6
July, 2014	I	32.8	26.6	89.6	74.3	212.6
	II	32.3	26.4	88.1	71.9	127.2
August, 2014	I	32.9	26.5	90.5	78.2	270.2
	II	32.5	25.9	91.2	73.9	81.7
September, 2014	I	32.4	25.6	90.2	69.7	61.2
	II	32.5	25.9	91.2	73.9	68.2
October, 2014	I	32.7	23.6	91.4	63.9	81.6
	II	30.2	19.2	90.4	52.6	0.0
November, 2014	I	30.0	16.2	88.8	43.8	0.0
	II	27.2	11.6	85.4	37.9	0.0
December, 2014	I	21.3	12.6	92.9	71.7	0.0
	II	18.4	8.5	91.3	70.0	0.0
January, 2015	I	19.4	10.1	9.8	11.3	7.4
	II	19.3	11.9	8.9	10.1	1.0
February, 2015	I	23.1	9.3	88.6	50.5	0.0
	II	26.2	15.3	91.3	61.5	1.2

I-First fortnight ; II- Second fortnight

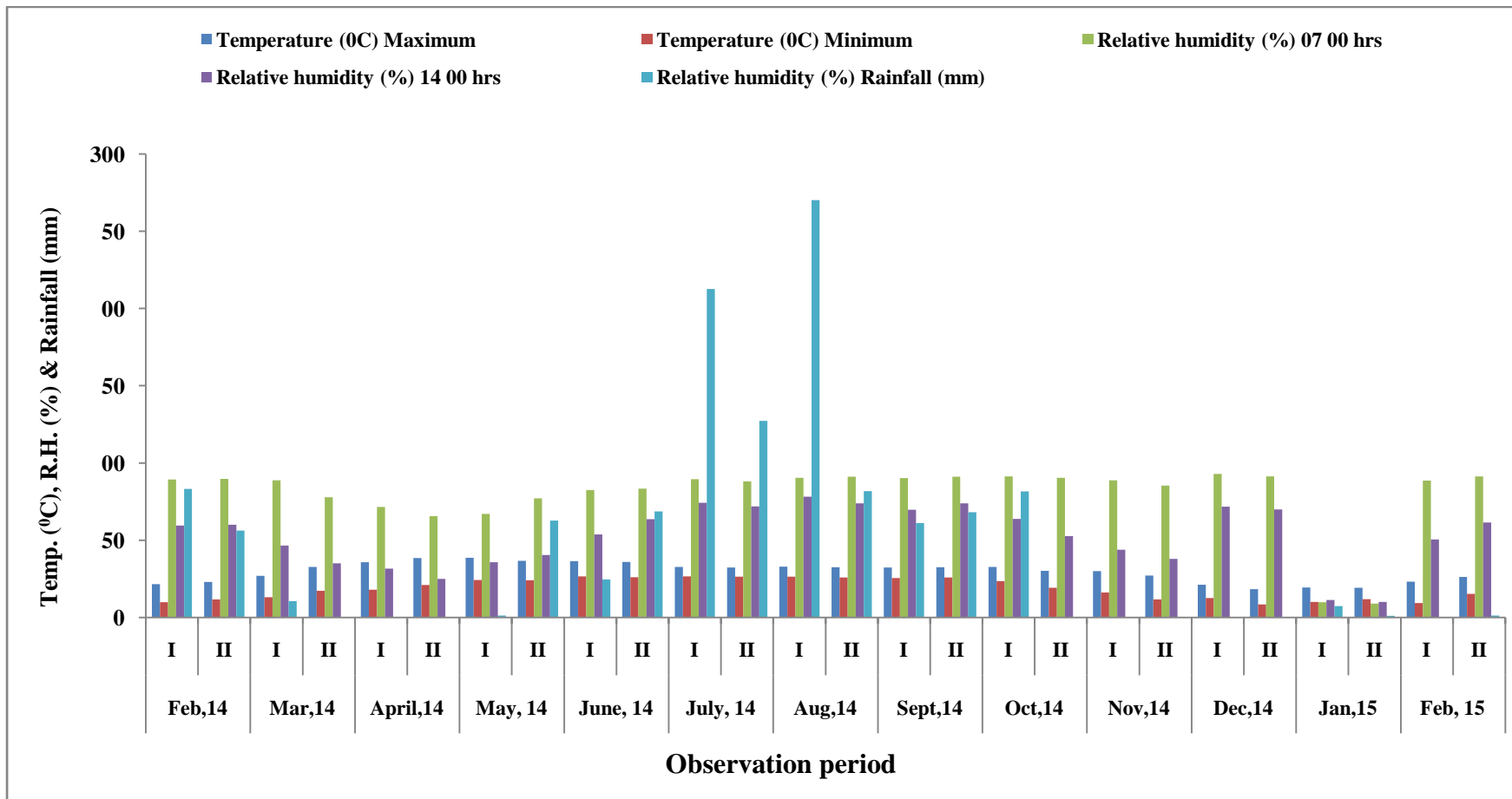


Fig. 1 Prevailing meteorological observations during 2014-15

3.3 Materials required

3.3.1 Biology of Sugarcane shoot borer, *Chilo infuscatellus* Snell.

In order to study the biology of shoot borer the experiment was conducted in the laboratory during 2014-15 at the Department of Entomology, Sugarcane Research Institute, R.A.U, Pusa.

3.3.2 Rearing of *Chilo infuscatellus*

The fresh soft cane pieces (cv. CoP-2061) was used for rearing the insect in rearing cages (24" x 12" x 12"). The cane was cut into pieces of 10 cm length. Five small holes are made in the pieces of cane. Caterpillars of the borer collected from the field were introduced at the rate of one per hole. The pieces of the cane were changed once in two days and the larvae taken out and introduced into fresh ones. This was continued till pupation. After pupation the cocoons are collected and kept in glass troughs covered with muslin cloth for adults emergence.

3.3.3 Egg:

Newly emerged adults were collected. Male and female adults were separated based on their rostral characters (Jayashree, 1992). Ten pairs of borers were isolated from the cages immediately after adults emergence from the cocoons. They were kept in separately in small rearing cages. Pieces of healthy canes are provided in the cages with 2 % sugar solution for feeding. Sugarcane leaves were also provided in the cages for laying of eggs. The eggs laid in the under surface of leaves were collected from the cages and deposited on the leaves were isolated with fine camel hair brush and counted separately. The pieces of canes were replaced with fresh ones every day. Eggs were examined every day for the emergence of larvae.

