

**BIONOMICS OF THE SUGARCANE TOP SHOOT BORER,
TRYPORYZA NIVELLA (FAB.) (PYRALIDAE: LEPIDOPTERA)**

MD. SIRAJUDDIN

M. Sc. (Ag.)

D-1560

**Thesis submitted to the University of Rajshahi in
fulfilment of the requirements for the degree of**

Doctor of Philosophy

November, 1990

**Department of Zoology
Faculty of Life and Earth Science
Rajshahi University
Rajshahi—6205**

STATEMENT

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and, to the best of my knowledge and belief, the thesis contains no material previously published or written by any other person, except when due reference is made in the text of the thesis.

November, 1990

Md. Sirajuddin

MD. SIRAJUDDIN

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ABSTRACT

The bionomics of the top shoot borer, Tryporyza nivella (F.) of sugarcane have been carried out as follows:

- i) The systematics has been reviewed and the identification has been confirmed.
- ii) The biology of the pest was studied both in the field and under laboratory condition. The female lays eggs in masses on the undersurface of sugarcane leaves. Newly-hatched larva bores through the midrib and enters into the spindle causing 'dead heart' or 'shot-holes'. A single larva infests a single cane only and there it passes its larval and pupal stages. The moth comes out of the cane through the exit hole. The top shoot borer passes five instars during its larval stage. The instars were identified by regular sampling of the infested canes and confirmed by the application of Dyar's law. Occurrence of five broods in a year was confirmed.
- iii) Seasonal and regional (11 north-western sugarmills zones of Bangladesh) incidence of the pest have been surveyed. The incidence in all the mills zones was always minimum in the first brood. It increased up to brood number four and

decreased in the last or fifth brood. The incidence was the highest at Panchagarh among all the eleven study areas. It is also evident that the relationship between temperature and humidity is not independent but the two variables interact on the percentage of infestation.

iv) Varietal behaviour (susceptibility to pest attack, reducing ability for loss in yield and recovery) of the four promising varieties Isd-16, Isd-17, Isd-2/54 and L.J.C. has been assessed. Variety Isd-16 was the least susceptible to top shoot borer while L.J.C. was the most susceptible one. Infestation of the top shoot borer produces a remarkable reduction in the length, circumference and weight of all the varieties. It has also a detrimental effect on the sucrose recovery in all the varieties studied. The loss was highest (35.598%) and the lowest (6.28%) in Isd-17 and L.J.C. respectively.

v) Efficiency of mechanical control practice has been evaluated. Without mechanical control the incidence of T. nivella was 4.80 - 55.80% in the grower's field and it was 4.64-13.45% in all other study areas where usual mechanical control practice was adopted. But this practice adopted properly in the present investigation efficiently reduced the incidence and it was 4.20-6.60% only.

vi) The natural enemies (parasites) of top shoot borer prevailing in the study areas have been identified

and their effectiveness in controlling the pests in different broods at different sugarmill zones have been observed.

Biology of the most common three parasites (Elasmus, Stenobracon and Topobracon sp.) has been studied.

During the study six hymenopterous parasites have been recorded. These are: Isotima javensis Rohw. (Ichneumonidae), Elasmus zehntneri Ferr. (Elasmidae), Stenobracon nicevillei Bingh (Braconidae), Topobracon jokohamensis Cam. (Braconidae), Rhaconotus schoenobivorous Rohw. (Braconidae) and Apanteles flavipes Cam. (Braconidae). Of them, I. javensis was solitary and found both in larvae and pupae of the host. S. nicevillei and T. jokohamensis were also solitary but they were found only in the larvae. But E. zehntneri, R. schoenobivorous and A. flavipes were gregarious larval parasites. T. jokohamensis was marked as the most effective species in controlling the top shoot borer. A. flavipes and I. javensis were very much rare and they were totally absent at Mobarakganj, Dorshona and Jogoti. A. flavipes was also absent at Jaipurhat. The percentage of parasitism by six different parasites collectively was maximum (49.50%) at Panchagar and the minimum (21.50%) at Shyampur in the peak period of parasitism i.e. in the fourth brood.

ACKNOWLEDGEMENTS

I express my deepest sense of gratitude and indebtedness to the late Professor Mustafizur Rahman, Department of Zoology, Rajshahi University. Most of the research work had been carried out under his invaluable supervision. I will ever remember his sincere, expert help in planning of the experiments, for his constant interest, stimulating discussion and valuable suggestions. I am also grateful to Professor Munshi Abdul Quayum, Director, Institute of Biological Science, Rajshahi University and Dr. M. Khalequzzaman, Associate Professor, Department of Zoology, Rajshahi University for able supervision, valuable suggestions and constructive criticism.

I am very much thankful to Dr. M. Sayedur Rahman and Mr. M. Sohrab Ali, ex-Chairmen and to Dr. N.I.M. Abdus Salam Bhuiyan, Chairman, Department of Zoology, Rajshahi University for providing necessary laboratory facilities. Deep appreciation is due to Dr. M.A. Hossain (i) and Dr. M.A. Hossain (ii), Professors and other teachers of the Department for their kind interest, occasional help and encouragement.

Grateful thanks are due to the University Grants Commission, Bangladesh for offering a fellowship and to the Ministry of Education, Government of Bangladesh for granting a study leave.

I would like to extend grateful thanks to the authorities of the Sugar Mills Corporation and Sugarcane Research Institute, Ishurdi for their co-operation during the field works. Director, Institute of Bangladesh Studies, Rajshahi University deserves special thanks for offering accommodation facilities during the tenure of the study. Occasional suggestions extended by Professor Humayun Kabir, Department of Zoology, Dhaka University is gratefully acknowledged. Efficient typing of the thesis by Mr. Ajit Kumar Chakrabarty, Institute of Bangladesh Studies, Rajshahi University is thankfully acknowledged.

I wish to express my gratefulness to relatives, members of my family and other well-wishers for moral support. Finally, I wish to thank my wife Mrs. Jinnat Mohal for her moral support, sacrifice and constant encouragement during this work.

MD. SIRAJUDDIN

INTRODUCTION

CHAPTER-1



INTRODUCTION

INTRODUCTION

Sugarcane (Saccharum officinarum L.) is an important cash crop of different countries of the world. It is grown in tropics and sub-tropics (i.e., 35°N and 35°S). South Africa, Cuba, Mexico, U.S.A., Argentina, Brazil, Columbia, Dominica Republic, Equader, Bangladesh, China, India, Indonesia, Pakistan, Philippines, Thailand and Australia are the principal sugarcane growing countries. Some other cane growing countries are Mauritius, Swaziland, Barbadas, Haiti, Honduras, Jamaica, Puerto Rico, Trinidad, Guyana, Nepal, Afghanistan, Spain, Fiji, Malawi, Nigeria, Reunion and Rhodesxia (Bishop, 1975).

According to Agricultural Directorate of Bangladesh only 76.113 hactre (0.188 million acres) of land were brought under sugarcane cultivation in the crop season 1978 and there were 14 sugarmills in the country. But the acreage now has gone up to 1,73,309 hactre (0.428 million acres) and the number of sugarmill is 16 in all (Anon, 1984). Though the acreage has gone up, the yield per acre has not gone up substantially at that rate. It is about 500 mds. per acre as it were in 1978. Whereas in Hawaii the yield is about 3500 mds. per acre. We are not only defficient in yield but the recovery percentage of sugar is also the lowest.

Here the recovery percentage is about 7.50 per cent while it is about 14 per cent in Austria.

There are various reasons for the low yield and less recovery of sugar. The reasons are i) poor variety, (ii) insufficient pest and disease control methods, (iii) low doses of fertilizer given, (iv) lack of irrigation facilities, (v) lack of proper drainage facility and above all (vi) lack of scientific knowledge (Rahman, 1970b). According to Huq (1988) lack of proper cultivation of sugarcane results sufficiently inadequate yield and there is a room for 2-3 fold improvement. Thus it calls for immediate attention of our scientist.

The ultimate aim of agriculture is to produce a sustained economic yield and thus it becomes necessary to understand the impact of insect pest population on the subsequent yield or harvest. The insects causing no crop loss and subsequent damage to the plant may be ignored, and in the context of ecological stability they should be left uncared. However most pest populations produce significant damage but the damage assessment in relation to possible or expected yield loss is difficult. The total number of interacting factors responsible for determining crop yield is quite overwhelming, and any decision as to the probable effect of any single factor, such as the population of one insect species,

is problematical. However, the gradual accumulation of empirical data over many years has resulted in our being able to make various generalizations about some pest populations and their probable effect on crop yield. These results are used to define economic injury levels for some pests on some crops in different parts of the world (Hill, 1983).

Pests of sugarcane may be generalized plant feeders (polyphagous) or there may be restricted to grasses or to Saccharum species and their near relatives (Oligophagous), (Williams, et al. 1969). There are 12 alternative hosts of top borer (Fletcher and Ghosh, 1919; Gupta and Avasthy, 1954; Ghani, 1962; Huque and Agarwala, 1955a and Nair et al., 1971). It has also been reported to occur on Oryza sativa Linn, (Jepson, 1954 and Hill, 1983).

Insect species feeding on sugarcane are diverse, very numerous and characteristically of limited geographical distribution (Pemberton and Williams, 1969). Box (1953) listed about 1,300 species, about 75 per cent of which were listed from sugarcane in only one country or island. About 1,500 species have so far been recorded in this crop all over the world (Long and Hensly, 1972).

Insect pests play a significant role in reducing crop yields of sugarcane in Asia (Grist and Lever, 1969; Barr et al., 1975). Rai and Rai (1979) reported severe damage

to crops by the pest to such an extent and frequency that they often result in economic and social changes in many places. A large number of countries are loosing millions on agricultural productions due to ravages of weeds, plant diseases, insect and rodents of which loss due to insect alone is 25 per cent (Miah et al., 1980).

The species T. nivella occurs throughout the Orient including Pakistan, India, Srilanka, Bangladesh, Burma, Indonesia, Indo-China (Laos, Cambodia and Vietnam), China, Japan, Pyuka Island, Taiwan and Philippines. It is widely distributed in India, though is paritively destructive in Northern region than in the Southern (Srivastava et al., 1983). It has also been reported to cause serious damage to the sugarcane by top shoot borer in various Asian countries like Burma, Cylon, China, Formosa, India, Japan, Malayasia, Pakistan, Philippines and Thailand (Carl, 1962; Gupta, 1959a and Pemberton, 1962). Scirpophaga, Chilo and Emmalocera are considered as serious old world genera (Lever, 1972).

In Bangladesh, sugarcane is attacked by a large number of insect pests, of which some are of minor importance, but quite a few of them cause considerable damage to sugarcane from seedling stage to harvest stage (Rahman, 1970a). The

important ones are: top shoot borer, *Tryporyza* (= *Scirpophaga*) *nivella* (F.); Stem borer, *Chilo infuscatellus* Snel; *C. tumidicostalis* Hamp; *C. auricilius* Dudge; Node borer, *Chilo* (= *Proceras*) *indica* Kapur; Root borer, *Emalocera dipressela* Walker; Leaf hopper, *Pyrilla perousilla* Walker; Termites, *Odentotermes obesus*; *O. assmuthi*; Black leaf hopper, *Eocrysa flavocapitata* M.; Scale insect, *Ripersia sacchari* G.; Leaf cutting weevil, *Tenymechus* sp. and *Millocerus discolour* (Alam *et al.*, 1964; Ali, 1974; Shahjahan, 1974; Rahman and Kabir, 1970; Alam, 1975; Siddique, 1978; Karim *et al.*, 1979 and Imam *et al.*, 1980).

The top shoot borer, *T. nivella* heads the list of the pests of sugarcane in India in general and particularly in Punjab (Rahman and Singh, 1944). It was reported as one of the most injurious insects attacking sugarcane in south and South-East Asia (Kalra and Sidhu, 1955; Rao and Chandy, 1957; Gupta, 1959a; Venkatraman 1961; Pemberton, 1962; Gupta, 1961; Carl, 1962 and Gupta *et al.*, 1965). It was the most destructive insect pest in Florida (Gifford, 1964). Hill (1983) described *T. nivella* (white Top Borer) as a pest of sugarcane in South-East Asia, India and China.

In Bangladesh, *T. nivella* is a serious pest of sugarcane (Hazarika, 1952; Ahmed, 1962; Kabir and Khan, 1974; Shahjahan, 1974a, 1974b, 1976; Rahman, 1970ab, 1976; Rahman *et al.*, 1979 and Khalequzzaman and Mannan, 1980). Damage

caused by this pest alone may go up to 30 per cent (Alam, 1967). Hence top shoot borer is obviously a major pest of sugarcane causing serious economic losses and thus becoming perennial pest problem of sugar producing countries.

In view of the severity of damage caused by this pest, it has been receiving a good deal of attention from Entomological workers (Gupta and Avasthy, 1954, 1956; Agarwal and Prasad, 1956; Rajani, 1960; Siddiqi 1961a; Kalra and Chaudhary, 1964b; Kalra and Sidhu, 1965; Gupta et al., 1965; Miah et al., 1980 and Khalequzzaman and Mannan, 1980) in Bangladesh.

Before taking any control measures against an insect species in a crop, the species must be correctly identified. Then its systematic position and biology are required to be known clearly. Besides that the knowledge about the incidence, occurrence of broods, varietal resistance and damage caused by the pest should be perfect. Finally survey of the alternate hosts of the pest and natural enemies if any, their identification, incidence, biology including host selection, solitary or gregarious, host-parasitoid interactions and the physiological interactions between them become the factors for study.

In Bangladesh some works have been carried out by different workers (Alam, 1967; Shahjahan, 1974a, 1974b; Rahman,

1976; Karim and Islam, 1976; Kabir and Khan, 1973; Karim, et al., 1979; Rahman et al., 1979; Khalequzzaman and Mannan 1980 and Miah et al., 1980). It is not surprising therefore that this pest claimed serious attention of the sugarcane Entomologists in home and abroad since more than six decades now. But progress towards finding a practical control, has been disappointing on account of lack of the detailed studies of this pest. This led to the present investigation.

CHAPTER-2



BRIEF LITERATURE SURVEY

2. BRIEF LITERATURE SURVEY

2.1 SYSTEMATIC POSITION OF THE SUGARCANE TOP SHOOT BORER :

The species of top shoot borer of sugarcane are the natives of the South and South-East Asian countries (Gupta, 1961). They are known as top shoot borer in Bangladesh and formosa, top borer in India, while Pyralid moth-borer in the Philippines, and white top borer in Java, all being the species of the genus Tryporyza.

The sugarcane top shoot borer belongs to the family Pyralidae and the sub-family Schoenobiinae under the order Lepidoptera. This pest was originally described by Fabricius in 1794 from India as Tinea nivella. But its systematic position has undergone good many changes (Butani, 1970). Tinea was transferred later into genus Crambus in 1798 (Banerji and Butani, 1975).

Available literature reveals that the Asiatic species are considered under the genus Scirpophaga which was established by Treitschke (1832) who stated that the name Scirpophaga is derived from the name of the plant, Scirpus and Phagein (means to eat). The main characters for the genus are: hindleg of the adult is long and the pupal stage is white, thin and transparent, with the hindleg extending beyond the body. Duponchel (1836) added further characters of the genus

and listed four other species as conspecific with Scirpophaga phontasmella [sic]: Tinea dubia Rohw., Bombyx alba Hubner, Phalaena albinella Craner and Eyprepia sericea Passerini. Among these P. albinella has subsequently been transferred to Rupela, and the last species E. sericea, cannot be traced from the original reference. In the same volume Duponchel (1846) called one closely related genus Schoenobius.

Zeller (1839) determined Phalaena, Alucita latidactyla Hubner as conspecific with S. phantasmatella, but he considered the specific names phantasmatella and latidactyla to be wrongly latinized, and so he used the name alba as the senior synonym.

Walker (1863a) wrongly synonymized Topentis (misspelling of Thopeutis Hubner 1818) with Scirpophaga. He discovered that Phalaena praelata Scopoli, 1763 had priority over S. phantasmatella. At the same time he erected a new monobasic genus, Apurima for the new species Apurima xanthogastrella. Apurima was subsequently placed as a synonym under Scirpophaga by Hampson (1895).

Because of the absence of a clear definition of the genus, the species in Scirpophaga were in the past, described in various other genera. For example, excerptalis and incertulas species were described in Chilo; innotata in Tipanaea and occidentella in Rupela. Even in the same species when sexual dimorphism occurred, the male and female

were named as two separate species. Walker (1863a) described the male of a species as Catagela admotella and later (Walker 1863b) the female as Tipanaea bipunctifera. These two names were subsequently placed as junior synonyms of S. incertulas.

Zeller (1863) redescribed Scirpophaga and added six new species to the genus: cirrea, gilviberbis, auriflua, chryso-rrhoa, monostigma, leucatea, which with virginia Zeller, albinella Cramer and the type-species praelata made nine species in all of which the first five species are true Scirpophaga, and that among these only gilviberbis is a valid name. In Schoenobius, Zeller (1863) described the male of Scirpophaga incertulas as minutellus and the female as punctellus. After this, Scirpophaga was mentioned in minor detail by many authors (Heinemann, 1865; Moore, 1867; Wocke, 1871; Butler, 1880; and Meyrick, 1882, 1885, 1886, 1889, 1890) Meyrick (1889) mentioned that in general Schoenobius could be separated from Scirpophaga by the relatively long labial palpi, but that in some forms when there was no difference in length the rough, erectly spreading tuft in the patagia of the male was a good character for distinguishing Scirpophaga. Moore (1886) cited S. praelata as type species of Scirpophaga.

Before 1891 the sub-family status of Schoenobiinae had not been recognized and Scirpophaga was placed in different families according to various authors. Duponchel (1846) erected the family Schoenobidae to include Scirpophaga and Schoenobius. Walker (1863a): Moore (1867, 1886) and Butler (1880) placed Scirpophaga in the Crambidae. Heinemann (1865) listed this genus under Chilonidae. Guenee (1875) erected the family Scirpophagidae to include Scirpophaga. But Meyrick (1882) placed the genus in the family Schoenobidae [sic] but later (1885: 1886: 1889: 1890) he referred it to Hydrocampidae.

The group, including the three genera Scirpophaga, Schoenobius and Donacaula was reduced to sub-family status by Ragonot (1891). Hampson (1895) was the first to attempt a classification of the Schoenobiinae. He separated them from the Cranbinae by the absence of both the proboscis and a cubital pecten. He recognized 25 genera in the sub-family and, under Scirpophaga listed Apurima, Rupela and Tipanaea as junior synonyms. Twenty-two species were included in Scirpophaga and the synonyms of the species were also listed. This paper caused much confusion to later workers as subsequently it was found that most of the species listed as junior synonyms are actually distinct species, or are synonyms of different species to those under which they are listed. In the following year Hampson (1896) recorded six species of

Scirpophaga from Congo, China, Borneo, Java, Formosa, Burma, Cylon and India. The species were S. auriflua (= Apurima xanthogastrella Walker = S. intacta Snell), S. monostigma, S. cilviberbis Zeller (= S. fusciflua Hampson), S. bisignata Swinh., S. excerptalis Walker and S. cramboides Walker.

Leech (1901) mentioned Scirpophaga after studying Chinese, Japanese and Korean material. Dyar (1913) in studying the North American species, found that the species, counted under the name Scirpophaga in the Nearctic region, are not true Scirpophaga. So he transferred the North American species to Rupela. The genus Rupela has been studied in detail by Heinrich (1937).

The biology of the pest was reported first in India by Lefroy (1906). He observed two types of female moths namely S. auriflua with yellowish brown anal tuft and S. intacta with red anal tuft. Fletcher and Ghosh (1919) mentioned two species from Pusa (Bihar), S. xanthogastrella (discarding S. auriflua as a synonym of the same) and S. monostigma. Later on Fletcher (1928) replaced S. xanthogastrella with S. nivella and referred to monostigma as a species different from nivella owing to the presence of one black spot on each of the forewings.

When Hampson (1919a) included Siga Hubner in the subfamily, he changed Schoenobiinae to Siginae because Siga had

priority. Later in the same year he replaced Scirpophaga by Topeutis [sic] for the same reason. He also described five new species under this genus (Hampson 1919b). But most authors still used Scirpophaga as the name of the genus. Topeutis [sic] remained, of course, in Schoenobiinae for quite a long time. It was recently that Bleszynski (1965) transferred it to Crambinae.

In spite of the rejection of the generic name Topeutis [sic], many authors (Caradja, 1925, 1932; Joannis, 1927, 1929 and Manrumo, 1934) followed Hampson (1919b) and used the term Siginae as sub-family. Joannis (1927) also mentioned species under Topeutis [sic]. But in 1929 he changed the generic name to Scirpophaga.

Forbes (1923), in studying the Lepidoptera of New York continued to use Schoenobiinae for the name of the family. Later (1926) he pointed out that the Schoenobiinae could be separated from other sub-families by the presence of vein 1A at the margin of the forewing. He also mentioned that Siga, which Hampson (1919a) included in Schoenobiinae (resulting in the changing of the name of the sub-family to Siginae), was actually Pynatine. Shibuya (1928) studied the Schoenobiinae of Taiwan and listed four species: S. praelata, S. nivella, S. excerptalis, and S. brunnescens.

and also provided a key to separate those species by using the colour of the forewing and of the anal tuft. Fletcher (1928) replaced S. zanthogastrella with S. nivella and referred to monostigma as a species different from nivella owing to the presence of one black spot on each of the forewings. Turner (1937) placed Sciepophaga in the family Schoenobiadae [sic].

Cherian and Subramanian (1938) observed dimorphic anal tuft in female moths -- yellow in S. auriflua and red or pinkish in S. rhodoproctalis. Gupta (1959c) reported that the later was identified by Dr. Tams of the Commonwealth (Imperial) Institute of Entomology, London, who kept the female moth red or pinkish tuft as a species other than S. auriflua. He (Gupta, 1959b) also added that insufficient description did not make him (Dr. Tams) able to trace out S. monostigma to be a species with certainty. Ayer (1940) also treated S. monostigma as a distinct species.

The controversy regarding the nomenclature of auriflua, xanthogastrella, rhodoproctalis, monostigma and nivella was set at rest by Narayanan and Venkatraman in 1951. They based their findings on the study of a large collection of both immature and adult stages of the borer collected from different localities in India. They observed that the larvae and the pupae of the two species bear identical morphological

characters. The authors also proved that as S. nivella and S. monostigma interbreed freely and, therefore, the two belonged to the same species. Gupta (1959c) reported to claim safely that only one species of the top borer, i.e., S. nivella occurs in all the cane tracts in India. He also opined that the presence of black dots on the forewings is simply a seasonal character and are found only in over wintering male moths and these dots should not be taken as a distinguishing factor for the species.

Box (1953) reported S. auriflua, S. intacta and S. xanthogastrella as synonyms of S. nivella. He has, however, mentioned S. monostigma and S. rhodotroctalis to be distinct species. Probably he did not come across the paper of Narayanan and Venkatraman (1951) and, therefore, the existence of three different species of top borer in India according to his list should not be considered authoritative.

Munroe (1956), in studying Hampson's Schoenobiinae, supported Forbes (1926) in his opinion that the true Schoenobiinae could not be separated from the Crambinae by the presence of vein 1A at the margin of the forewing. He (Munroe, 1956) listed 24 genera, including Scirpophaga, in the Schoenobiinae, and also discussed the position of some of the genera removed from the family. This paper has clarified much about the sub-family. Gupta (1954), Agarwal and Siddiqi (1964) and Butani (1966) in their review have stated that

the six species mentioned by Box (1953) are only synonyms of S. nivella.

Common (1960) classified the Australian species Scirpophaga and Schoenobius by using genital structures and assigned these species to six genera: Scirpophaga, Helonastes, Niphadoses, Catagela, Tryporyza and Tipanaea. Of these, Helonastes, Niphadoses and Tryporyza were described as new. In Scirpophaga, Common (1960) listed eight species, chrysorrhoea, phaedima, limnochares, xantharrenes, imparella, helodes, perena and ochrolenca and also erected the genus Tryporyza and characters used by him for separating this genus are found mainly in the genitalia. In the male, the subgenital process is curved, hook-like while in the female ostium bursae is broad, thickened and strongly wrinkled.

Avasthy (1969) considered Scirpophaga as congeneric to Tryporyza. Butani (1970) identified the Top borer of sugarcane as Tryporyza nivella. "This species had in the past, been misidentified as S. nivella and S. incertulas, has been identified as T. incertulas, a borer of rice in Indian sub-continent." He (1970) assumed that a male of the plain white winged species known as S. nivella and freely mated with a female of the spotted winged species known as S. monostigma. As the offspring consisted of

spotted and non-spotted forms, he concluded that in Indian region there is only one species of sugarcane top borer, T. nivella.

This scientific name T. nivella Fab. against top borer was used by so many authors in the following years, for example -

Agarwal et al., 1974

Ashref et al., 1974

Sindhu et al., 1977

Singh, 1978

Kalra et al., 1978

Singh et al., 1979, 1980

Gupta and Roy, 1982

Misra and Hora, 1982

Roy and Bains, 1983

Srivastava et al., 1983

Hill, 1983

Kumar et al., 1987

In Bangladesh, no study has yet been made on the taxonomy of sugarcane top shoot borer. But many workers carried out different experiments on this pest and passed the opinions as regards the naming and number of species.

Alam et al. (1964) and Alam (1967) reported S. auriflua, S. excerptalis and S. monostigma as three different species of top shoot borer. Later on Alam (1975) reported two species namely T. excerptalis and T. nivella. Rahman and Kabir (1970) observed two species of the pest S. auriflua and S. monostigma. According to Kabir and Khan (1974) S. monostigma is a rather common species in all sugarcane growing districts of Bangladesh. Shahjahan (1975, 1976) mentioned only Scirpophaga spp. and he did not mention specific name for the pest. Rahman (1976) reported that there is only one species of S. nivella which exists all over the cane growing areas of Bangladesh. But Karim et al. (1978) reported S. excerptalis as only species of the pest.

Rahman et al. (1979) used S. excerptalis (Fabricious) as the specific name of top shoot borer. But Mannan et al. (1980) used T. nivella (Fabricious). Miah et al. (1980) reported top shoot borer as S. excerptalis Walk. which was also used by Khalequzzaman and Mannan (1980) and Khan and Biswas (1981).

In the present study, the name of the only top-borer species of sugarcane in Bangladesh has been used as T. nivella, which is also confirmed by CIE, London.

The synonyms of T. nivella are

Tryporyza nivella (Fabricius, 1794)

Tinea nivella Fabricius, 1794: Zimsen, 1964: 577.

Holotype , India: Crambus niveus, ex. Ind. Or:
Mus. Sch. and T.L. (ZM. Copenhagen, genitalia
slide no. 3602).

Crambus niveus (Fabricius) Fabricius, 1798: 472: Zimsen,
1964: 577.

Scirpophaga monostigma Zeller, 1863. 3: Hampson, 1895:

913: 1896: 46(Partim); Joannis, 1929: 608. Holotype ,
locality unknown. Call. H. Sch-Patria Ignota: Coli.
Standingae (MNTIU, Berlin).

Scirpophaga butyrota Meyrick, 1889. 520: Lectotype ,
New Guinea; Part Moresby, K/88(BMNH, Pyralidae
genitalia slide no. 4021).

Scirpophaga intacta Snellen, 1890, 94: Hampson, 1895:

913: 1896: 46 (as synonym of Scirpophaga auriflua
Zeller): Joannis, 1929: 608 Lectotype: Java: Java Tagal,
Luc.; Dr. Kruger, Kagok, Tagal, Java. Brooder, PL. I.
Fig. 3 (RNH. Leiden). designated by Munroe et al.
(1958: 77).

Scirpophaga excerptalis (Walker) Hampson, 1895; 913:

Leech, 1901: 402 [Partin]: Butani, 1970; 169

[as synonym of Tryporyza nivella (F.).

[Scirpophaga chrysonrhoa Zeller sensu Hampson,

1895: 913 [Partin] Misidentification].

[Scirpophaga auriflua Zeller sensu Hampson, 1895: 913;

1896; 46 [Partin]: Senu Leech, 1901; 401 [Partin].

Misidentifications.

Topeutis [sic] rhodoproctalis Hampson, 1919b; 319, Holotype.

Singapore: Singapore (HN. Ridley) (BMNH,

Pyralidae genitalia slide no. 6324.

Scirpophaga xanthgastrella (Walker) sensu Fletcher and

Ghosh, 1919; 381 Pl. 41 Pl. 42, Fig. 1 [Partin].

Misidentification.

Tryporyza butyrota (Myrick), Common, 1960; 340.

Tryporyza nivella (F.) sensu Butani, 1970: 169: sensu

Nagaraja, 1972: 507.

2.2 REVIEW OF LITERATURE:

Lefroy (1906) was the first to work on the biology of top borer, T. nivella F. of sugarcane. Subsequently, identification, various aspects of its biology, anatomy, feeding habit and field life cycle have been studied in some details by a number of authors (Issac and Misra, 1933; Rahman, 1940; Pradhan and Arren, 1940, 1941; Issac and Rao, 1941; Issac and Venkatraman, 1961; Rao, 1947; Halbe, 1950; Bagal and Patel, 1951, 1953; Narayanan, 1953a; Raja, 1953; Bates, 1954; Doss, 1954; Huque and Agarwala, 1955a; Srivastava and Singh, 1956; Puri 1957ab, 1958ab; Gupta 1959c, 1959b; Butani, 1961; Patel, 1963; Singh, 1964ab; Kalra and Sidhu, 1965; Avasthy, 1969; Rahman and Kabir, 1970; Rahman et al., 1979; Singh et al., 1980, 1984; Perez et al., 1980; Patil and Hapase, 1981 and Mukunthan, 1986.)

The studies on the broods of the pest were carried out in India by Hussain (1935), Huque and Agarwala (1955b), Patel and Bagal (1956), Gupta (1959a), Kalra and Sidhu (1965), Venkatraman (1963) and Mukunthan (1986). In Bangladesh, Rahman (1970) observed the number of generations by studying the adult moths and egg laying of the pest. Studies on the occurrence of the broods of the pest was also studied by Rahman et al. (1979).

Information on the number and duration of larval instars of top shoot borer is surprisingly lacking. There is only one report in Bangladesh by Khan and Biswas (1981) regarding this aspect. They estimated the duration and number of larval instars by following Dyar (1890). But there is no statement about the ecdysis or moulting by them.

Studies on sex attractants and mating behaviour were carried out by Kalra et al. (1969, 1978), Jen (1981) and Chapman (1983). Mukunthan (1986) also stated the mating behaviour of the pest. 'Dead-hearts' formation by different species of sugarcane borer was studied by Khan (1944) and Rahman and Singh (1944). Kabir and Khan (1974) observed the mode of entry into the stem, formation of 'dead-hearts' and nature of damage of the sugarcane top shoot borer. Regarding the monopoly of one larva in one cane several authors (Huque and Agarwala, 1955a; Gupta, 1959a; Avasthy, 1969 and Srivastava et al. 1983) reported clearly.

The population study received a good deal of attention from entomological as well as ecological workers. Of course, the proper population studies requires the investigation of the incidence of larvae, pupa and abundance of pest moth in the field (Southwood, 1969). Different workers (Sharma, 1938; Pruthi and Narayanan 1939; Chaturvedi, 1942; Khan and Singh, 1942; Khanna and Ramanathan, 1946; Khanna and Bandyopadhyay, 1951; Sulaiman, 1954; Huque and Agarwala, 1955b;

Acharya et al., 1957; Nagaraja and Chandy, 1957; Rao and Chandy, 1957; Singh et al., 1957; Venkatraman 1961; Patel, 1963 and Agarwal, 1964) studied the population of T. nivella in the field. The population of this pest was also studied by Pali (1965), Kalra and Sidhu (1965), Rahman and Kabir (1970), Soedjono (1975), Shahjahan (1975, 1976), Rahman (1976), Kalra and Prasad (1978), Karim et al. (1978), Wirioatmojjo (1978), Mannan et al. (1980), Kalra (1980), Alvarez and Kidder (1981), Shah et al. (1981), Mukunthan (1984b), Hall (1986) and Masih et al. (1988) in relation to different factors.

The effect of rainfall on the pest incidence and correlation of the incidence with relative humidity and temperature were studied by Gupta (1955, 1959a), Butani (1963), Gupta et al. (1965), Atwal and Sidhu (1967), Rahman (1970a), Rahman and Kabir (1970), Mannan et al. (1980) and Rahman (1982). Drooping leaves with weak mid-ribs were thought to appear most prone to attack (Narasimhan, 1962). Hardness of spindle leaves has also been considered as a factor of resistance (Hazelhoff, 1932; Issac, 1939; Khanna et al. 1947; Khanna and Sharma 1949). Different authors (Hart, 1932; Hussain, 1935; Pruthi and Narayanan 1938; Rao and Venkatraman, 1941; Khanna, 1946; Adlakha, 1964; Rahman, 1970b and Mukunthan, 1984ab) reported the varietal resistance in relation to different factors. Consequently, low infestation and damage

to plant varieties by a particular insect species are designated as 'the resistant varieties' (Panthak, 1971). Thus the varietal resistance may be considered to help cumulative reduction of pest populations and lessens the need for chemical control.

Loss in yield due to top shoot borer was assessed by Sehgal et al. (1942), Khan and Rao (1956), Rajani (1960), Ahmed (1962), Summers et al. (1977), Kalra and Prasad (1980), Miah et al. (1980) and Kabir et al. (1989). Siddiqi (1961b) studied the loss of yield as well as sugar recovery. Variations in juice quality in top shoot borer affected canes was observed by David and Ranganathan (1960). Khanna (1956) recorded the tiller mortality and compensation due to the attack of top shoot borer.

Soman (1951), Barve (1951), Wagle (1952), Narayanan (1953b), Srivastava and Singh (1956), Long and Cancienne (1964), Alam (1967), Cancienne and Hensely (1966), Dorge and Murthi (1967), Avasthy (1967), Pali (1972), Shahjahan (1975) and Dubey and Sharma (1981) reported the possible measures of controlling top shoot borer.

Chemical control of top shoot borer was practised by Dugas and Smith (1933), Mehrotra and Bajpai (1938), Patel and Bagal (1953), Agarwala and Prasad (1954), Singh et al. (1954), Singh et al. (1956), Prasad and Prasad (1957), Siddiqi and

Rajani (1957), Gupta (1957), Gupta and Avasthy (1957ab), Long et al. (1959), Muthuswamy (1959), Kalyanaraman et al. (1959, 1960), Singh et al. (1961), Hensley and Concienne (1968), Waiyaki (1968), Kabir and Rahman (1968), Sandhu et al. (1974, 1977), Sandhu and Waraitch (1982), Chaudhary et al. (1982) and Mannan and Biswas (1989). But chemicals sometimes work against natural enemies of insect pests and should never be used in such a way that their sum effect is disadvantageous (Long, 1969). Long and Hensely (1972) reported that the chemical control of sugarcane top shoot borer is not satisfactory in spite of considerable development in the field pesticides. Moreover, spraying of foliar pesticides was also ineffective (Anonymous, 1983). This failure of chemicals necessitated biological control (Nickel, 1964; Dyck, 1972, 1973, 1974 and Alba and Estioko, 1981) as well as natural, integrated, cultural and mechanical control methods. One of the above agents can control an organised population or restrict or reduce the number of population (Debach, 1964). Humbert (1976), Avasthy (1977), Verma et al. (1979), Agarwal (1980) and Gupta and Roy (1982) reported the efficacy of integrated control. Charpentier and Mathes (1969) reviewed the cultural practices for sugarcane pest control in various countries and recommended this method as an adjunct to other control measures. Wagle (1951), Singh et al. (1954), Basheer, (1959), Lee and Pao (1962) and Shahjahan (1979b) observed the results of mechanical control against top shoot borer attack.