3.3.4 Incubation period:

For the study of incubation period, ten freshly laid eggs were taken out from the leaves and were kept on filter paper in the five covered petridishes with sufficient moisture. To maintain sufficient moisture inside, a few drops of water were given on the filter paper. At the time of hatching the hand lens was used to see the changes occurring on the eggs.

3.3.5 Caterpillar:

To assess the larval behaviour and the duration of different larval instars of sugarcane shoot borer, the newly hatched larvae were collected and transferred carefully using a wet camel hair brush into fresh soft cane pieces of 10 cm length into test tube. The pieces of cane were changed once in two days till pupation of the larvae. While transferring into fresh cane pieces, the larvae were examined for sign of moulting. The interval between two moults was taken as duration of the each instar. Constant humidity of 100 per cent RH level was maintained by utilizing water soaked cotton bolls. The rearing provided an opportunity to observe the behaviour and development of the larvae and to assess the number of larval instars.

3.3.6 Pupa:

The fifth instar larvae enter a non feeding pre pupal stage and construct a cocoon by winding the short pieces of fibrous materials of the sheath around its body (Padmanaban and Sathi moorthy, 2001). The data and time of cocoon formation were recorded as soon as they were formed. After pupation the cocoons were collected along with pieces of canes and kept in petridishes per adult emergence and the pupal period was recorded.

3.3.7 Adults:

As soon as the adult borers emerged from the cocoons, they were separated in pairs and reared in rearing cages on pieces of cane. The longevity of both male and female borers along with prevailing temperature was noted.

3.4 Seasonal incidence of sugarcane shoot borer, *Chilo infuscatellus* Snell.

In order to determine fluctuations in the seasonal incidence of shoot borer, *Chilo infuscatellus* Snell. mid late matured sugarcane cv. (CoP-2061) in one acre was planted during 2nd fortnight of February, 2014 at Pusa farm of S.R.I., Pusa as per recommended package of practices of RAU for production of sugarcane, keeping them completely free from insecticidal contamination. The observation on pest activity was initiated from 30 days after planting to monitor the pest population based on dead hearts at fortnightly intervals throughout the cropping season (Feb., 2014 to Feb., 2015). Dead hearts after every count were removed to facilitate the recording fresh dead hearts in that fortnight. The data obtained were merged together to calculate mean fortnightly population. The per cent incidence of shoot borer was calculated by using following formula:



Plate 1- Experimental plot



Plate 2- Experimental site of investigation



Plate 3: Caterpillars rearing cage.



Plate 4: Male and Female moth rearing cage.

$$\text{Per cent incidence of shoot borer} = \frac{\text{Number of dead hearts}}{\text{Total number of tillers}} \times 100$$

3.4.1 Injury observation on plant infestation: Dead hearts

Infestation of shoot borer was calculated by counting number of dead hearts from five random rows of five meters length were selected for observations at fortnightly intervals.

Area of crop	1 acre
Test crop	Sugarcane
Test variety	CoP-2061 (Mid late)
Target pest	<i>Chilo infuscatellus</i> Snellen
Date of planting	2 nd fortnight of February, 2014
Period of harvest	3 rd week of February, 2015

The weather parameters viz., maximum & minimum temperatures (⁰C), relative humidity at 07 00 and 14 00 hrs and rainfall (mm) were recorded at fortnightly interval during the period of study. These factors were correlated with the population fluctuations of shoot borer.



RESULTS AND DISCUSSION

In order to plan an appropriate control measure, a comprehensive knowledge of biology as well as the incidence of the pest is of utmost importance. In view of the above fact, an attempt has been made to find out the biology and seasonal incidence of sugarcane shoot borer, *Chilo infuscatellus* Snell. in agro-ecosystem of Bihar. The results on the biology and seasonal incidence of *Chilo infuscatellus* are present and discussed as under.

4.1 Biology of the sugarcane shoot borer, *Chilo infuscatellus* Snell.

Results on the biology of the sugarcane shoot borer have been presented in table 2 and table 3.

4.1.1 Incubation period

Under laboratory condition, the eggs were oval in shape, dorsoventrally flattened, looked like a scale of fish and were laid in masses on the under surface near to mid rib of the leaf. Freshly laid eggs were creamy white in colour, which gradually changed to yellowish with pin head size spot after 24 hours of egg laying. Empty egg shells were white and remained attached to the leaf. The incubation period was studied by taking these eggs from the leaves and kept on filter paper in 10 covered petridishes with sufficient moisture. The incubation period ranged from 4.35 to 4.45 days with an average of 4.4 ± 0.02 days, where as the per cent egg hatching varied from 78.3 to 92.4 with an average of 85.35 ± 3.15 percentage (Table 3). The fecundity number was 324 to 352 with an average of 338 ± 3.15 number.

This is in close proximity with Habse and Khaire (1994), Venugopala Rao, (1998), Sunil Kumar (2003) and Kumar *et al.* (2004) they reported that the egg period as 3-6 days, 3.7 days, 4.39 days and 4.36-4.44days, respectively. The variation in egg period might be attributed to variation in the atmospheric temperature and relative humidity in that location. The present finding is also in conformity with the results of Karla and Sunil kumar (1996) and Agrawal and Haque (1955).

4.1.2 Larval period

Five larval instars were recorded in the present investigation under laboratory. Freshly emerged larva (1st Instar) was greyish white in colour with black head and immediately after hatching moved fast in search of food material. The first instar larva lasted from 2.12 to 2.18 days with a mean of 2.15 ± 0.01 days. It was unable to make hole across the leaf sheath.

The second instar larva was dirty white in colour with prominent dark stripe on mid dorsal portion and impression of the stripes was found on the body. The duration of second instar larva was 3.15 to 3.26 days with an average of 3.21 ± 0.02 days.

The third instar larva was similar in colour of second instar larva with the dark black head. Black spots on tubercles were absent. It lasted from 3.25 to 3.38 days with an average of 3.31 ± 0.03 days.

The fourth instar larva increased in size and occupied 3.52 to 3.63 days with an average of 3.57 ± 0.02 days. It was dirty white in colour with dark brown head. The body possesses five violet stripes, one on dorsal surface, one pair each on the sub-dorsal and lateral surface of the body. Black spots were observed on the tubercles which were present on the eight abdominal segments.

The fifth instar larva took about 4.62-4.78 days, with an average of 4.7 ± 0.04 days to enter into pupation. It was dirty white in colour with dark brown head and with five violet stripes extending from second thoracic to eighth abdominal segments. The crochets on the prolegs were arranged in the form of incomplete circles which open towards outside. The larval duration of each instar were presented in the table 2. These results are in close conformity with those of Chandy *et al.* (1964), Venugopala Rao (1998) and S. Kumar (2003).