Effect of gamma BHC was reported by Siddiqi et al. (1959) and Singh and Sandhu (1963).

Regarding the control of top shoot borer, integrated control has been advocated by many workers (Rahman, 1970a). Biological control, the part of the integrated control for sugarcane pests, is a must for keeping the pest population below economic injury level (Shahjahan, 1975).

Studies on the pest and parasites were conducted by Holloway (1915), Thompson (1925), Cherian and Israel (1937, 1938, 1939, 1941, 1942), Flanders (1939), Lal (1939), Mani (1941), Rahman (1941), Walcott et al. (1943), Alam (1945), Ahmad and Mathur (1946), Rao and Kurian (1951), Narayanan and Mookherjee (1954), Gupta (1958) and Puttarudriah and Sastry (1958).

The possibility of introducing natural enemies to control sugarcane pests had been considered and inspired by Douth (1958) round the world. Attempts were taken in different aspects of natural enemies and biological control of top shoot borer in and around the country (Douth, 1959; Flanders, 1959; Gupta, 1960; Alam et al., 1961; 1971; Raja, 1961, 1964; Puttarudriah and Usman, 1961; Ali, 1962; Chen and Hung, 1962, 1963, 1975; Rao et al., 1963, 1964; Debach, 1964; Kalra and David, 1964; Mohanraj and Saxena, 1964; Rao, 1964; Singh, 1964b; Huffaker, 1971; Butani, 1972; Bindra et al., 1972; Hagen and Franz, 1973; Nagarkatti and Nair, 1973; Rahman,

1982; Shahjahan, 1974b; Rao and Murthy, 1976; Karim and Islam, 1977; Avasthy and Tiwari, 1978; Risco, 1978; Hall and Ehler, 1979; Summers and Prewitt, 1979; David et al., 1980; Vinson and Iwantsch, 1980; Sithananthan and Solayappan, 1980; Khalequzzaman and Mannan, 1982; Greany et al., 1984; David and Easwaramoorthy, 1985, 1986; Wardle and Borden, 1985; Chaudhary et al., 1986; Smith et al., 1987; David, 1987; Miah et al., 1986 and Pawar, 1987).

Williams et al. (1969) reported that the top shoot borer is killed by large number of parasites belonging to the families Anthocoridae (Hemiptera); Ichneumonidae; Braconidae; Pteromalidae, Eulophidae; Trichogrammatidae; Elasmidae; Bethyidae and Scelionidae (Hymenoptera) phoridae, Chloropidae and Tachinidae (Diptera). It has been reported that some of these parasites are quite active in killing the top shoot borer in India (Box, 1953; Cherian and Israel, 1937, 1938, 1941 and Gupta, 1960, 1961).

In Bangladesh, the presence and activity of some natural enemies (indigenous species) of top shoot borer larva or pupa are reported. Rahman and Kabir (1970) listed such type of four hymenopterous parasites. Six parasites occurring in nature was reported by Rahman (1976). Karim et al. (1978) reported two species of parasite of this pest.

The importance of egg parasites in controlling sugarcane borers has long been recognised by Flanders (1930), Gupta

(1960), Lee and Chiu (1961), Avasthy (1965) and Metcalfe and Breniere (1969). Trial with egg parasites have been conducted in U.S.A., Puerto Rico, Cuba, Jamaica, Madagascar, Taiwan, Mauritius, South Africa, China, Formosa, Japan, the Philippines and in India with success by Chen (1971), Saxena (1978), Verma and Singh (1979), Nagarkatti (1980), Agarwal (1980), Alba and Estioko (1981) and Sithananthan et al., 1982. In Bangladesh Shahjahan (1974b), Miah et al. (1984) and Alam et al. (1985, 1986) worked on egg parasitisation in sugarcane top shoot borer.

CHAPTER-3



MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 STUDY AREA

3.11 For intensive study:

Biology of T. nivella (Fab.) was studied in the Department of Zoology, Rajshahi University. Field observations and collections were mostly done in Meherchandi area (Fig. 1), located at $24^{\circ}2' N$ of latitude and $88^{\circ} E$ of longitude with $18.1^{\circ} N$ elevation. The nature of the soil of this area is sandy loamy. Most of parts of this area are high with some water logging low lands. Only the high fields were selected for the experiment. Plantation in this area was started in the month of November and continued till December. Irrigation was made twice a year in this field. The experiment was conducted between March 1987 to October 1990.

The biological study of three parasites was also carried out in the same study area during the year 1987-89.

An experiment on estimation of losses of sugarcane due to the infestation of top shoot borer was also conducted at Sugarcane Research Institute, Ishurdi, Pabna during the harvesting season in the month of February, 1988.

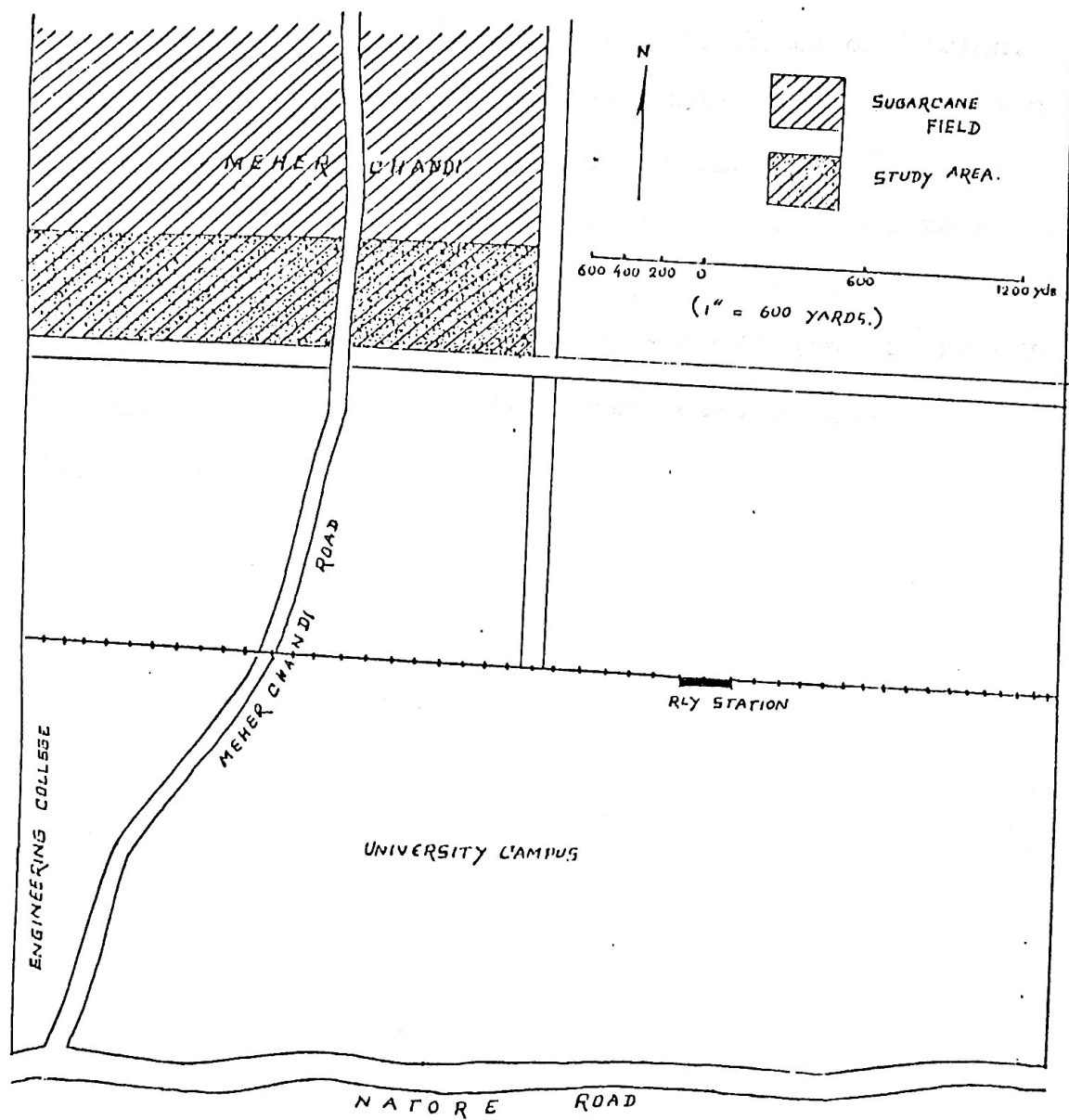


FIG. 1: INTENSIVE STUDY AREA OF MEHERCHANDI.

3.12 For extensive study:

Incidence of the pest and its parasites as well as efficacy of mechanical control practice were studied in as many as 11 sugarcane growing zones viz. Meherchandi (R.U. Agril. Farm) (Fig. 1) and Sugar Mill Farms of Harian, Jaipurhat, Mohimaganj, Shaympur, Setabganj, Thakurgaon, Panchagar, Jogoti, Dorsona and Mobarakganj (Fig. 2). The soil condition of all those experimental zones is sandy loamy except Shaympur and Setabganj where the soil is comparatively sandy. Detail weather condition of the experimental zones were collected from Meteorological Directorate, Bangladesh.

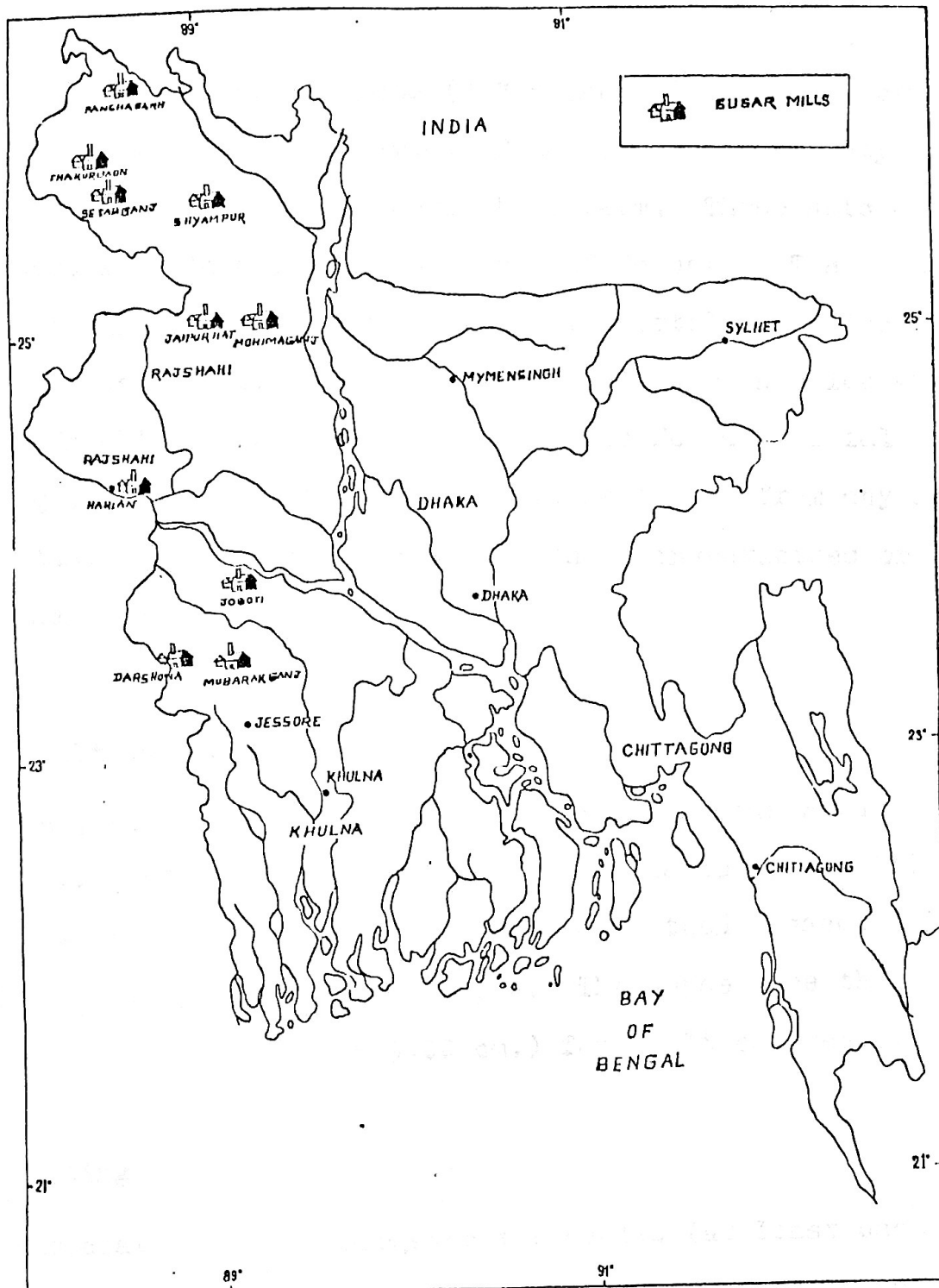


FIG. 2: SURVEY AREAS UNDER 10 DIFFERENT SUGAR MILL FARMS.

3.2 BIOLOGY OF THE PEST

3.21 Preparation of sugarcane plants in earthen pots

One hundred earthen pots (10" diameter) were properly filled with soil and press-mud. Seeds of Isd-16 variety were collected from Harian Sugar Mill Farm. Three sets of seed were sown in a pot in the month of January. The sprouted plants were watered properly. Fertilizers (Phosphate, Potash and Urea) at the ratio 3:3:1 were applied every year. In all, 500 plants were kept ready for artificial rearing of the pest. The plants were kept free from any sort of contamination either by application of insecticides or any other source.

3.22 Adult collection

Top shoot borer infested samples of sugarcane with 'dead heart' (DH) or 'shot-holes' were collected from different sugarcane fields. The sampled plants were then dissected in the laboratory to collect the pupae. The pupae were then kept in petridishes (1.7 x 9.00 cm.) for adult emergence.

3.23 Mating

Immediately after emergence the adults (at least one male and one female) were released on the caged sugarcane plants in the pots. Thus 25 pairs of adults were released at different cages for direct observation on mating behaviour and its

duration. Constant observations were made for 3 consecutive nights. The time of mating starts as well as the time of mating over were recorded carefully.

3.24 Pre-oviposition period, egg laying habit, eggmass and oviposition period

The mated females were kept under constant observations in the cage for observing pre-oviposition period, egg laying habits, oviposition period and number of egg masses per female. Besides, the size of egg masses were also recorded.

3.25 Fecundity

The egg masses of a single female moth were collected together. They were cleaned by removing the hair with the help of a fine camel hair brush under a simple microscope. The total number of eggs laid by a single female were counted with the help of a fine needle. The fecundity was finally ensured by counting the hatched larvae and unhatched eggs.

3.26 Developmental stages

3.261 Incubation period:

Some of the egg masses were kept unhurt to record the incubation period. The time of hatching of the first egg and that of the last egg was recorded. Five replications were taken for each of the five broods.

3.262 Hatching, movement and other activities of the neonate larvae:

A small number of potted infested plants having egg masses were taken in the laboratory to observe the change in eggs, hatching and movement of the neonate larva. To study the change in eggs, the hairs covering the egg masses were removed carefully with a camel hair brush. Similarly hatching was also observed keenly in the laboratory.

The movement of neonate larvae was studied in the infested potted plants under natural condition. Besides movement of the larva, tunnel formation, mode of entry into the shoot, formation of 'dead-heart', exit hole and pupal chamber etc. were also observed.

3.263 Larval stage:

The larvae just after hatching were carefully transferred to the spindle of 500 plants at the rate of 2-5 per cane to ensure the artificial infestation of them. From the next day five infested shoots were cut on alternate day. The shoots were carefully dissected in the laboratory and examined with the help of hand lens to record the number of larvae present inside the shoots. Stereo binocular microscope was used to detect the presence of exuviae and the consequent changes on the larval body. The width of head capsules was regularly measured by the said microscope with

the help of a stage micrometer. The measurements were recorded and calculated to have the means and their log 10 values. With the log values a graphical representation was prepared following Dyar's law (Dyar, 1890). The days in between the hatching of eggs and the formation of pupa were recorded and thus the larval periods were observed.

3.264 Pupal stage:

Some of the infested shoots were kept reserve for pupae collection. These shoots were dissected later on to collect the pupae. The pupae after collection were kept in petridishes (1.7 x 9.00 cm.). The pupae were kept separately in petri-dishes upto adult emergence to determine the pupal period. The days in between the formation of pupa and the emergence of imago were taken for pupal period. The changes took place in the pupa before the emergence of imago were also studied.

3.265 Emergence of imago and its activities:

Just after emergence the imago was transferred to the breeding chamber (caged sugarcane plants) separately to find out the time taken by the male and female imago to complete the process of emergence. Moreover, the activities of the imago after the completion of emergence was also studied.

3.266 Sex ratio and longevity of the adults:

The emerged adults were preliminary identified and was subsequently confirmed by CIE, London.