The larval period ranged from 16.66 to 17.23 with an average of 16.94 ± 0.12 days. The duration of first instar larva ranged from 2.12 to 2.18 with a mean of 2.15 ± 0.01 days whereas, second instar larva was 3.15 to 3.26 with a mean of 3.21 ± 0.02 days. The duration of third instar larva ranged from 3.25 to 3.28 with an average of 3.31 ± 0.03 days. The duration of fourth instar and fifth instars larva was 3.52 to 3.62 with a mean of 3.57 ± 0.02 days and 4.62 to 4.78 with an average of 4.7 ± 0.04 days, respectively (Table 2).

The young larvae immediately after hatching crawled to tip of the leaf and suspended themselves by silken thread to reach the base of the shoot. It has also observed that the newly hatched larvae were observed first feeding of the leaf sheath as a minor and only after attaining second instar stage, started boring into the shoot. The larva has been observed to feed on the growing point and consequently unopened spindle leaves were found to be damaged at base and finally the dead heart formation occurred in about 10 days after the entry of borer into the plant. Similar behaviour of larva was observed by Shivra Rao (1960), Karla and Sunil kumar (1966). The finding on the duration of the larval instars in presents study are in conformity with reports of Chandy *et al.* (1964) and Sunil kumar (2003).

4.1.3 Pupal period

The pupa was obtect type. The newly formed pupae were elongated, slender and greyish in colour which later turned into dark brown in colour. The female genital aperture was situated on the ventral side of eighth abdominal segments in the form of a slit. The male genital aperture was situated on the raised oval sclerite with linear depression in the middle of ninth abdominal segment. The pupal period lasted from 6.92 to 7.5 days with an average of 7.21 ± 0.13 days.

The present findings were comparable with the observation of earlier workers with reference to *Chilo infuscatellus* Snell. in different states of India the pupal period varied from 8-10 days in Uttar Pradesh (Gupta, 1959), 7-8 days in Mysore (Usman *et al.*, 1957), 5-8 days in Rajasthan (Karla and Sunil kumar, 1966), 8-10 days in Haryana (Garg and Chaudhary, 1979), 7.7-19.2 days in Assam (Saikia *et al.*, 1996) and 6-10 with an average of 7.2 days in Andhra Pradesh (Venugopala Rao, 1998). The larva was pupate within the shoot itself generally at its base. Before pupating, a larva cut a slanting hole leading outside the shoot and plugs it with its fros to facilitate emergence of the adult moth later.

4.1.4 Adult stage

The female adult moth was light straw to brownish in colour without any clear markings on the outer edge of the forewings and the hindwings were greyish white in colour. The male was light straw to brownish grey coloured forewing with the dark marking on the edge and greyish white wings. Female moths were observed to be slightly bigger than male moths. The present findings were almost similar to those recorded by Gupta (1959) and Sunil kumar (2003).

4.1.5 Adult longevity

The longevity of the moths, which were recorded under laboratory ranged from 3.62 to 3.80 days with an average of 3.71 ± 0.04 days, while that of the females ranged from 4.31 to 4.45 days with an average of 4.38 ± 0.03 days (Table 3) which are in close conformity with the findings of Habase and Khaire (1994) and Venugopala Rao (1998).

4.1.6 Total life cycle

The data collected on life history of *Chilo infuscatellus* Snell. from egg to adult indicated that life cycle was completed within a period of 31.95 to 32.82 days with an average of 32.28 ± 0.20 days and the results were more or less in agreement with reports of Shivra Rao and Kamalakara Rao (1963) and Sunil kumar (2003).

Table 2. Duration of different larval instars of *Chilo infuscatellus* Snell.

Instars	*Larval duration (days)		Mean	± S.D.
	Minimum	Maximum		
I	2.12	2.18	2.15	0.01
II	3.15	3.26	3.21	0.02
III	3.25	3.38	3.31	0.03
IV	3.52	3.63	3.57	0.02
V	4.62	4.78	4.7	0.04
Total	16.66	17.23	16.94	0.12

*- Average of 10 individuals ; S.D. - Standard deviation

Table 3. Developmental period of different stages of *Chilo infuscatellus* Snell.

Sl. No.	Life stages	Duration (days)		Mean	± S.D.
		Minimum	Maximum		
1.	Incubation period	4.35	4.45	4.4	0.02
2.	Larval period	16.66	17.23	16.94	0.12
3.	Pupal period	6.92	7.5	7.21	0.13
4.	Adult longevity				
	a. Male	3.62	3.80	3.71	0.04
	b. Female	4.31	4.45	4.38	0.03
5.	Total life cycle	31.95	32.82	32.28	0.20
6.	Fecundity (No.)	324	352	338	3.15
7.	Per cent hatching	78.3	92.4	85.35	3.15

Average of 10 individuals ; S.D.- Standard deviation



Plate 5: Eggs



Plate 6: 1st Instar



Plate 7: 2nd Instar



Plate 8: 3rd Instar



Plate 9: 4th Instar



Plate 10: 5th Instar



Plate 11: Pupa



Plate 12: Adult female

4.2.1 Estimation of absolute population of *Chilo infuscatellus* Snell. on sugarcane

The absolute population of shoot borer was estimated by counting the number of larvae of the insect by splitting the damaged canes from 20 plants, randomly selected at 5 places at fortnightly interval, from March, 2014 to August, 2014 and the data on the population of larvae are presented in Table 4 and figure 2. The data reveals from the table that population of the insect which comprised of only larvae started to buildup from the first fortnight of March, 2014 i.e. 75 days after the planting of setts in the experiment. There was steady increase in the population of larvae during next two months i.e. April and May thereafter gradually decreased trend was observed.

The population of larvae ranged from 0.3 to 8.3 per cane during course of investigation (Table 4). The perusal of data indicated that the peak was observed in the month of May when the maximum and minimum temperature ranged from 36.6 °C to 38.6 °C and 24.0 °C to 24.2 °C, respectively. With RH 07 00 hrs and 14 00 hrs ranged from 67.0 to 77.2 and 35.8 to 40.8 per cent the respectively. The rainfall was recorded from 1.3 to 62.7 mm during first and second fortnight of May, respectively. There was untraceable rainfall recording in the month of April. Pest population declined during rainy season. It was also seen that shoot borer does not tolerate heavy rains and population was noticed in declined trend. The peak population of shoot borer in the experimental plot was reflected in April and May months. The temperature (maximum and minimum) prevailing in rainy months i.e. from June to August was found unfavourable for the pest when it undergoes diapauses. It was also noticed from the data that inspite of relative humidity which was highest varied from 90.5 to 91.2 % and 73.9 to 78.2 % at 07 00 hrs and 14 00 hrs respectively, in the month of August, but population was lowest and ranged from 0.3 to 0.5, it might be due to heavy rain in that month. The rainfall was recorded in that month was 270.2 and 81.7 mm during first and second fortnight, respectively which was highest during course of study.

Correlation Coefficient:

Simple correlation was worked out between weather factors and population of shoot borer (Table 5). It was observed that maximum temperature showed significant positive correlation with population (larvae) of the insect, while relative humidity showed significant correlation but statistically was found as negative relationship. Rainfall and minimum temperature exhibited negative role and were non significant. Multiple linear regression was worked by taking shoot borer population (larvae) as dependant variable and climatic factors as independent variables (Table 5a). Data revealed that coefficient of determination (R^2) was significantly high and being 85.85 per cent with population. This is clear that high maximum temperature was the congenial weather element for buildup of shoot borer population.

Thus, it may be inferred that prevalence of high maximum temperature, as it is the congenial weather element for increase in population of shoot borer. This may require further intensive study reducing the time interval from fortnight to one week for recording the pest population fluctuation. The present finding on the population fluctuation of shoot borer were in partial agreement with the result of Mohammad *et al.* (2012) who reported that the population dynamics of *Chilo infuscatellus* (Snellen) emerge from over wintering larvae during fourth week of February and population of adults occurs in early vegetative growth stage of sugarcane crops. The maximum population of 37.4 ± 2.20 was recorded during August. The population of *Chilo infuscatellus* was declined after August as 18.6 ± 2.42 and 14.6 ± 1.74 moths were captured / trap in the month of September and October, respectively.

According to Mali (1990) that there are two population peaks of *Chilo infuscatellus* in sugarcane, one in May and another one in October, when high temperature and low humidity were prevailed.

Further Hapse *et al.* (1979) attempted to establish a correlation between borer infestation and weather parameters, individual's year's data analysis showed poor relationship, but from pooled analysis revealed that maximum temperature had significant positive correlation with borer infestation, while relative humidity showed a negative relationship.

Again Rao *et al.* (2004) reported that peak period of infestation of sugarcane early shoot borer was in May and September. They also observed that maximum and minimum temperatures had a significant effect (positive correlation) on light trap catches and relative humidity exerted a weak negative correlation. Multiple regression analysis showed that the number of rainy days exhibited significantly negative effect on light trap catches.

Table 4. Population of larvae (shoot borer) on Sugarcane

Observation period	Observations interval	*Population of larvae	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
			Minimum	Maximum	07 00 hrs	14 00 hrs	
March, 2014	I	1.5	13.2	26.9	88.8	46.6	10.6
	II	2.3	17.2	32.7	77.8	35.1	0.0
April, 2014	I	5.2	18.0	35.7	71.6	31.6	0.0
	II	7.6	21.0	38.4	65.6	25.0	0.0
May, 2014	I	8.3	24.2	38.6	67.0	35.8	1.3
	II	8.1	24.0	36.6	77.2	40.8	62.7
June, 2014	I	4.8	26.6	36.5	82.5	53.8	24.6
	II	4.2	26.1	35.9	83.4	63.7	68.6
July, 2014	I	3.2	26.6	32.8	89.6	74.3	212.6
	II	2.1	26.4	32.3	88.1	71.9	127.2
August, 2014	I	0.5	26.5	32.9	90.5	78.2	270.2
	II	0.3	25.9	32.5	91.2	73.9	81.7

I– 1st fortnight ; II- 2nd fortnight

*- Mean of five replications.