The number of adult moths (male or female) were carefully noted and thus the total number of males and females emerged, were recorded in each brood to determine the sex ratio. The adult moths were kept under observation till their death and thereby longevity of them was recorded.

3.3 MECHANICAL CONTROL

Experiment on efficiency of proper mechanical control over the incidence of top shoot borer of sugarcane was conducted in 11 sugar Mill Farms and in a grower's Farm of Harian in the year 1988-89. The variety L.J.C. was selected for this experiment. A plot was randomly taken under the experiment for each experimental zone. One hundred plants of any alternate line were randomly selected for observation. Then the top shoot borer infested shoots were separated for recording the infestation percentage. Five replications were taken for each brood at each experimental zone. Accordingly, infestation percentage of top shoot borer at all experimental zones were recorded.

Under usual mechanical control practice all the experimental zones were taken into consideration in one group. A plot of Harian Sugar Mill however, taken in the present investigation where proper mechanical control was adopted. Its effect on the percentages of infestation was recorded separately. A grower's plot without practice of mechanical control close to the said sugar Mill Farm was also taken under the experiment. And the percentages of infestation of this plot were also recorded.

The plots under proper mechanical control practices were kept under constant supervision. The mechanical control practice was adopted twice per brood while most of the pests were at larval stage.

The incidence of TSB in eleven experimental zones under usual mechanical control practices, in plots under proper mechanical control practices and in grower's plot were recorded separately and a graph was prepared with the mean percentages of pest of all the broods and data were analysed statistically.

3.4 ESTIMATION OF LOSSES

This experiment was carried out at Sugarcane Research Institute (SRTI), Ishurdi, Pabna during harvesting period in the month of February, 1988. Thirty infested and 30 uninfested sugarcane plants of each variety were randomly collected from Block 'B' of the Farm. During sampling of the infested plants, the plants infested only by top shoot borer but free from other pests or pathogens were taken. On the other hand, the plants free from any insect attack or pathogen were taken as uninfested samples. The canes after proper cleaning were taken in Physiology and Nutrition department of SRTI for further investigation.

Lengthwise and circumferencewise (at the base, middle and top) measurements were taken by a steel tape. Thirty samples (both infested and uninfested) of each variety were grouped into 6 and weighed with a spring balance of 23 kg capacity. The sampled canes were then subjected to chemical analysis for recovery percentage.

The average length, circumference and weight were recorded and their percentage of losses has been calculated. The differences between the infested and non-infested canes were subjected to t-test. In case of sugar recovery, the estimation of loss in percentage was also calculated by the formula

$$\text{Recovery} = \text{Pol} - \frac{(\text{Brix} - \text{Pol})}{2} \quad \text{E.F.}$$

3.5 INCIDENCE OF THE PEST

Incidence of top shoot borer was studied in 11 sugar Mill Farm areas viz. Meherchandi, Harian, Panchagar, Thakurgaon, Setabganj, Shaympur, Mohimaganj, Jaipurhat, Mobarakganj, Dorsona and Jogoti in the year 1987-88-89 . Four promising varieties Isd-16, Isd-17, Isd-2/54 and L.J.C. used by the farmers were taken into consideration for this experiment.

Continuous one hundred plants of any alternate line were randomly collected. The plants were checked properly to separate only the TSB infested ones and were counted. Thus 5 replications for each variety were taken and recorded. The data were collected 5 times at five different broods i.e.; in the month of March-May, May-June, June-August, August-October and October-March. The collected data were analysed.

3.6 OCCURENCE OF BROODS

Among the three techniques to determine the number of brood of top shoot borer as mentioned by Patel and Bagal (1957), the 3rd technique i.e., by determination the relative proportion of larvae to pupae in randomised samples collected, was followed in the present investigation.

The samples surely infested with top shoot borer were randomly collected from the study area Meherchandi during the crop season 1987. One hundred such samples were collected five times in a month at six days interval. They were carried to the laboratory. Then they were cleaned and split open with a sharp knife to note the number of larvae; pupae and empty shoots. Such examinations were made from March to December, 1987. In January and February, there were no plants in the field because old plants were harvested by then and young plants did not contain much infestation. So, the sampling in those two months was avoided.

3.7 STUDIES ON PARASITES

3.71 Incidence of the parasites:

Incidence of the parasites of top shoot borer was studied in all the experimental zones during the year 1987 to 1989. At each experimental zone 20 top shoot borer infested shoots were collected randomly from any alternate line. The shoots were then dissected and the shoots having parasitic stages were counted and recorded. Thus five replications were taken for each experimental zone. The data were collected five times a year at five different broods. The collected data were analysed.

3.72 Biology of the parasites:

The study of the biology of three common parasites (Stenobracon, Topobracon and Elasmus) of top shoot borer was conducted in the Department of Zoology, Rajshahi University during the year 1988-89. This study was conducted while the third and fourth brood hosts prevailed in the field.

Sugarcane shoots infested by top shoot borer were collected regularly from Meherchandi and Harian sugarcane fields. The shoots were dissected carefully in the laboratory just to observe whether the pest was parasitized. The shoots

having parasitic larvae inside were kept date-wise in glass jars (10.50 x 26 cm.) with small amount of water at the bottom to keep the condition of the shoots normal. Constant observations were made until the larvae pupated. Then the pupae were dissected out of the shoots. The gregarious parasitic pupae per host were counted and recorded. The solitary as well as the gregarious pupae of a host were kept in petri-dishes separately until adult emergence. The adult parasites just after emergence, were transferred into other petri-dishes separately to observe their longevity. Thus the larval, pupal and adult periods with sex ratio of three parasites were recorded. The data were analysed statistically. The adult parasites were preliminarily identified and they were finally confirmed by CIE, London.

3.73 Description of the less common parasites:

Three other parasites (Isotima, Rhaconotus and Apanteles) were less available during the survey of the work. So those species while available were kept under observation in the laboratory to study their habit and morphology. Thus a short description regarding those parasites was prepared.

3.74 Behaviour of the adult parasites:

During the biological study of common parasites and observation of habit and morphology of less common parasites, their adult emergence and egg laying behaviour were also observed.

CHAPTER-4



RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 BIOLOGY OF THE PEST:

4.11 Mating:

Mating is the precondition for propagation of life and maintenance of a race. This phenomenon varies from species to species in response to habit, habitat and other similar factors.

The adult sugarcane top shoot borer did not mate in the breeding chamber under laboratory condition even if it was provided with light facilities. But under natural field condition the adults were found to mate in the night where similar light facilities were available.

Mating (copulation) generally took place at any part of the night facing the body in the opposite directions (Plate I) on either side of the leaves. But some of the adults were found to mate in the dusk and dawn.

In the present study mating was found to occur in between evening and early morning and the process continued for 2-6 hours. Huque and Agarwala (1955b) reported that S. nivella mated only in the first half of the night and its duration was several hours. Mukunthan (1986b) observed that the adults copulated mostly during night and the copulation period was 25 minutes to 5 hours.



Plate - 1: Mating of T. nivella

The males and females were found to mate only once, but never they were found to mate twice. But Kalra et al. (1978) reported that some females rarely mated twice. During mating, on disturbance the paired adults pretended to remain moribund but ultimately flew away. Huque and Agarwala (1955b) and Mukunthan (1986) reported the same observation.

4.12 Pre-oviposition period:

The data on the pre-oviposition period have been represented in table I. The mean pre-oviposition periods were 1.30 ± 0.07 , 1.19 ± 0.05 , 1.14 ± 0.09 , 1.27 ± 0.07 , and 1.38 ± 0.06 days for 1st, 2nd, 3rd, 4th and 5th broods respectively (Fig - 3).

The maximum average pre-oviposition period was observed in the 5th brood and it was minimum in the second brood. This findings support the views of Huque and Agarwala (1955b) , Gupta (1959a) and Patel (1963). In the present findings, the pre-oviposition period ranged from 1.14 to 1.38 days. According to Huque and Agarwala (1955b) the pre-oviposition period was one day is general but in certain cases it was two days. Gupta (1959a) observed this period as one day. Patel (1963) observed pairing on the first night after emergence and egg laying in the second evening (i.e. this period lasts for two daya).

Analysis of variance shows a significant difference ($P < 0.05$, Appendix table- I) of pre-oviposition period among different broods with least significant difference (hereinafter called LSD) at 5 per cent level of significance and it has been calculated as 0.166 i.e. the average pre-oviposition period of fifth brood significantly differ with other broods.

4.13 Egg laying habit and eggmass:

Eggs were laid on the following day of mating. They were deposited in clusters of 1-4 overlapping rows. The egg masses were found mostly on the under surface of the leaves near the midrib and were covered by hairs of the anal tuft (Plate 2A). The egg laying habit observed in the present study as stated above is almost similar to the statement of Huque and Agarwall (1955) only with a slight difference of 2-5 overlapping rows of eggs in a cluster. But Avasthy (1965) observed the eggs in clusters of 2-4 overlapping rows.

The eggmasses were deposited on the 2nd to 5th leaves. This observation agrees with the opinion of Lee and Pao (1962).

Females preferably laid eggs on the young green plants i.e. the plots with comparatively young and green plants were always found to be more infested than the plots with old

plants. Doss (1956) found that the moths prefer young cane crops less than 6 months old for oviposition.

The eggmasses were generally 2-6, but sometimes they were more than 6 and the number was high as 10. According to Huque and Agarwala (1955b) generally 5-6 eggmasses were laid by a female but sometimes this number varied from 2-13 depending upon the size of the egg masses. Avasthy (1965) reported that the number of the egg masses were about 6 and was high as 13. Mukunthan (1986) observed that the eggs were laid by a female in 3-6 masses.

The egg masses were of different sizes. The width of it varies from 0.40-0.65 cm in all the broods, while it was 0.85 to 1.65 cm in length. The number of eggs per egg mass was found to vary in accordance with egg mass size. There were 13-75 eggs per egg mass. The number of eggs was always found to be directly proportional with the size of the egg mass. But Tiwari et al. (1983) reported that the number of eggs in an egg mass may be estimated on the basis of its length for the fourth and fifth broods only and for the other broods, the length of the eggmass has no relationship to the number of eggs in it.

Huque and Agarwala (1955b), Gupta (1959b) and Kalra and Sidhu (1965) reported that there were 30-80 eggs per mass.

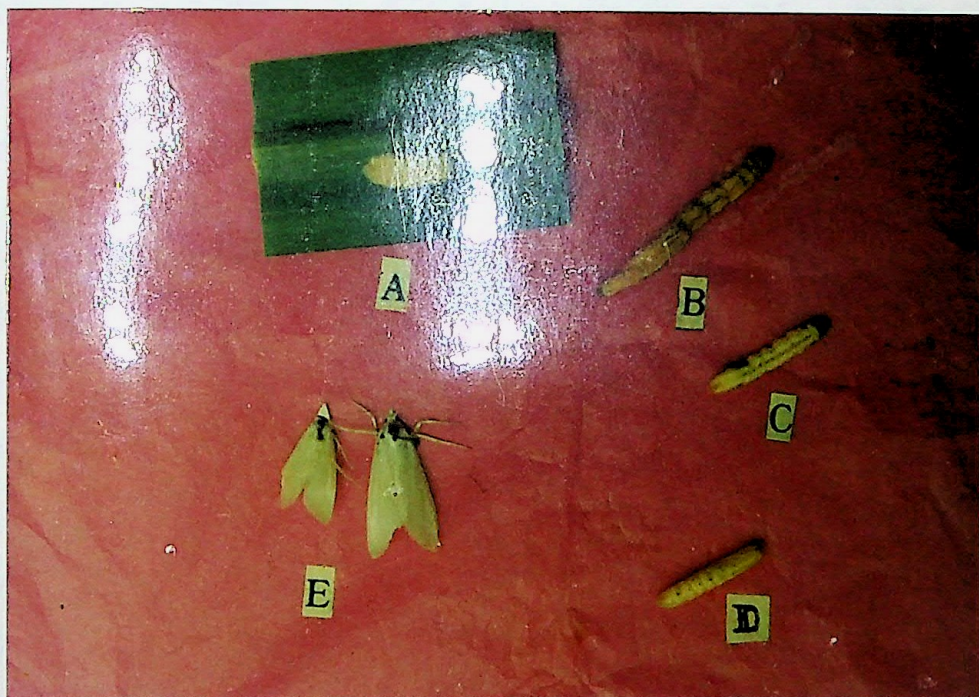


Plate - 2: Life stages of *T. nivella*: Eggmass (A), Larva (B), Pre-pupa (C), Pupa (D) and Adults (E).

But according to Mukunthan (1986), an egg mass had 10-80 eggs and the width of an egg mass was 0.3 cm in all broods, while the length varied from 0.3-1.2 cm.

4.14 Oviposition period:

Most insects do not lay their eggs in a day but continue for a longer period which is called oviposition period. The oviposition period of T. nivella have been shown in table I. The oviposition period lasted for 1.49 ± 0.15 , 2.26 ± 0.19 , 2.38 ± 0.14 , 2.58 ± 0.19 and 1.70 ± 0.17 days in 1st, 2nd, 3rd, 4th and 5th broods respectively (Fig. 3).

It is evident from the present findings that the oviposition period ranged from 1.47 to 2.58 days while it was 1-4 days as observed by Huque and Agarwala (1955b) and Kalra and Sidhu, (1965). But according to Gupta (1959c) and Patel (1963) the oviposition period was reported to be 3-4 and 2-3 days. The variation of oviposition period in the present study is due to variation of locality.

Statistical analysis shows that there is highly significant difference of oviposition between different broods ($P < 0.001$, $LSD = 0.83$, Appendix table II). After comparing the LSD value it is observed that the mean oviposition period of fourth brood significantly differ with first and fifth broods, again the mean oviposition period of second, third and fifth broods significantly differ with other two broods.

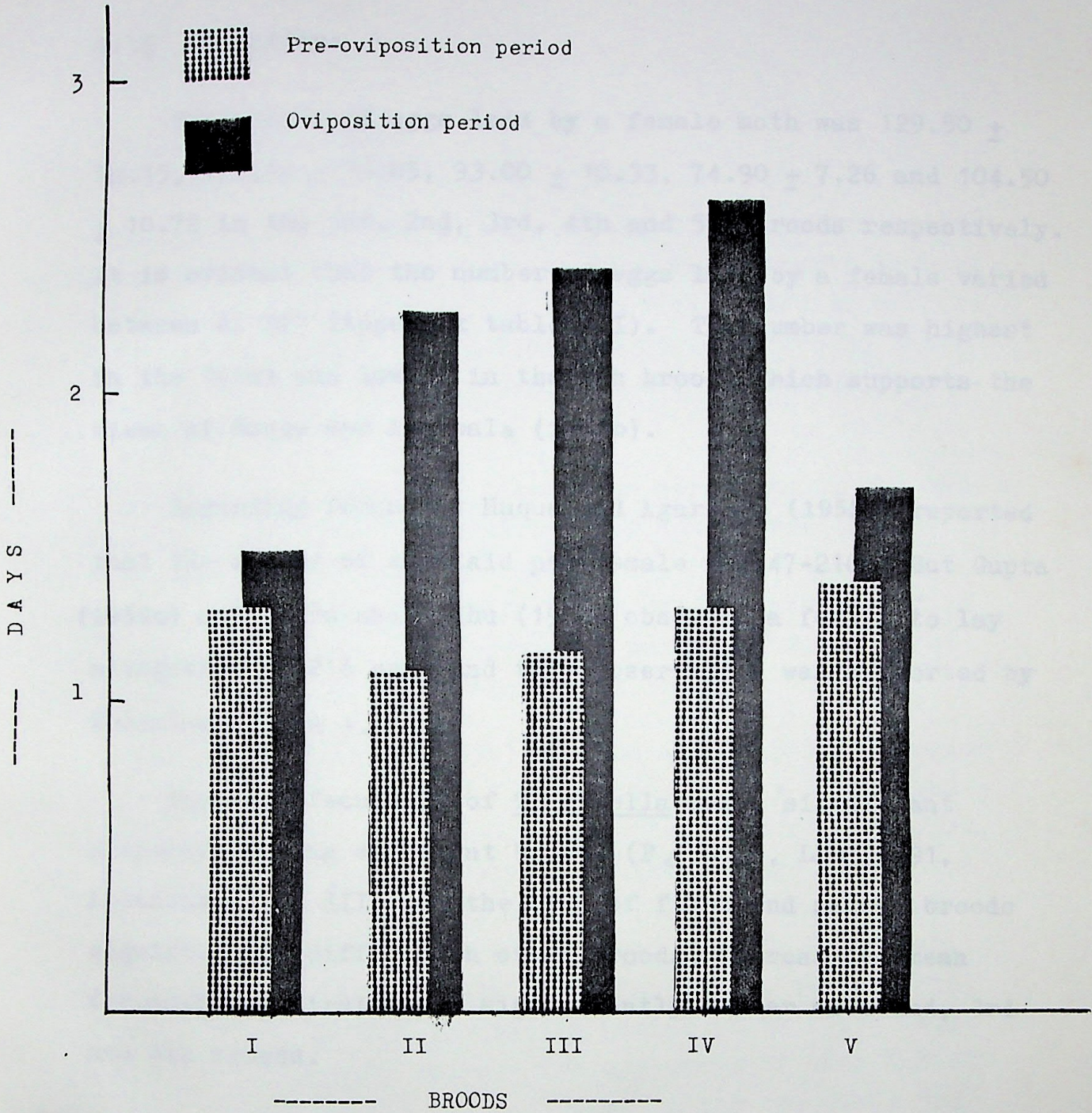


FIG. 3 : AVERAGE PRE-OVIPOSITION AND OVIPOSITION PERIOD OF T. nivella.

4.15 Fecundity:

The number of eggs laid by a female moth was 129.50 ± 18.15 , 110.50 ± 10.05 , 93.00 ± 10.33 , 74.90 ± 7.26 and 104.50 ± 10.72 in the 1st, 2nd, 3rd, 4th and 5th broods respectively. It is evident that the number of eggs laid by a female varied between 42-227 (Appendix table III). The number was highest in the first and lowest in the 4th brood, which supports the views of Huque and Agarwala (1955b).

Regarding fecundity Huque and Agarwala (1955b) reported that the number of egg laid per female was 47-216. But Gupta (1959c) and Kalra and Sidhu (1965) observed a female to lay altogether 46-216 eggs and this observation was supported by Mukunthan (1986).

The mean fecundity of T. nivella shows significant difference among different broods ($P < 0.05$, LSD 33.91, Appendix table III) and the mean of first and second broods significantly differ with other broods, whereas the mean fecundity of first brood significantly differ with 2nd, 3rd and 4th broods.

4.2 DEVELOPMENTAL STAGES

4.21 Incubation period:

The insect eggs pass through a period (incubation period) in which the deposited eggs develop into first instar larvae. In the present investigation the incubation period in average was 8.57 ± 0.15 , 7.50 ± 0.17 , 7.83 ± 0.23 , 8.06 ± 0.25 and 8.09 ± 0.19 for the 1st, 2nd, 3rd, 4th and 5th broods respectively (Table 1 and Fig. 5).

Analysis of variance of incubation period among the broods shows significant difference at one per cent level ($F = 3.879$, $LSD 0.67$, Appendix table IV). Result shows that the mean incubation period do not significantly differ from second to fifth broods, but the mean incubation period of first brood only significantly differs with second brood.

Huque and Agarwala (1955b) studied the incubation period of T. nivella Fab. which was 7.16 ± 0.11 , 5.20 ± 0.09 , 5.60 ± 0.01 , 5.61 ± 0.01 and 5.35 ± 0.09 days for the 1st, 2nd, 3rd, 4th and 5th broods respectively. But the average incubation period of this pest was 6-13, 6-8, 6-7, 8-9, 6-15, 7-9 and 6-7 day in the Punjab, U.P., Bihar, West Bengal, Hyderabad, Madras and Bombay respectively in India (Gupta, 1959c). Patel (1963) reported that the incubation period of this pest was 7 days in South Gujrat, India. The egg stage of this insect was 11-13, 6-8, 6-7, 6-7 and 9-11 days in the 1st, 2nd, 3rd, 4th and 5th broods respectively recorded during 1954-55 (Kalra and Sidhu, 1965).

The present findings on the incubation period is almost similar with the findings of Huque and Agarwala (1955b).

Gupta (1959c) and Patel (1963) but slightly varied with the findings of Kalra and Sidhu (1965). The variation occurred probably due to climatic condition.

4.22 Hatching, movement and other activities of the neonate larva:

Viable eggs undergo a process of hatching to produce first instar larva. Hatching took place while the eggs were of 7-9 days old. No change was marked in the egg during the first 5 days, but their change in colour started on 6th day. Ultimately the eggs became almost black in colour prior to hatching. But the eggs, though small in number, often remained unchanged in colour and those were the eggs which failed to hatch finally.

Hatching usually started about one or two hours before sunrise. Sometimes it also occurred 3-4 hours after sunrise. The eggs of an egg mass generally hatched at about the same time in 4-5 minutes. But sometimes 8-10 minutes was taken by all the eggs of an egg mass to hatch.

According to Huque and Agarwala (1955b) hatching took place during early morning hours (6-9 A.M.), rarely extending upto noon. Eggs laid on the same day hatched at a time and the hatching in an egg mass was completed within 4-5 minutes. Avasthy (1969) reported that eclosion normally starts an hour or two before sunrise and all eggs in a batch hatched at about

the same time in 4-5 minutes.

Newly hatched larvae began to move about on the leaves for searching host plant. As this pest is strictly monopolised and only one larva lives in a plant, so, for dispersal it immediately spinned out a silken thread (from its salivary glands) by which it hanged in the air for a short while. This type of a larva was marked either to climb up to the same leaf or to get itself transferred to some other leaf nearby. This type of behaviour was also shown by disturbed larva. After moving about on the leaves for 3-4 hours, the larva bored into the midribs of the youngest opened leaf.

The activities of newly hatched larvae observed in the present study are exactly similar to the observations of Rao (1947), Verma and Mathur (1950), Haque and Agarwala (1955b), Chang and Shih (1959), Patel (1963), Kalra and Sidhu (1965) and Mukunthan (1985). They reported that the newly hatched larvae crawl actively on leaves, suspend themselves by silken threads and get dispersed to adjacent plants by wind. After 3-4 hours they bore into midribs of leaves through the lower epidermis.

More than one neonate larvae (2-5) were transferred to 500 potted plants (Plate 3), however, only one larva succeeded in piercing into the leaf spindle. Because the larva first reaching the central core near the growing point could survive

ultimately, while those away from the growing point perished. Similar observation was reported by Huque and Agarwala (1955b) and Gupta (1959c). Even sometimes more than one larva bored into the same midrib forming parallel tunnels. But usually only one larva monopolies one cane and 70-90% of the larvae fail to enter a midrib and perish (Avasthy, 1969). Srivastava et al. (1983) reported that a larva can bore a length of 70 mm (maximum 150 mm) affecting 1-6 nodes and usually one larva monopolies one cane.

The tunnel made in the leaf midrib appeared as a white, and later as a red track (Plate 4). The larva tunneled down through the midrib till it reached the point where the leaf sheath starts. It came out of the midrib at that point and piercing its way through the central whorl of unopened leaves. Then it bored down the spindle towards the growing point. By this time the soft, rolled and unopened spindle leaf being bored by the larva expressed the characteristic 'shot-holes' or 'dead heart' (Plate 5B). The observation regarding the mode of entry of a larva in the host plant found similar with the findings of Kabir and Khan (1974) and Mannan (1979). This is also reported by Flecher and Ghosh (1919), Holloway et al. (1928) and Ruinard (1958).

The larva bored down the growing point leaving back a black track. A larva normally traversed a distance of 21-30 cm (i.e. 2-4 nodes). But in case of the cane having parasitised

larva the distance was much less and it was only 13-20 cm as because the activities (boring ability) of the host larva was ceased by the parasites. Avasthy (1965) reported that the larva tunneling through the spindle traversed a distance of 18-24 cm.

Prior to pupation, the larva prepared an exit-hole for the subsequent emergence of the moth from the tunnel. In case of young crop, the larva bored down the ground level and when it was fully grown, it again travelled upwards till it was just above the ground level where it prepared that exit-hole (Plate 6) to ensure the emergence of the moth. Patel (1963) reported that the larva moved up in case of small shoot and made the hole above soil level.

Usually the exit-hole is formed in the nodal region through the bud, but variations are noticed in different agro-climatic conditions (Singh, 1978). Singh et al. (1980) have observed azimuthal influence on the exit-hole formation.

The exit-hole is circular and it measures 0.30-0.35 cm. The location of it is generally 12-18 cm away from the tip of the spindle. The larva finally blocks the exit-hole carefully by silken lid so that no foreign material can enter through it but the adult in future may easily escape away from the tunnel. The lid is actually made of 6-7 silken discs and leaf sheath, when present. Huque and Agarwala (1955b) reported that the larva before pupating cut a hole in the stem for emergence which

was then blocked with 6-7 silken discs. Four to twelve silken discs are made towards the exit-hole (Kalra and Sidhu, 1965).

Normally the exit-hole was formed before 3-5 days pupation, but the full grown 5th brood larvae were found to make this hole before they entered hibernation. Before pupation the larva spins out a pupal chamber (Plate 7) within which it pupates later on. This chamber is located within the tunnel at a distance of about 0.8-1.8 cm from the exit-hole. A number of protective membranous silken discs are made in between the exit-hole and the pupal chamber. Normally the number of these discs varies from 3-8, but in some cases it may be as high as 12. The observations on the time of exit-hole formation, location of pupal chamber and the discs of pupal chamber are similar to that of Kalra and Sidhu, (1965).

4.23 Moulting:

Careful investigation was continuously made to observe moulting i.e. to detect exuviae or any change of the larva till pupation. No exuviae was found, in the tunnel throughout the larval period.

The larvae seemed to be sluggish and their bodies were found to be shortened on the 13th, 19th and 26th day of their hatching. Moreover, some striking changes of those larvae

(indicating probable post moulting behaviour) were clearly observed on the following days of 13th, 19th and 26th day of hatching.

The changes are --

- i) The head capsule of the larva looked almost white like fresh moult (Plate 8) while it is deep chocolate normally.
- ii) The larvae (supposed to be freshly moulted) while placed under diethyl ether body movement ceased within 1-2 minutes and they failed to resume the activity and finally died. Such larvae while kept in 70% alcohol, the body colour changed to black (Plate 9B). But the larvae of almost same age of other days (non-moulted) treated with above chemicals of the same concentration showed no lethal effect or any other change. So it was presumed that the moulted larvae were less resistant to diethylether as well as alcohol probably their body tissues were then very soft.
- iii) The digestive tract throughout the mid-dorsal line of the body seemed to be much more distinct (Plate 10).

These observations led to believe that the 13th, 19th and 26th day of hatching were the moulting days. These

observations have not yet been mentioned in any related works.

Ecdysis of a larva of later instar was clearly marked to happen. It starts from the anterior part of the body and the exuviae was marked to slide over the body towards both the ends (Plate 11B) quickly. This observation may also prove the occurrence of moulting and no such observation has yet been reported.

Further detailed investigation is required to assess the actual number of moulting as well as instars of larva through ecdysis.

4.231 Application of Dyar's law for the assessment of numbers of larval instar:

Growth in the animal is always more or less cyclical, periods of comparative rest alternating with periods of activity. But in no group is this so evident as in insects, in which development is punctured by a series of moults or ecdysis, each preceded by a period of active growth and followed by a period in which true growth may be entirely absent (Wigglesworth, 1972).

In the present study moults or ecdysis was hardly seen and assessment of larval instars was not possible at all by following the number of moults. But a period of active growth and a period of inactive growth were alternately marked.

The recorded head width in between those two periods were grouped. The mean of head width of 5 different brood from 1st to last were 0.369 ± 0.049 , 0.512 ± 0.017 , 0.722 ± 0.042 , 1.035 ± 0.058 and 1.412 ± 0.026 (Table - 2). The log of these mean values, while plotted against the expected 5 instars a straight line was formed (Fig. 4).

Development ratio in between the different instars was also calculated. The ratio of all cases was below 1.4.

According to Dyar's Law (Dyar, 1890) the larval instars of Lepidoptera follow a regular geometrical progression in growth. He (Dyar) also reported that the head capsule of caterpillars grows in geometrical progression, increasing in width at each moult by a ratio (usually about 1.4) which is constant for a given species. This rule applies to many parts of the body, so that when the number of the instar is plotted against the logarithm of some measurement on the insect, a straight line is generally obtained. De Abate (1969) applied this Dyar's Law successfully to 5 species.

The straight line formed by the logarithm of head width and the development ratios of different groups of the present study in correspondence with the opinion of Dyar proves that TSB larval period is consisted of 5 instars with five moults.

Table - 1

Pre-oviposition period, oviposition period, fecundity and duration (days) of different stages of T. nivella in different broods

Stages	Broods					Mean	P-level
	First	Second	Third	Fourth	Fifth		
Pre-oviposition period	1.298±0.072*	1.190±0.049	1.137±0.027	1.267±0.073	1.378±0.059	1.254	P < 0.05
Oviposition period	1.488±0.146	2.256±0.189	2.384±0.136	2.575±0.187	1.700±0.171	2.081	P < 0.001
Fecundity	129.50±18.152	110.50±10.051	93.00±10.327	74.90±7.262	105.20±10.718	102.62	P < 0.05
Incubation period	8.566±0.144	7.495±0.171	7.830±0.227	8.058±0.248	8.098±0.190	8.009	P < 0.01
Larval period	27.484±0.707	24.162±0.539	23.789±0.580	26.675±0.840	122.362±3.119	44.894	P < 0.001
Pupal period	11.055±0.398	11.728±0.397	10.252±0.487	14.842±0.597	19.428±0.646	13.461	P < 0.001
Adult longevity (male)	3.113±0.128	3.400±0.147	4.102±0.102	4.322±0.151	2.971±0.107	3.582	P < 0.001
Adult longevity (female)	2.451±0.177	2.572±0.106	3.039±0.141	3.135±0.137	2.272±0.058	2.694	P < 0.001

*Mean ± S.E.

Table - 2

Mean head capsule breadth (mm) of the larva of T. nivella

Instar	Average head capsule breadth			Mean $\pm$ S.E. ($\bar{x}$)	Log 10 $\bar{x}$
	Early instar	Middle instar	Late instar		
First	0.274	0.393	0.442	0.369 $\pm$ 0.049	-0.433
Second	0.484	0.510	0.542	0.512 $\pm$ 0.017	-0.291
Third	0.651	0.717	0.797	0.722 $\pm$ 0.042	-0.141
Fourth	0.922	1.071	1.112	1.035 $\pm$ 0.058	0.015
Fifth	1.367	1.413	1.458	1.412 $\pm$ 0.026	0.150

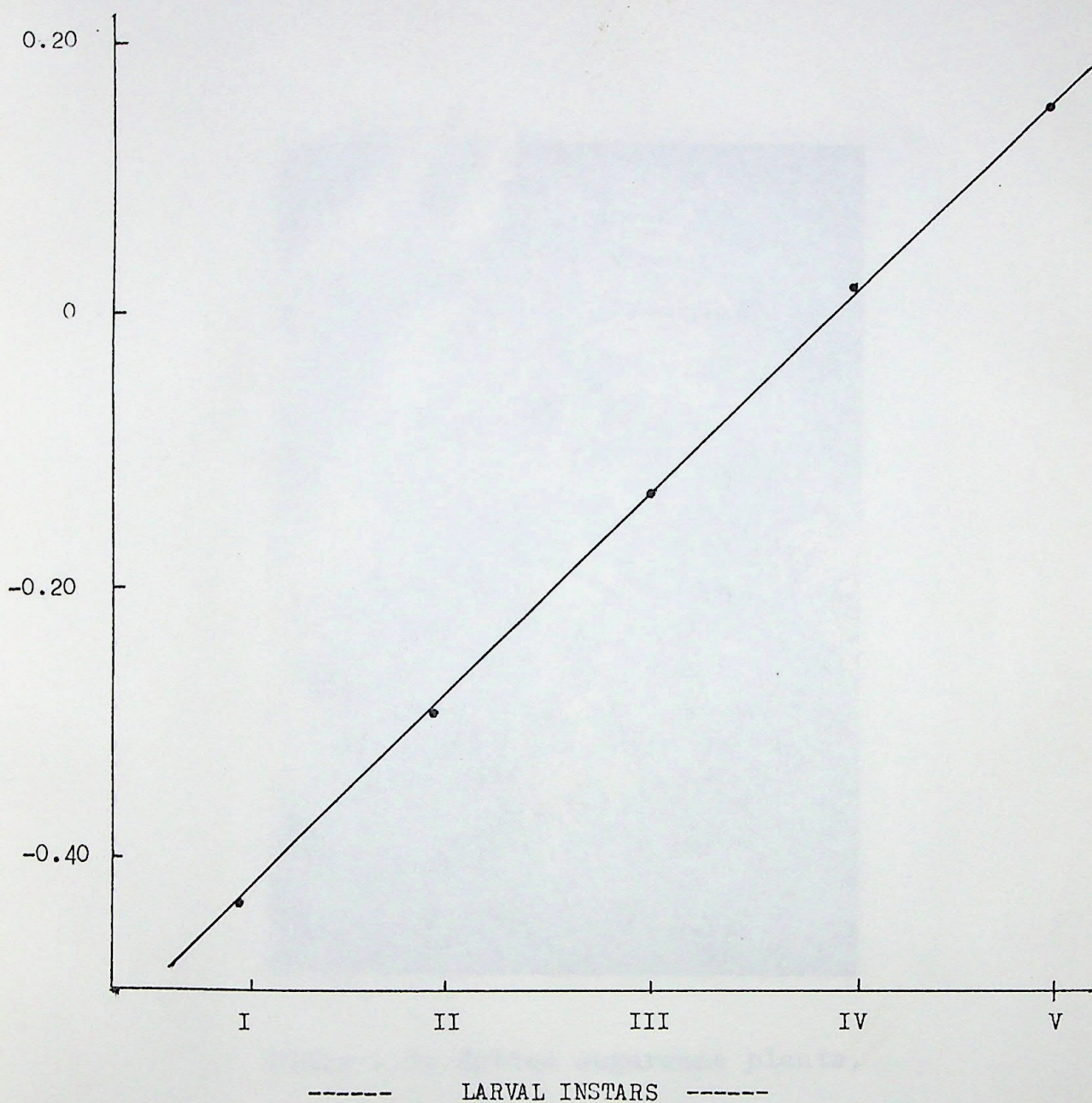


FIG. 4 : THE RELATIONSHIP BETWEEN THE HEAD CAPSULE BREADTH
AND RELATED LARVAL INSTARS



Plate - 3: Potted sugarcane plants.



Plate - 4: Sugarcane leaf with a red tract,
a sign of T. nivella infestation.



Plate - 5: Top shoots of sugarcane:

A normal top shoot (A)

T. nivella infested top shoot having
'dead heart' (B).



Plate - 6: Exit-hole in an infested cane prepared by T. nivella larva.



Plate - 7: Pupal chamber in an infested cane spun by T. nivella larva.



Plate - 8: *T. nivella* larva having white head capsule.