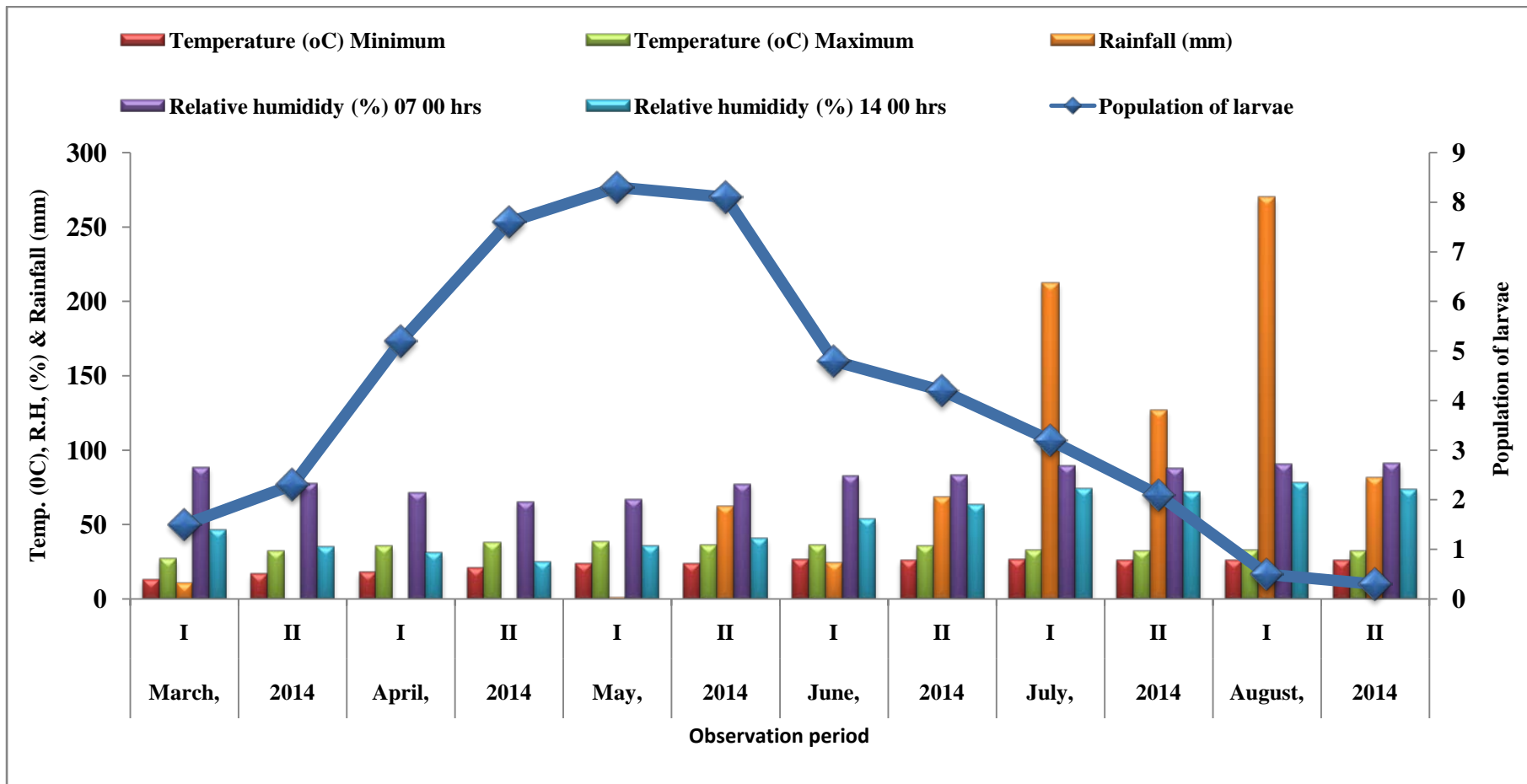


Fig. 2 Population of larvae (shoot borer) on Sugarcane

Table 5. Correlation: Effect of weather parameter on shoot borer population in sugarcane

Population	No. of observation	Weather parameter				Rainfall (mm)
		Temperature (°C)		Relative humidity (%)		
		Minimum	Maximum	07 00 hrs	14 00 hrs	
Larvae	12	0.0109	0.8122**	-0.8439**	-0.6952*	-0.4906

*- significant at 5 % probability level.

** - significant at 1 % probability level.

Table 5(a). Multiple linear regression models for weather parameters on shoot borer population in sugarcane

Population (Y)	No. of observation	Pure constant	Weather parameter				Rainfall (mm) (X ₅)	R ²
			Temperature (°C)		Relative humidity (%)			
			Minimum (X ₁)	Maximum (X ₂)	07 00 hrs (X ₃)	14 00 hrs (X ₄)		
Larvae	12	7.3974	0.6788	-0.2150	0.0144	-0.2503	0.0052	0.8585**

** - significant at 1 % probability level.

Multiple regression equation:

$$Y = 7.3974 + 0.6788(X_1) - 0.2150(X_2) + 0.0144(X_3) - 0.2503(X_4) + 0.0052(X_5)$$

4.3.1 Seasonal incidence of shoot borer, *Chilo infuscatellus* Snellen on sugarcane.

Biotic and abiotic factors have a great role in influencing the population buildup of any organism. Abiotic factors viz., temperature, relative humidity and rainfall regulate the population of the organism.

The data pertaining to mean per cent incidence has been presented in the table 6 and illustrated in the figure 3, it was evident from the table that the incidence of shoot borer ranged from 1.2 to 9.32 per cent during course of study. The maximum (9.32 %) incidence noticed in the first fortnight of May followed by 8.72 and 8.1 per cent during second fortnight of May and second fortnight of April, respectively. Whereas, minimum (1.2 %) incidence was recorded during second fortnight of August. It is clearly indicates that the incidence gradually increased from first fortnight of March to first fortnight of May, thereafter declined trend was recorded during course of investigation.

So far as the effect of the weather parameters is concerned, the highest incidence (9.32 %) during first fortnight of May was recorded with corresponding weather parameters i.e. maximum, minimum temperature ($^{\circ}\text{C}$), relative humidity (%) at 07 00 and 14 00 hrs and rainfall (mm) were 38.6, 24.2, 67.0, 35.8, and 1.3 respectively. On the other hand minimum incidence of pest (1.2 %) was recorded during second fortnight of August when the weather parameters were 32.5, 25.9, 91.2, 73.9 and 81.7, respectively. It was evident from the data that the incidence of the pest started declining from first fortnight of June to August (Table 6).

From the above experimental findings, it was obvious that the incidence of the pest was maximum during the May and minimum during August. This might be due to variation in the maximum, minimum temperature, relative humidity and rainfall during the study period. The present finding is in close to conformity with the report of Rao *et al.* (1991) who reported that the planting time, temperature, humidity, rainfall and variety had little influence on infestation by *Chilo infuscatellus*, while soil type, moisture stress and moon light had sown to definite influence on pyralid activity. Besides plant physiological factors also appeared to have a prominent role in the population of *Chilo infuscatellus*. Further Jenna and Patnaik (1996) studied the effect of planting dates on the incidence of *Chilo infuscatellus* on sugarcane, revealed that planting of sugarcane from January to April resulted in 13.04-24.84 per cent dead

hearts at 105 days after planting. Planting during June-October revealed the pest infestation of 1.54-5.45 per cent, while planting during November –December resulted increase in infestation (5.08-10.56 per cent). However, the present results are in accordance with the reports of few workers (Rachappa and Naik, 2000; Kumar *et al.* 2007 and Bhatti *et al.*, 2008).

Correlation Coefficient:

The correlation analysis between weather parameters and the mean per cent of incidence of the pest summarised in table 7. The data revealed that among the weather parameters under study only maximum temperature influence the pest incidence and showed positive correlation. The correlation coefficient (r) for maximum temperature was computed as 0.694*. The relative humidity at 07 00 hrs, 14 00 hrs and rainfall showed significant negative correlation and correlation (r) was computed as -0.899**, -0.864** and -0.698*, respectively. The minimum temperature (r= -0.297) showed non significant effect on pest incidence.

Multiple linear equation was also worked out by taking incidence as dependant variable and climatic factors as independent variable (Table 7a). It was evident from the data that coefficient of determination (R^2) was significantly high and showed 88.36 per cent with incidence. This showed that variability in incidence during different months of study could be governed to the extent of 88.36 per cent due to combined effect of climatic factors.