Plate - 9: Larvae of *T. nivella*: Fresh larvae (A), molted larvae treated with 70% alcohol (B) and non molted larvae treated with 70% alcohol (C).



Plate - 10: Distinct mid-dorsal line of T. nivella larva (Middle).

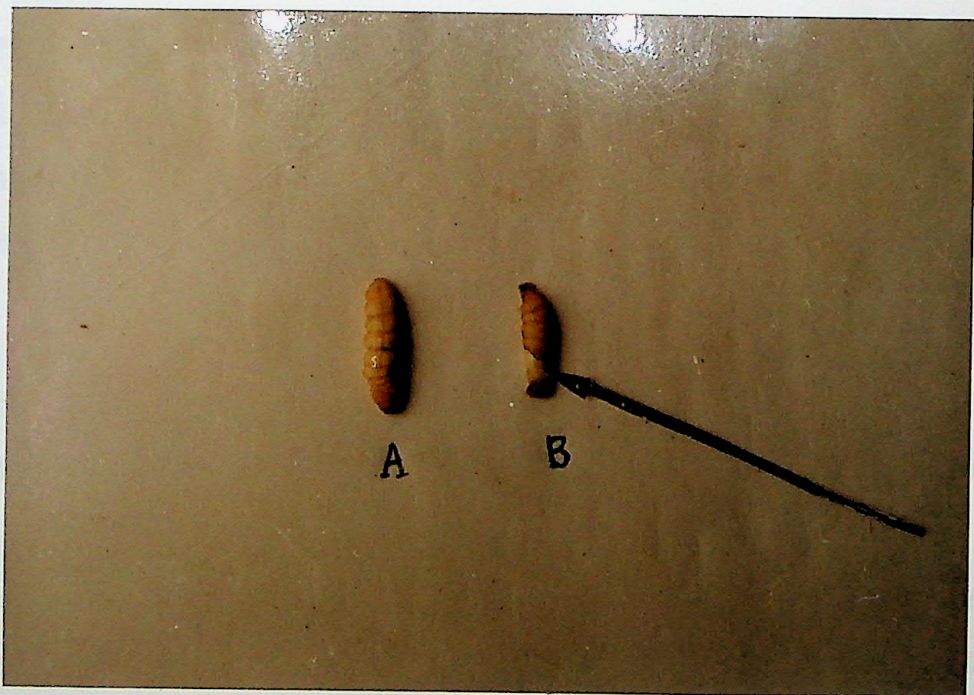


Plate - 11: Non molted larva of T. nivella (A)
A larva of T. nivella under ecdysis (B).

4.24 Larval period:

The larval period of this pest is the active stage during which damage to sugarcane, resulted. The affected shoot was killed outright if young, otherwise its growth stopped and development of side buds produced a bunched top (Plate 12) which results in loss of yield and encourages the infection by top rot disease.

The larval periods of T. nivella Fab. in different broods have been represented in table I. The periods on an average were of 27.48 ± 0.707 , 24.16 ± 0.539 , 23.79 ± 0.580 , 26.68 ± 0.840 and 122.36 ± 3.119 days for the 1st, 2nd, 3rd, 4th and 5th brood respectively.

From the statistical analysis it is found that the mean larval period from first to fourth broods was more or less similar but the F value is highly significant ($P < 0.001$, Appendix table V), which means the larval period of fifth brood significantly differs with other broods.

The durations of 1st and 4th broods were a little more than the 2nd and 3rd broods (Fig. 5). In the 5th brood the larvae underwent hibernation which extended the period into 122.36 days. Similar observation was reported by Huque and Agarwala (1955b). Kalra and Sidhu (1965) reported that the pest larva remains inactive till the end of October or beginning of November after which it enters hibernation.

Huque and Agarwalla (1955) recorded the average larval period of T. nivella for five broods as an average of 30.69 ± 0.39 ; 27.96 ± 0.54 ; 27.09 ± 0.59 ; 30.29 ± 0.41 and 129.73 ± 2.02 days for I, II, III, IV and V broods respectively. Gupta (1959) recorded the larval period of this insect as 19-52, 40-45, 30-35, 29-38, 15-34, 20-40 and 21-42 days in Punjab, U.P., Bihar, West Bengal, Hyderabad, Madras and Bombay respectively. Patel (1963) reported that the larval period of this insect was usually 4-5 weeks expecting in winter when it may be extended upto 3-4 months depending upon the length and severity of winter. Kalra and Sidhu (1965) observed the larval period at Jalundhur (1954-55) in India as 28-38, 26-36, 20-28, 42-52/42-166 and 118-142 days for 1st, 2nd, 3rd, 4th and 5th brood respectively. In Bangladesh the larval periods were an average of 28.03 ± 0.83 ; 26.08 ± 0.73 ; 25.75 ± 0.61 ; 27.52 ± 0.58 and 98.42 ± 2.00 days for the 1st, 2nd, 3rd, 4th and 5th brood respectively (Mannan, 1979).

4.25 Pupal period:

In the present study, the pupal period on an average were 11.06 ± 0.398 , 11.73 ± 0.397 , 10.25 ± 0.487 , 14.84 ± 0.597 and 19.43 ± 0.646 for the 1st, 2nd, 3rd, 4th and 5th broods respectively (Table I and Fig. 5).

The analysis of variance of pupal period among different broods shows that the mean values of first, second and third

broods significantly differ with fourth and fifth broods ($P < 0.001$, $LSD = 2.58$, Appendix table VI).

Huque and Agarwala (1955b) observed the average pupal period as 8.00 ± 0.27 , 8.03 ± 0.19 , 7.88 ± 0.15 , 9.29 ± 0.13 and 21.74 ± 1.03 days for the broods I, II, III, IV and V respectively. Gupta (1959c) reported the pupal period of this insect were 4-13, 7-13, 7-12, 6-10, 17-20, 6.16, 18-21 and 7-10 days in Punjab, U.P., Bihar, West Bengal, Hyderabad, Madras and Bombay respectively. The pupal period as 7-11, 6-8, 7-9, 15-23 and 9-11/9-23 days for I, II, III, IV and V broods was observed by Kalra and Sidhu (1965).

Pupa showed body movement often in the initial stage. But prior to emergence for 5-10 minutes, the movement became very vigorous. The movement initiated in the anterior region and ended posteriorly. At that time pupae became dusk in colour (Plate - 13-B). Huque and Agarwala (1955b) reported that two or three hours before emergence the pupal skin took on a grown shining hue because it separated from the body of the insect within. Vigorous pulsating movements, beginning in the anterior region and ending posteriorly, commence and the insect roles inside restlessly. This went on intermittently for 8-11 minute; when the case ruptured in the anterior and thoracic regions allowing the head, antennae and legs to escape. Holding itself with the legs, the insect now needed only 2-7 minutes more to free itself completely.

The duration of pupal period of the present investigation supports the findings of Huque and Agarwala (1955b) and Kalra and Sidhu (1965) but varied with the findings of Gupta (1959). The variations observed as compared with the findings of Gupta (1959c) resulted from the differences due to climatic and other factors.

4.26 Emergence of the imago and its activities:

Male and female imago took 1-5 minutes respectively to complete the process of emergence. The imago being free from the puparium came out through the exit-hole (Plate 14). Just after emergence they expelled grey coloured fluid (meconium) with which fixed themselves up to supports such that their wings hung down to unfold and expand. The wings became fully developed within 10-15 minutes and looked somewhat like two pairs of dorsally convex plates. They remained in that condition for another 12-17 minutes. Then the wings were suddenly raised up vertically on the back and held there till fully stretched and dried. In a few cases wings did not unfold properly and such moths died within 1-2 days. All the findings were observed similar with that of Patel (1963), Kalra and Sidhu (1965) and Mannan (1979).

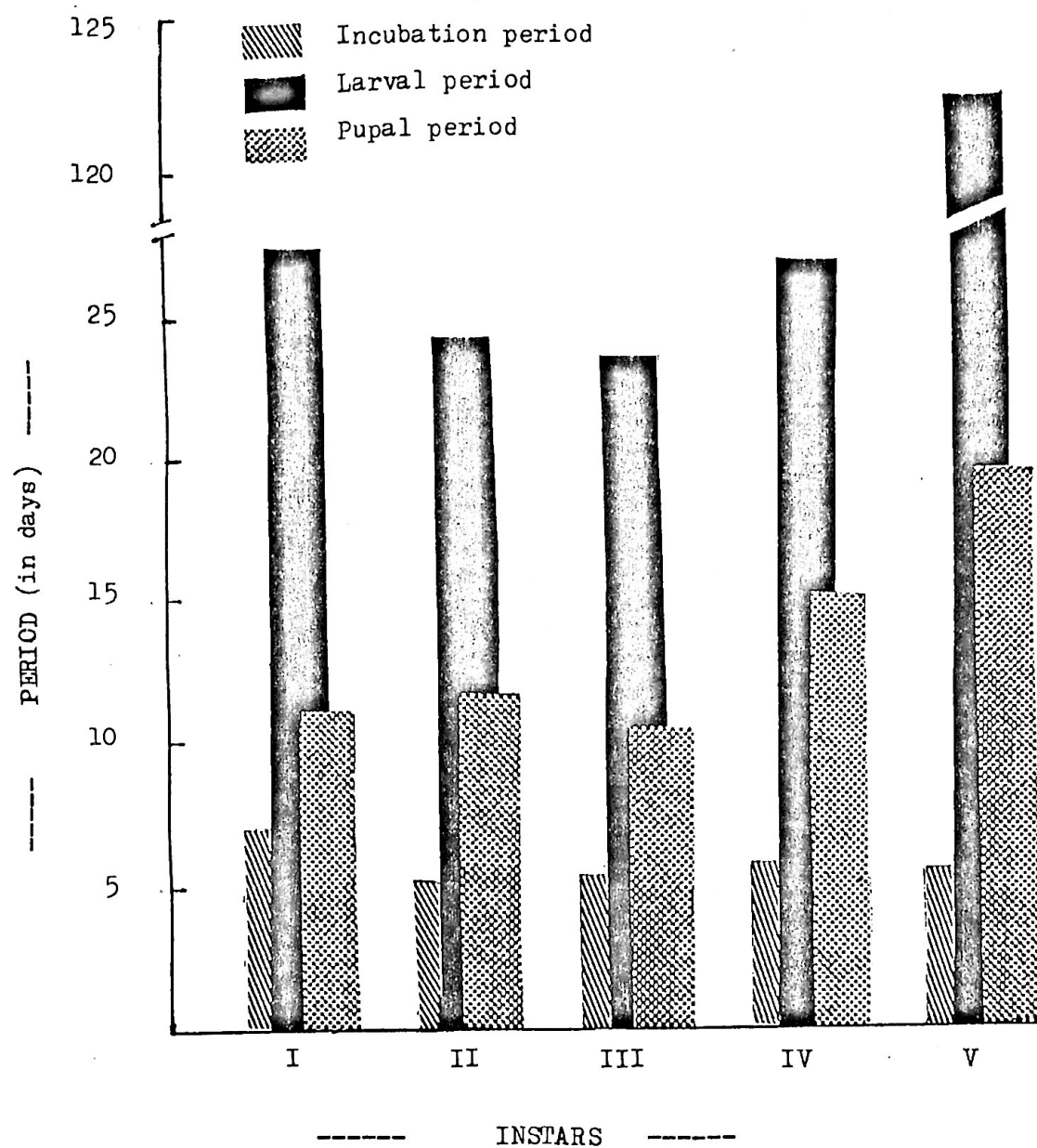


FIG. 5: INCUBATION, LARVAL AND PUPAL PERIODS OF *T. nivella*.



Plate - 12: Bunchy top of sugarcane.



Plate - 13: Early pupae of T. nivella (A)
Late pupae of T. nivella (B).



Plate - 14: Imago of T. nivella coming out the exit-hole.

4.261 Sex ratio:

The higher level of organisation within insects makes it necessary -- the presence of individuals of opposite sexes i.e. male and female to propagate the life cycle and for the continuity of the races. In insects such male and female sexes are present in a particular ratio. But the proportion of their sexes are considered to be important aspect of ecological investigation for predicting their population dynamics.

The number of male and female moths with their sex ratio in different broods have been shown in table 3. The average percentage of male and female varies with the variation of broods. The percentage of male was less than the female in the 1st, 2nd and 4th brood. The percentages were 48:52, 42:58 and 40:60. But in the 3rd brood the males were higher in percentage (54:46).

Huque and Agarwala (1955b) reported the female and male sex ratio of S. nivella Fab. was 2:3, 1:1, 1:1, 10:17 and 1:1 for I, II, III, IV and V broods respectively.

4.27 Longevity of adult moths:

Every organism in the living world is subjected to natural death. The normal life span of adult insects varies considerably from a few days to several years depending upon

the species and length of life is correlated with fecundity and mating (Ross, 1965). The longevity of adult S. nivella varied from 2-4 days in different cane tracts of India (Gupta, 1959c).

The mean longevity of adults have been shown in the table I. The average longevity for females was 2.45 ± 0.177 , 2.57 ± 0.106 , 3.04 ± 0.141 , 3.14 ± 0.137 and 2.27 ± 0.058 days and for males 3.11 ± 0.128 , 3.40 ± 0.147 , 4.10 ± 0.102 , 4.32 ± 0.151 and 2.97 ± 0.107 days for the 1st, 2nd, 3rd, 4th and 5th broods respectively (Fig. 6).

For adult longevity the analysis of variance shows significant difference ($P < 0.001$) for both male and female moths. In case of male moth the longevity of 3rd and 4th broods significantly differ with those of other broods (Appendix table VII). But in case of female moth the longevity of 1st, 2nd and 5th broods significantly differ from other broods (Appendix table VIII). In case of longevity between male and female moths result has always been significant for all the broods (Appendix table IX).

Mannan (1979) reported the longevity for females was 2.76 ± 0.78 ; 2.99 ± 0.72 ; 3.33 ± 0.77 ; 3.99 ± 0.94 and 2.83 ± 0.66 days and for males was 2.87 ± 0.69 ; 3.09 ± 0.76 ; 3.50 ± 0.72 ; 4.10 ± 0.91 and 2.69 ± 0.69 days for the broods I, II, III, IV and V respectively.

Huque and Agarwala (1955b) studied the longevity of the adults S. nivella Fab. and it was an average of 2.60, 2.71, 2.91, 3.20 and 2.70 days for female while 2.85, 2.87, 3.50, 3.07 and 2.40 days for male for the broods number I, II, III, IV and V respectively.

Table - 3

The sex-ratio of T. nivella

Year	Repli- cation	Sex	B r o o d s			
			First	Second	Third	Fourth
1987-88	1	♂	7	5	12	6
		♀	13	15	8	14
	2	♂	9	8	10	8
		♀	11	12	10	12
	3	♂	10	10	9	10
		♀	10	10	11	10
	4	♂	9	9	10	9
		♀	11	11	10	11
	5	♂	8	8	11	7
		♀	12	12	9	13
1988-89	1	♂	11	7	13	6
		♀	9	13	7	14
	2	♂	9	8	12	7
		♀	11	12	8	13
	3	♂	11	11	9	10
		♀	9	9	11	10
	4	♂	10	10	12	9
		♀	10	10	8	11
	5	♂	12	8	10	8
		♀	8	12	10	12
Total			96	84	108	80
			104	116	92	120
			0.320	5.120	1.280	8.000

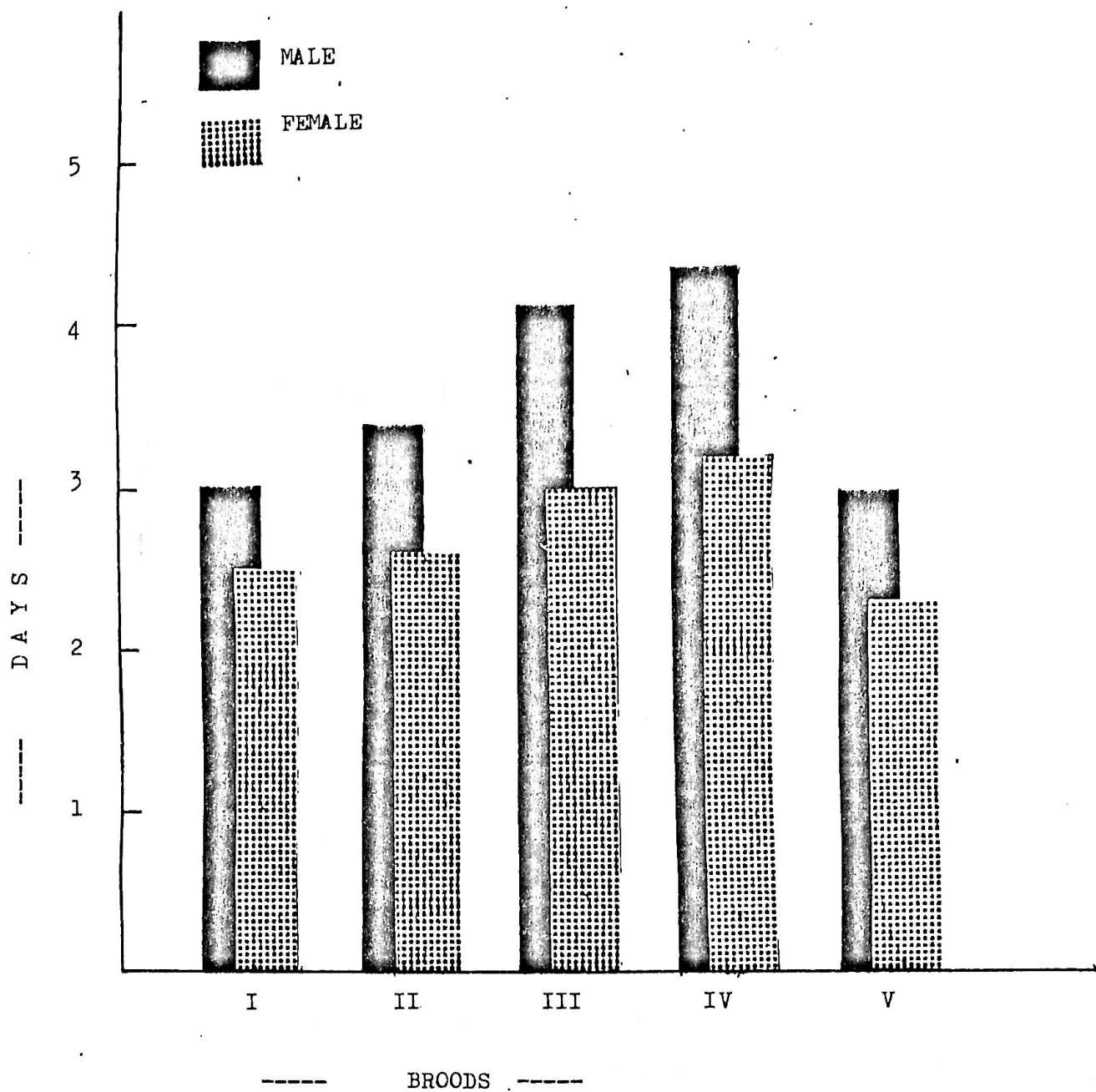


FIG. 6: ADULT LONGEVITY OF T. nivella.

4.3 MECHANICAL CONTROL:

The experiment indicates clearly that usual mechanical control practice generally goes a long way to keep the infestation level low. Due to such control practice table 4 shows that the average peak infestation percentage of 11 Sugar Mill Farms including Harian Sugar Mill Farm in an average is 13.45 ± 4.22 . But proper mechanical control practice is found to be much more effective and adoption of it decreases the percentage of infestation to 9.20 ± 1.92 . While in absence of any mechanical control in the grower's field, the infestation percentage may be as high as 55.80 ± 8.64 (Table 4 and Fig. 7).

Regarding the control of top shoot borer integrated control has been accepted widely (Rahman, 1970a). On the other hand, biological control, for sugarcane pests, is a must for keeping the borer population below economic injury level (Shahjahan, 1975). Emphasis has been given on the mechanical, biological and cultural methods of borer control in different parts of the world. Charpentier and Mathes (1969) reviewed the cultural practices for sugarcane pest control in various

countries and recommended this method as an adjunct to other control measures.

Present findings of proper mechanical control clearly indicates to be the most useful in preventing top shoot borer attack. For this method to be more effective, the operations should be started timely and simultaneously in all the infested areas and the operation is to be completed within a week. The appropriate time of operation can be determined through field samplings and the operation should be carried out twice per brood for better success. In the first brood of the pest, mechanical control (infested top cutting) is better to be avoided but adult and eggmass collection are to be encouraged. This method of mechanical control practice is economic and can easily be integrated with any other pest control measures (Shahjahan, 1979b).

The analysis of variance of T. nivella infested canes between different conditions of mechanical control shows that the mean value of usual mechanical control practices significantly differ with those of farmers field. But there is no difference in percentage of infested canes between different broods (Appendix table X).

Table - 4

Incidence of *T. nivella* infested canes in different sugar mill zones
under different condition of mechanical control

Condition	Experimental zones	First brood	Second brood	Third brood	Fourth brood	Fifth brood
Usual mechanical control practice	Different sugar mill zones	4.64±1.27	6.27±1.67	10.27±2.83	13.45±4.22	7.84±1.20
Proper mechanical control practice	Harian	4.20±1.92	5.40±2.07	6.60±1.14	9.20±1.92	4.60±2.07
Without mechanical control practice (control)	Grower's plot at Harian	4.80±1.30	15.20±4.21	35.40±4.04	55.80±8.64	28.40±7.57

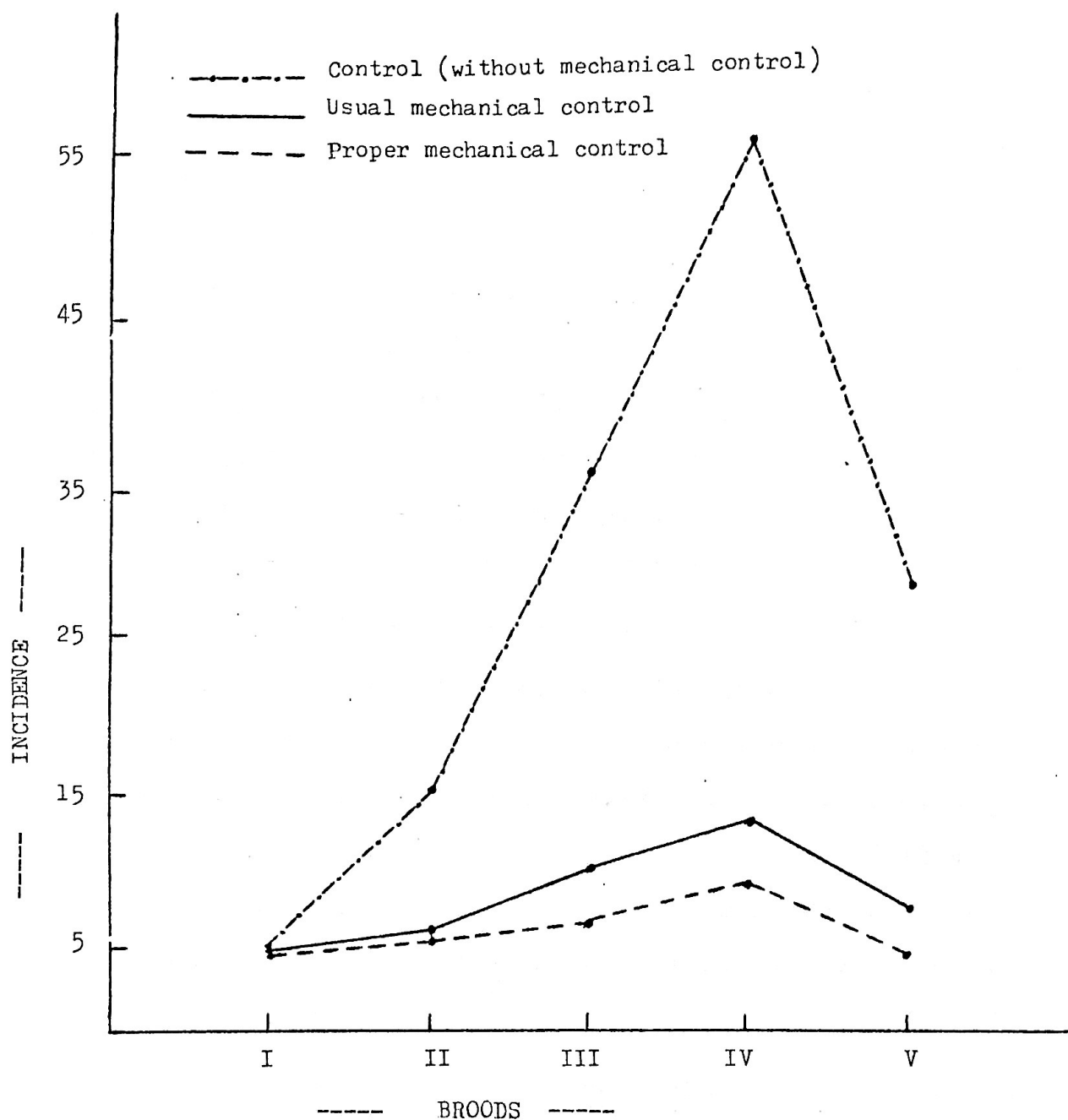


FIG. 7: INCIDENCE OF TOP SHOOT BORER UNDER DIFFERENT CONTROL MEASURES AND AMONG THE DIFFERENT BROODS.

4.4 ESTIMATION OF LOSSES:

The effect of infestation by T. nivella (Fab.) on the length, circumference, weight and sugar recovery of four varieties of sugarcane and consequent estimation of loss in percentage have been calculated and shown in tables 5 and 6.

The difference in length in between the infested and non-infested canes of the four varieties is very striking (Plate-15). The average length (in metre) of the infested and uninfested canes and loss in percentage of four varieties were 1.38 ± 0.26 , 2.55 ± 0.33 and 45.67; 1.38 ± 0.46 , 2.35 ± 0.14 and 41.01; 1.17 ± 0.25 , 2.05 ± 0.21 and 42.72; and 1.07 ± 0.20 , 2.09 ± 0.18 and 48.54 for the varieties Isd-16, Isd-17, Isd-2/54 and L.J.C. respectively. The t-test values of the above data were highly significant for all the varieties (Appendix tables XI, XII).

The circumference (cm) of both infested and uninfested canes and estimation of change in percentage were on average of 8.12 ± 0.51 , 7.47 ± 0.53 and 8.72; 6.51 ± 0.58 , 6.89 ± 0.47 and 5.48; 6.74 ± 0.46 , 6.72 ± 0.52 and 0.36; and 7.15 ± 0.52 , 6.92 ± 0.40 and 3.21 respectively for the above described varieties. t-values of the above data in case of Isd-16, Isd-17 and L.J.C. were significant (Appendix table XI, XII).

The weight (kg) of healthy and infested canes and loss in percentage were 3.25 ± 0.31 , 5.35 ± 0.57 and 39.25%; 2.13 ± 0.21 , 4.12 ± 0.69 and 48.37%; 2.03 ± 0.27 , 3.38 ± 0.29 and 40.14% and 1.77 ± 0.31 , 3.57 ± 0.55 and 50.48% and 1.77 ± 0.31 ,

3.57 $\pm$ 0.55 and 50.48% for Isd-16, Isd-17, Isd-2/54 and L.J.C. respectively. t-test values were found to be significant for the four varieties (Appendix table XI, XII).

The sugar recovery percentage of healthy and infested canes and estimation of loss in percentage were 8.50 $\pm$ 0.114, 11.09 $\pm$ 0.121 and 23.36; 7.51 $\pm$ 0.124, 11.31 $\pm$ 0.118, 35.59; 8.12 $\pm$ 0.056, 11.61 $\pm$ 0.041 and 30.06 and 9.70 $\pm$ 0.056, 10.35 $\pm$ 0.049 and 6.28 respectively for the four varieties (Table- 6). The t-test values show significantly different in all the varieties studied (Appendix tables XI, XII).

Many workers observed the loss of cane yield in the field and mill due to the damage caused by the attack of T. nivella. Gupta and Avasthy (1954) recorded that the loss in yield was directly influenced by an increase of infestation. In Bihar, Agarwala and Prasad (1956) recorded a loss of yield 7.47 to 7.68 per cent by this insect. Kalra (1960a) and Venkatraman (1961) reported the overall loss in yield of millable cane as 30% and 21.4-36.8% respectively. Rajani (1961) used a sample of 30 canes for determination of losses in yield as comparing the healthy canes with top-borer attacked canes and concluded that in severe case there is a loss in yield upto 20 per cent. The loss in yield as 5.51-9.80 per cent for the attack of the top shoot borer was recorded by Siddiqui (1961a). Kalra and Chaudhary (1964a) observed

the overall loss in the yield of the crop as 8.80 per cent. It is also reported that loss in yield due to top-borer varied from 7.50 to 20.50 per cent in early varieties and 8.50 to 22.80 per cent in late varieties of sugarcane (Kalra and Sidhu, 1965). Gupta et al. (1965) observed that the top-borer affecting 25 per cent on an average of millable canes.

In Bangladesh Miah et al. (1980) recorded weight loss and sugar loss in percentage as 14 and 29.6 respectively due to the attack of top shoot borer. Khalequzzaman and Mannan (1980) reported loss in cane weight, length and circumference due to top shoot borer attack as 6.50-50.17, 5.14-40.74 and 1.94-10.20 per cent respectively.

The observations regarding losses (loss in weight, length, circumference and sugar recovery) by the workers stated above may not be exactly similar with the present findings. Because the varieties of sugarcane taken in the present investigation were different from the available varieties of the earlier workers.

In the present findings the maximum loss of length was 48.54% in L.J.C. and minimum loss was 41% in Isd-17. Whereas loss percentage in circumference was maximum 8.71 in case of Isd-16 and minimum 0.36 only in case of Isd-2/54. But the change in percentage of weight were maximum 50.48 and minimum 39.25 for the varieties L.J.C. and Isd-16 respectively.

In case of sugar recovery, the percentage of loss was high (35.60) in case of Isd-17 while it was minimum (6.28) in case of L.J.C. which is the most susceptible to top shoot borer.

Table - 5

Effect of infestation by *T. nivella* on the length, circumference and weight of four different varieties of sugarcane.

Variety	Category of cane samples I = Infested U = Uninfested	Mean and + S.E.		Estimation of loss in percentage			Calculated value of 't'		
		Single cane length in mtr.	Single cane circumference in cm.	Single cane wt. in kg.	Length	Circum-ference	Weight	Length	Circum-ference
Isd-16	I	1.387±0.261	8.120±0.508	3.250±0.308	45.671	8.716	39.252	2.803 ^{***}	0.888
	U	2.553±0.325	7.469±0.525	5.350±0.571					
Isd-17	I	1.384±0.462	6.514±0.584	2.125±0.213	41.005	5.484	48.372	2.242 [*]	0.505
	U	2.346±0.142	6.892±0.471	4.116±0.696					
Isd-2/54	I	1.176±0.249	6.741±0.463	2.025±0.267	42.717	0.357	40.141	2.690 [*]	0.034
	U	2.053±0.212	6.717±0.515	3.383±0.292					
L.J.C.	I	1.074±0.200	7.145±0.521	1.766±0.314	48.538	3.206	50.476	3.724 ^{***}	0.338
	U	2.087±0.183	6.923±0.404	3.566±0.546					

* P < 0.05

*** P < 0.01

*** P < 0.001

Tabulated value t are 2.048, 2.763 and 3.674 for 0.05, 0.01 and 0.001 probability at 28 d.f.

Table - 6

Effect of infestation by T. nivella on the sucrose recovery percentage of four varieties of sugarcane.

Variety	Category of cane samples I = Infested U = Uninfested	Average sucrose recovery % of a single cane $\pm$ S.E.	Estimation of loss in percentage
Isd-16	I	8.50 $\pm$ 0.114	23.355
	U	11.09 $\pm$ 0.121	
Isd-17	I	7.51 $\pm$ 0.124	35.598
	U	11.31 $\pm$ 0.118	
Isd-2/54	I	8.12 $\pm$ 0.056	30.06
	U	11.61 $\pm$ 0.041	
L.J.C.	I	9.70 $\pm$ 0.056	6.280
	U	10.35 $\pm$ 0.049	

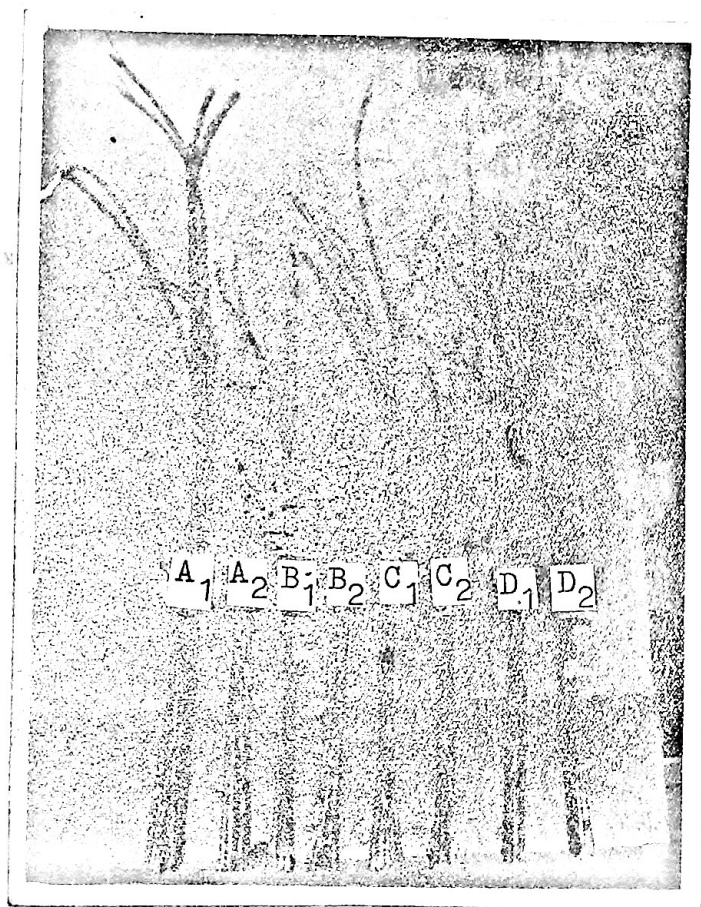


Plate - 15: Non-infested sugarcane of four varieties
(A₁, B₁, C₁ and D₁)
Infested sugarcane of four Varieties
(A₂, B₂, C₂ and D₂).

4.5 INCIDENCE OF THE PEST:

The incidence of top shoot borer among different varieties of sugarcane in different mill zones has been shown in table 7. The percentage of infestation was always minimum in the first brood (March-May) i.e. 2.39 ± 0.200 , 2.88 ± 0.212 , 3.84 ± 0.343 and 4.27 ± 0.354 for the varieties Isd-16, Isd-17, Isd-2/54 and L.J.C. respectively. Then infestation was gradually increased upto fourth brood. Fourth brood i.e. July to August was found to be the peak period of infestation and it was 7.30 ± 0.406 , 8.06 ± 0.489 , 10.85 ± 0.719 and 12.14 ± 0.840 per cent for the varieties stated above. Then the infestation was noticed to be decreased in the fifth brood (Table-8).