Table 6. Incidence per cent of shoot borer on sugarcane

Observation period	Observations interval	Cumulative incidence (%)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
			Minimum	Maximum	07 00 hrs	14 00 hrs	
March, 2014	I	3.25	13.2	26.9	88.8	46.6	10.6
	II	4.36	17.2	32.7	77.8	35.1	0.0
April, 2014	I	7.91	18.0	35.7	71.6	31.6	0.0
	II	8.1	21.0	38.4	65.6	25.0	0.0
May, 2014	I	9.32	24.2	38.6	67.0	35.8	1.3
	II	8.72	24.0	36.6	77.2	40.5	62.7
June, 2014	I	7.1	26.6	36.5	82.5	53.8	24.6
	II	6.8	26.1	35.9	83.4	63.7	68.6
July, 2014	I	3.56	26.6	32.8	89.6	74.3	212.6
	II	2.98	26.4	32.3	88.1	71.9	127.2
August, 2014	I	1.78	26.5	32.9	90.5	78.2	270.2
	II	1.2	25.9	32.5	91.2	73.9	81.7

I- First fortnight ; II- Second fortnight

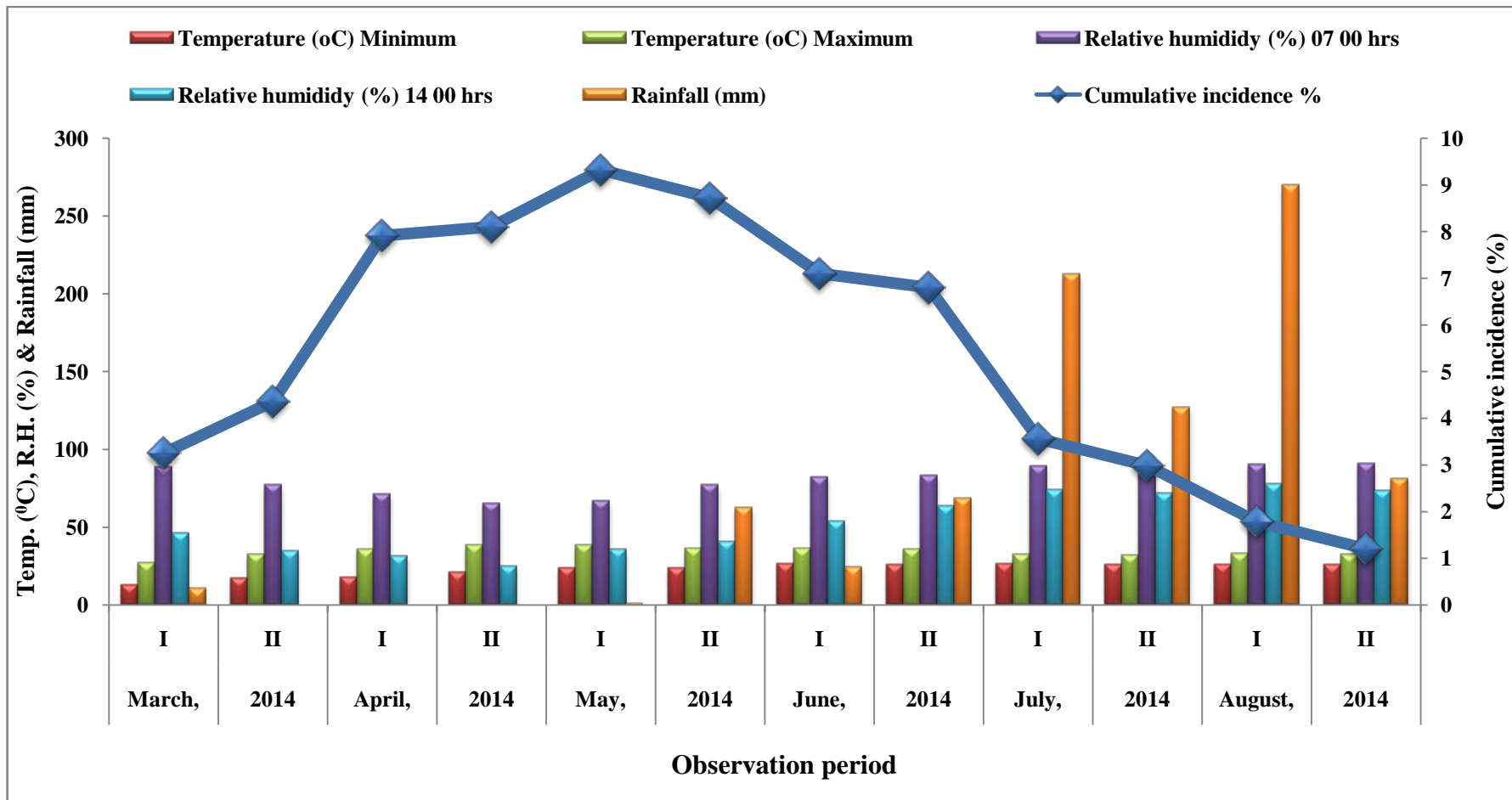


Fig. 3 Incidence per cent of shoot borer on sugarcane

Table 7. Correlation: Effect of weather parameter on shoot borer incidence in sugarcane

Larvae	No. of observation	Weather parameter				Rainfall (mm)
		Temperature (°C)		Relative humidity (%)		
		Minimum	Maximum	07 00 hrs	14 00 hrs	
Shoot borer incidence (%)	12	-0.2937*	0.6945*	-0.8995**	-0.8642**	-0.6985*

*- significant at 5 % probability level.

** - significant at 1 % probability level.

Table 7(a). Multiple linear regression models for weather parameters on shoot borer incidence in sugarcane

Incidence (Y)	No. of observation	Pure constant	Weather parameter				Rainfall (mm) (X ₅)	R ²
			Temperature (°C)		Relative humidity (%)			
			Minimum (X ₁)	Maximum (X ₂)	07 00 hrs (X ₃)	14 00 hrs (X ₄)		
Larvae	12	-20.5701	-0.1078	0.6969	0.1368	-0.1369	-0.0005	0.8836**

** - significant at 1 % probability level.

Multiple regression equation:

$$Y = -20.5701 - 0.1078(X_1) + 0.6969(X_2) + 0.1368(X_3) - 0.1369(X_4) - 0.0005(X_5)$$



Plate 5: Leaf injury symptom



Plate 6: Damaged shoot by SB



Plate 7: Dead heart of SB



Plate 8: Damaged growing point



4.4.1 Extent of parasitization on shoot borer by *Trichogramma chilonis* in sugarcane under natural condition.

The extent of parasitization of *Chilo infuscatellus* eggs by *Tricogramma chilonis* Snellen in sugarcane in different months of the study during infestation and its correlation with weather parameters were presented in Table 8 to Table 9a and illustrated figure, 4. It is evident from the data (Table 8) that the parasitization of eggs started from first fortnight of March to first fortnight of July. Parasitization ranged from 3.6 to 15.6 per cent during the course of investigation and there was untraceable parasitization during second fortnight of July and in August. This might be due to heavy rainy days. Parasitization showed a steady increase and reaching a peak 15.6 per cent in first fortnight of May thereafter parasitization was observed gradually decline trend. However, there was statistically significant difference in the extent of parasitization during different months of study (March to July) on sugarcane crop.

So far as the effect of the weather parameters is concerned, the maximum (15.6%) parasitization during first fortnight of May was recorded with corresponding weather parameters i.e., maximum, minimum temperature ($^{\circ}\text{C}$), relative humidity (%) at 07 00 and 14 00 hrs and rainfall (mm) were 38.6, 24.2, 67.0, 35.8 and 1.3, respectively. On the other hand minimum (3.6 %) parasitization was recorded during first fortnight of July when the weather parameters were 32.8, 26.6, 89.6, 74.3 and 212.6, respectively. It was evident from the data that the parasitization started declining from second fortnight of June to first fortnight of July and became untraceable in the second fortnight of July and in August. The present findings on parasitization of shoot borer on sugarcane were in partial agreement with the results of Muhammad *et al.*, 2012 and Nadeem and Hameed, 2011.

Correlation Coefficient:

Simple correlation was worked out between weather factors and extent of paraitization (Table 9). It was observed form the table that maximum temperature showed significant positive correlation with parasitization of shoot borer while, relative humidity at 07 00 hrs ($r = -0.953^{**}$) and rainfall ($r = -0.742^{**}$) significant negative correlation but relative humidity at 14 00 hrs ($r = -0.443$) and minimum temperature ($r = 0-0.460$) were showed non significant negative correlation with parasitization.

Thus, it is clearly indicates that maximum temperature was congenial element for parasitization on shoot borer.

Multiple linear regression was also worked out by taking parasitization as dependent variable and climatic factors as independent variables (Table 9a). It reveals from the data that coefficient of determination (R^2) was significantly high and showed 93.39 per cent with parasitization, this shows that viability in parasitization during different months of the study could be governed to the extent of 93.39 per cent due to combined effect of climatic factors.

Table 8. Extent of parasitization per cent by *Trichogramma chilonis* on shoot borer under natural condition

Observation period	Extent parasitization (%)	Temperature(°C)		Relative humidity (%)		Rainfall (mm)
		Minimum	Maximum	07 00 hrs	14 00 hrs	
March, I 2014	4.3	13.2	26.9	88.8	46.6	10.6
II	7.6	17.2	32.7	77.8	35.1	0.0
April, I 2014	9.0	18.0	35.7	71.6	31.6	0.0
II	10.6	21.0	38.4	65.6	25.0	0.0
May, I 2014	15.6	24.2	38.6	67.0	35.8	1.3
II	12.3	24.0	36.6	77.2	40.8	62.7
June, I 2014	11.0	26.6	36.5	82.5	53.8	24.6
II	8.3	26.1	35.9	83.4	63.7	68.6
July, I 2014	3.6	26.6	32.8	89.6	74.3	212.6
II	0.0	26.4	32.3	88.1	71.9	127.2
August, I 2014	0.0	26.5	32.9	90.5	78.2	270.2
II	0.0	25.9	32.5	91.2	73.9	81.7

I-First fortnight ; II- Second fortnight

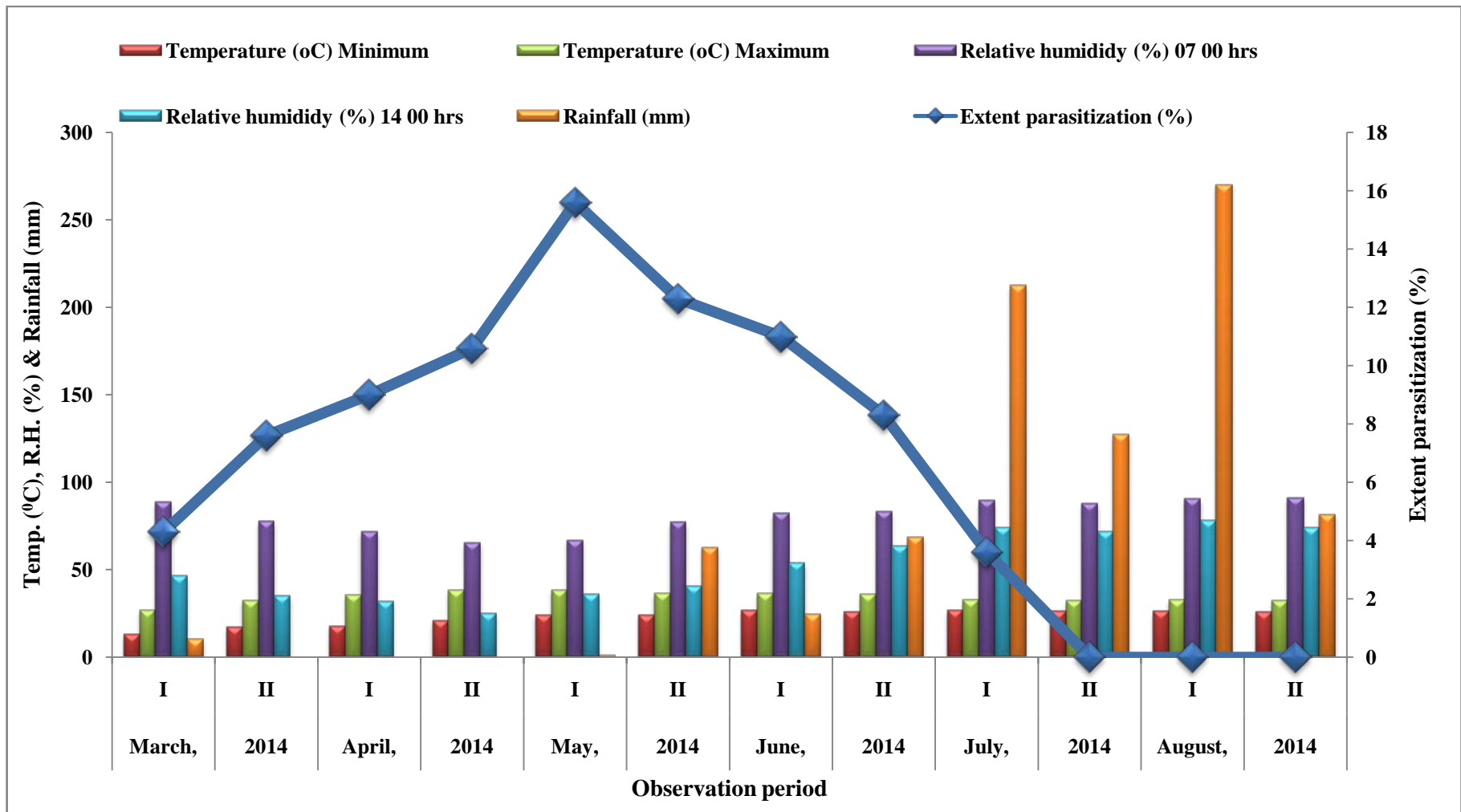


Fig. 4 Extent of parasitization per cent by *Trichogramma chilonis* on shoot borer under natural condition

Table 9. Correlation: Effect of weather parameter on Shoot borer parasitization in sugarcane

Eggs	No. of observation	Weather parameters				Rainfall (mm)
		Temperature (°C)		Relative humidity (%)		
		Minimum	Maximum	07 00 hrs	14 00 hrs	
Parasitization	12	-0.4603	0.6224*	-0.9528**	-0.4433	-0.7424**

*- significant at 5 % probability level.

** - significant at 1 % probability level.

Table 9(a). Multiple linear regression models for weather parameters on shoot borer parasitization in sugarcane

Eggs (Y)	No. of observation	Pure constant	Weather parameter				Rainfall (mm) (X ₅)	R ²
			Temperature (°C)		Relative humidity (%)			
			Minimum (X ₁)	Maximum (X ₂)	07 00 hrs(X ₃)	14 00 hrs(X ₄)		
Parasitization	12	57.8955	0.1855	-0.4300	-0.5091	0.0039	0.0209	0.9390* *

** - significant at 1 % probability level.

Multiple regression equation:

$$Y = 57.89 + 0.1855(X_1) - 0.4300(X_2) - 0.5091(X_3) + 0.0039(X_4) - 0.0209(X_5)$$



SUMMARY AND CONCLUSION

To study the biology and seasonal incidence of shoot borer, *Chilo infuscatellus* Snell. Laboratory as well as field experiments were conducted during 2014-15. The study on biology of *Chilo infuscatellus* was conducted in laboratory at Department of Entomology, whereas a field experiment was laid out at Research Farm of S. R. I., Pusa to assess the seasonal incidence of *Chilo infuscatellus*. The results obtained in the present investigation are summarised below

Biology of the sugarcane shoot borer, *Chilo infuscatellus* Snell.

The caterpillars were collected from the experimental plots and reared in the laboratory to study its biology. The caterpillars were released along with soft pieces of canes of 10 cm length for taking the observation.

The eggs were oval in shape, dorsoventrally flattened, looked like scale of fish and were laid in masses on the under surface near to mid rib of leaf. Freshly laid eggs were creamy white in colour, which gradually changed to yellowish and after 24 hours of eggs laying the pin head size spot was observed. Empty egg shells were white and remained attached to the leaf. The incubation period ranges from 4.35 to 4.45 (Mean 4.4 ± 0.02) days.

The larva passed through five instars to complete the larval period. Freshly emerged larva was active, greyish white in colour with black head and immediately after hatching moved fast in search in food material. The duration of first instar larva ranges from 2.12 to 2.18 (Mean 2.15 ± 0.01) days.

The second instar larva was dirty white in colour with prominent dark stripe on mid dorsal portion and impression of stripes was found on the body. The duration second instar larva ranges from 3.15 to 3.26 (Mean 3.21 ± 0.02) days.

The third instar larva was similar in colour of second instar larva with dark black head and black spots on tubercles were absent. The duration of third instar larva was ranges from 3.25 to 3.38 (Mean 3.31 ± 0.03) days.

The fourth instar larva was dirty white in colour with dark brown head. The body posses five violet stripes, one on dorsal surface, one pair each on the tubercles which were present on the eight abdominal segments. The duration of fourth instar larva ranges from 3.52 to 3.63 (Mean 3.57 ± 0.02) days.

The fifth instar larva was also similar in colour of fourth instar larva with dark brown head and five violet stripe extending from second thoracic to eighth abdominal segment and its duration ranges from 4.62 to 4.78 (Mean 4.7 ± 0.04) days. The total larval period varied from 16.66 to 17.23 (Mean 16.94 ± 0.12) days.

The pupa was obtect type, the newly formed pupa was elongated, slender and greyish in colour which later turned into dark brown in colour. The pupal period lasted for 6.92 to 7.5 (Mean 7.21 ± 0.13) days.

The female adult moth was light straw to brownish in colour without any dark markings on the outer edge of the forewings and the hind wings were grayish white in colour. The female duration ranges from 4.31 to 4.45 (Mean 4.38 ± 0.03) days. While the male moths were light straw to brownish grey coloured forewings with dark markings on the outer edge and grayish white hind wings. The male duration ranges from 3.62 to 3.80 (Mean 3.71 ± 0.04) days. The total life cycle of shoot borer, *C. infuscatellus* from egg to adult emerged from 31.95 to 32.82 (Mean 32.28 ± 0.20) days.

Estimation of absolute population of *Chilo infuscatellus* Snell. on sugarcane.

The absolute population of the larvae were noticed in the field during the first fortnight of March, 2014 to second fortnight of August, 2014. The peak population of larvae were recorded in the first fortnight of May thereafter population of shoot borer was decline on the crop. The relation between population of insect and weather parameters were studied through correlation and it was found that the positive correlation with maximum temperature as the temperature increased the population of the insect also corresponding increased.

Seasonal incidence of shoot borer, *Chilo infuscatellus* Snell. on sugarcane.

The incidence of shoot borer, *C. infuscatellus* on sugarcane commenced from March and continued its activity till the month of August, 2014. The maximum (9.32 %) incidence of shoot borer was recorded in the first fortnight of May, 2014 with corresponding weather parameters *i.e.* minimum, maximum temperature ($^{\circ}\text{C}$), relative humidity (%) at 07 00 hrs and 14 00 hrs and rainfall (mm) were 24.2, 38.6, 67.0, 35.8 and 1.3, respectively. The incidence of shoot borer with weather parameters, where maximum temperature showed significant positive correlation and relative humidity and rainfall showed significant negative correlation.

Extent of parasitization on shoot borer eggs by *Trichogramma chilonis* in sugarcane under natural natural condition.

Extent parasitization of *Chilo infuscatellus* Snellen eggs by *Trichogramma chilonis* Ishii. started from first fortnight of March to first fortnight of July. The peak parasitization was recorded in the first fortnight of May and minimum in the first fortnight of July, 2014. The parasitization started declining gradually from second fortnight of July. The maximum temperature showed the significant positive correlation with parasitization, while relative humidity at 07 00 hrs and rainfall showed significant negative correlation. The *Trichogramma chilonis* was an important egg parasitoid against shoot borer on sugarcane from March to July based on results.



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