The incidence of the pest for all the cane varieties and all mill zones studied found highly significant among different stations (Appendix tables XIII, XIV, XV, XVI).

The mean incidence of T. nivella in different study areas and their corresponding temperature and relative humidity has been shown in table 9. It was noted that the incidence of this pest is dependent upon the prevailing temperature and

relative humidity. So the data has been analysed statistically and the multiple regression equation of the incidence (Y) on temperature (x_1) and relative humidity (x_2) has been calculated (Appendix table XVII) and the equation being

$$Y = -362.40 + 5.093x_1 + 3.712x_2$$

The rate of change of percentage of infestation with respect to temperature is 5.093 and the rate of change of percentage of infestation with respect to moisture is 3.712. That means, the increase in the percentage of infestation corresponding to unit increase in temperature is 5.093 and the increase in percentage of infestation corresponding to the unit increase in relation humidity is 3.712. It is also evident after checking the relationship between temperature and moisture that these two variables are not independent but they interact on the percentage of infestation.

The variables i.e. the temperature and relative humidity are co-related explanatory variables. So the estimate of the percentage of infestation, though, will be unbiased but the sampling variance will be large due to the relationship between two explanatory variables. The multiple co-relation value for the above variables is positively co-related i.e. $R = .32$ (Appendix table XVII) and the analysis of variance between the variables is $F = 0.17982$ (significant $F = 0.8438$). Regarding regression co-efficients b_1 and b_2 are not significant among different months.

Table - 7

Incidence of T. nivella in four varieties of sugarcane
at different mill zones

Mill zones	Variety-wise incidence (Mean $\pm$ S.E.)			
	Isd-16	Isd-17	Isd-2/54	L.J.C.
Meherchandi	4.34 $\pm$ 0.540	5.08 $\pm$ 0.503	7.18 $\pm$ 1.123	9.46 $\pm$ 1.901
Harian	4.98 $\pm$ 0.803	5.48 $\pm$ 0.828	7.64 $\pm$ 1.586	8.46 $\pm$ 1.754
Panchagarh	6.68 $\pm$ 1.182	7.22 $\pm$ 1.333	10.32 $\pm$ 2.046	10.80 $\pm$ 2.097
Thakurgaon	3.68 $\pm$ 0.541	4.38 $\pm$ 0.566	7.24 $\pm$ 1.638	7.98 $\pm$ 1.669
Setabganj	3.70 $\pm$ 0.634	4.28 $\pm$ 0.645	5.80 $\pm$ 1.038	6.72 $\pm$ 1.272
Shyampur	4.14 $\pm$ 0.791	4.52 $\pm$ 0.801	5.06 $\pm$ 0.872	5.52 $\pm$ 0.902
Mohimaganj	4.46 $\pm$ 1.084	5.00 $\pm$ 1.034	5.80 $\pm$ 1.127	6.52 $\pm$ 1.202
Jaipurhat	4.88 $\pm$ 1.258	5.56 $\pm$ 1.343	6.94 $\pm$ 1.396	7.78 $\pm$ 1.596
Mobarakganj	5.38 $\pm$ 1.151	6.40 $\pm$ 1.202	6.92 $\pm$ 1.484	7.48 $\pm$ 1.522
Dorshona	5.56 $\pm$ 0.767	6.44 $\pm$ 0.807	7.50 $\pm$ 0.906	8.40 $\pm$ 0.843
Jogoti	5.72 $\pm$ 1.100	6.20 $\pm$ 1.157	8.46 $\pm$ 1.164	8.34 $\pm$ 1.092

Table - 8

Incidence of T. nivella in north-western zones of Bangladesh
(average of 11 study areas) among four varieties of sugarcane
of different broods

Varieties	Brood-wise incidence (Mean $\pm$ S.E.)				
	First	Second	Third	Fourth	Fifth
Isd-16	2.39 $\pm$ 0.200	3.65 $\pm$ 0.292	5.84 $\pm$ 0.436	7.30 $\pm$ 0.406	5.15 $\pm$ 0.411
Isd-17	2.88 $\pm$ 0.212	4.31 $\pm$ 0.314	6.45 $\pm$ 0.418	8.06 $\pm$ 0.489	5.81 $\pm$ 0.415
Isd-2/54	3.84 $\pm$ 0.343	5.15 $\pm$ 0.391	8.90 $\pm$ 0.639	10.85 $\pm$ 0.719	7.11 $\pm$ 0.466
L.J.C.	4.27 $\pm$ 0.354	5.87 $\pm$ 0.409	9.74 $\pm$ 0.614	12.14 $\pm$ 0.840	7.74 $\pm$ 0.422

Table - 9

Incidence of T. nivella in different varieties of sugarcane with temperature and relative humidity of 1987-88 and 1988-89

Study areas	Isd-16	Isd-17	Isd-2/54	L.J.C.	Y Mean (Inc.)±S.E.	x ₁ Mean temperature	x ₂ Mean relative humidity
Meherchandi	4.34	5.08	7.18	9.46	6.58±0.659	26.56	76.47
Harian	4.98	5.48	7.64	8.46			
Panchagarh	6.68	7.22	10.32	10.80	6.57±0.687	25.39	72.87
Thakurgaon	3.68	4.38	7.24	7.98			
Setabganj	3.70	4.28	5.80	6.72			
Shyampur	4.14	4.52	5.06	5.52	5.13±0.279	25.68	78.60
Mohinaganj	4.46	5.00	5.80	6.52			
Jaipurhat	4.83	5.56	6.94	7.78	6.29±0.656	25.56	75.98
Mobarakganj	5.38	6.40	6.92	7.48	6.55±0.447	27.17	77.67
Dorshona	5.56	6.44	7.50	8.40	7.08±0.438	26.44	77.07
Jogoti	5.72	6.20	8.46	8.34			

4.6 OCCURENCE OF BROODS:

The number of the infested canes along with the number and percentage of empty shoots, larvae and pupae found at different months are shown in table 10.

It was found that in young sugarcane plants, percentage of larvae was higher (65.40) than that of the pupae (13.40) in the month of March. In April, percentage of pupae increased (28.20) and it became higher than that of larvae (20.40) and a further fall was noted in May (14.20) with a rise in June (15.80). There was also a fall in July (11.60) and it rose in August (18.80) with a fall in September (12.80). It became again higher (18.60) in October but declined (13.60) in November (Fig. 8).

The pupal population observed in December was very low as compared with the number of larvae. This is explainable as the larvae during this month entered into hibernation, which was also observed by Patel and Bagal (1953), Patel (1963), and Kalra and Sidhu (1965). In the months of January and February the percentage of infestation was very low and whatever the infestation might be, it was mostly with young larvae. Therefore, it seems from the experiment that there was definitely

a peak pupal population in between the hibernation period and the peak pupal population in April. With this expected peak of pupal population there were 5 peaks in all, which clearly proved the occurrence of 5 broods in a year (Fig. 8).

The number of broods of top shoot borer observed by different workers varied from 3-7 with the variation of the locality. Gupta (1959a) observed 5-7 broods at different states of India. In Madras, 3 broods were observed by Venkatraman (1963). Patel (1963) studied 6 generations in the laboratory at South Gujrat.

Five broods recorded in the present investigation are in full agreement with Huque and Agarwalla (1955) in Bihar, Patel and Bagal (1953) at Walchandnagar, Patel (1963) in the field of South Gujrat, Kalra and Sidhu (1965) in Punjab of India and Rahman (1970a) of Bangladesh.

Table - 10

Number and Percentage of Empty Shoots, Larvae and Pupae among the TSB Infested Shoots Examined at Different Months of the Year 1987

Month and Year	No. of infested shoots examined	Number			Percentage		
		Empty shoots	Pupae	Larvae	Empty shoots	Pupae	Larvae
January, 1987	-	-	-	-	-	-	-
February, "	-	-	-	-	-	-	-
March, "	500	106	67	327	21.20	13.40	65.40
April, "	500	257	141	102	51.40	28.20	20.40
May, "	500	293	71	136	58.60	14.20	27.20
June, "	500	347	79	74	69.40	15.80	14.80
July, "	500	278	58	164	55.60	11.60	32.80
August, "	500	337	94	69	67.40	18.80	13.80
September, "	500	297	64	139	59.40	12.80	27.80
October, "	500	326	93	81	65.20	18.60	16.20
November, "	500	248	68	184	49.60	13.60	36.80
December, "	500	167	21	312	33.40	4.20	62.40

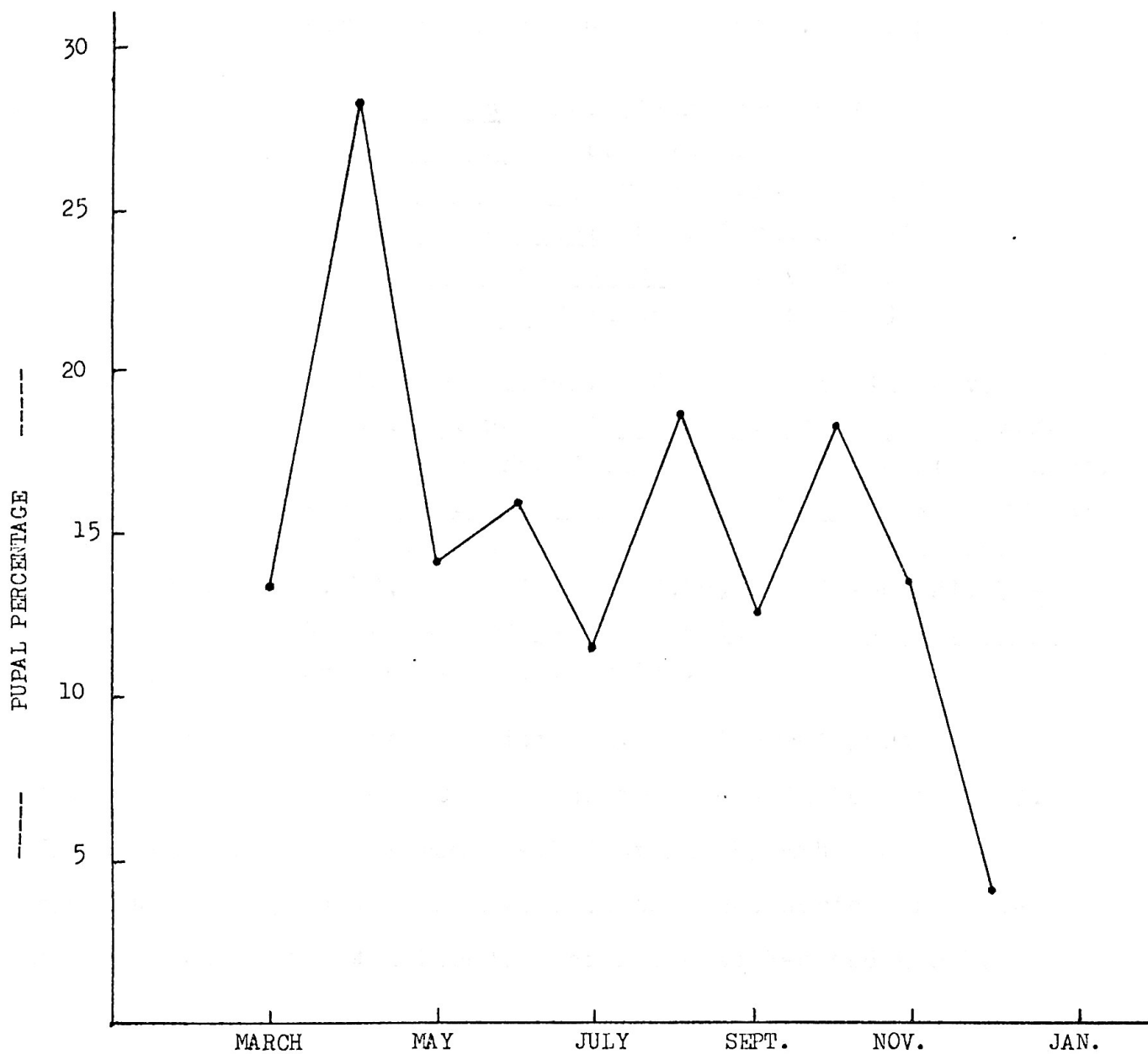


FIG. 8: PUPAL PEAKS AT DIFFERENT BROODS OF T. nivella.

4.7 STUDIES ON PARASITES

4.71 Incidence of the parasites:

During the study of the parasite incidence of top shoot borer, 6 hymenopterous parasites were recorded. The parasites were -

1. Isotima javensis Rohw. (Ichneumonidae)
2. Elasmus zehntneri Ferr. (Elasmidae)
3. Stenobracon nicevillei Bingh. (Braconidae)
4. Topobracon jokohamensis Cam. (Braconidae)
5. Rhaconotus schoenobivorous Rohw. (")
6. Apanteles flavipes Cameron (")

Of these, I. javensis was solitary and found both in larvae and pupae of the host. S. nicevillei and T. jokohamensis were also solitary but they were found only in the larvae of the host. But E. zehntneri, R. schoenobivorous and A. flavipes were gregarious larval parasites. A single host larva or pupa supported 40-142 (63.71 ± 2.57), 5-28 (15.33 ± 0.69) and 12-36 (21.37 ± 0.78) larvae of the parasites E. zehntneri, R. schoenobivorous and A. flavipes respectively (Table 11).

The percentage of parasitism by 6 different parasites collectively at different stations are shown in Tables 12-17. The percentage was maximum (49.50) at Panchagarh and it was minimum (21.50) only at Shyampur in the peak period of parasitism i.e. in the 4th brood. According to Rao and Murthy (1976) parasitism of E. zehntneri alone reached a maximum of 67% in August.

The LSD value at 1 per cent level of significance has been calculated as 5.77 for different stations, which shows that the mean incidence of Thakurgaon, Setabganj, Shyampur, Jaipurhat, Mobarakganj and Dorshona significantly differ from those of other stations, but Panchagar alone significantly

differ from all remaining stations regarding the incidence of the parasites (Appendix table-XVIII). Again the incidence of 1st brood significantly differs from the rest and the incidence of the 2nd and 5th broods differ significantly with 3rd and 4th.

Analysis of variance in case of incidence of the parasites in different broods and stations shows highly significant for all the varieties ($P < 0.001$, Appendix table. XVIII).

The percentage of parasitism by 6 different parasites at different stations are shown separately in Table 12, 13, 14, 15, 16 and 17. Among all the parasites, T. jokohamensis was the most common species in all the study areas and its highest mean percentage was 15.40 ± 1.74 at Panchagarh. But E. zehntneri, R. schoenobivorous and S. nicevillei were less common everywhere and their highest mean percentage were 6.50 ± 0.67 , 4.20 ± 0.44 and 3.00 ± 0.37 respectively. A. flavipes and I. javensis were very much rare and their respective highest mean percentage were 2.90 ± 0.32 and 1.60 ± 0.31 only. These two parasites were totally absent at Mobarakganj, Dorshona and Jagati. A. flavipes was also absent at Jaipurhat.

Rahman (1976) reported I. javensis, E. zehntneri, S. nicevillei, T. jokohamensis, R. schoenobivorous and R. scirpophagae in the northern districts of Bangladesh.

Table - 11

Record of the gregarious parasites per host larvae

Survey Years	No. of parasite per host larvae		
	<u>R. schoenobivorous</u>	<u>A. flavipes</u>	<u>E. jehntneri</u>
1987- 1988	9, 15, 11, 26, 14,	30, 19, 35, 33, 13,	80, 124, 63, 46, 59,
	18, 24, 15, 21, 27,	29, 22, 28, 36, 14,	67, 42, 41, 54, 73,
	6, 6, 22, 16, 23,	30, 18, 36, 27, 35,	91, 58, 47, 58, 66,
	28, 10, 20, 12, 7,	12, 31, 15, 22, 30,	116, 60, 48, 52, 93,
	16, 9, 17, 25, 12,	34, 23, 36, 17, 20,	57, 65, 44, 71, 46,
	16, 14, 10, 19, 28,	21, 16, 12, 18, 15,	67, 116, 71, 43, 78,
	10, 22, 8, 15, 21,	27, 29, 25, 24, 33,	49, 56, 51, 42, 66,
	9, 12, 26, 21, 9,	26, 32, 20, 12, 18,	48, 55, 82, 40, 61,
	12, 18, 11, 27, 8,	23, 16, 34, 34, 30,	57, 105, 53, 63, 74,
	20, 13, 23, 7, 24,	17, 26, 12	41, 53, 92, 57
	20, 11, 6, 23, 10,		
	16, 7		
1988- 1989	25, 17, 5, 22, 25,	19, 25, 32, 35, 29,	44, 45, 53, 62, 49,
	18, 15, 6, 11, 16,	22, 24, 31, 13, 14,	85, 110, 69, 42, 41,
	5, 28, 13, 9, 14,	14, 26, 18, 23, 16,	40, 52, 84, 96, 57,
	19, 22, 7, 24, 10,	21, 17, 15, 20, 19,	46, 132, 48, 47, 41,
	10, 21, 16, 27, 9,	17, 15, 12, 20, 19,	64, 71, 122, 50, 44,
	23, 18, 12, 28, 13,	24, 22, 12, 21, 36,	67, 114, 53, 46, 51,
	17, 26, 15, 11, 24,	22, 33, 26, 32, 23,	62, 56, 45, 66, 54,
	18, 12, 20, 19, 25,	31, 23, 20, 16, 15,	60, 54, 43, 47, 58,
	8, 14, 5, 16	14, 13, 18, 19, 16,	112, 95, 42, 140, 86,
		21, 14, 23, 28, 19,	44, 142, 58, 48, 55
		12, 22	
Maximum number	28	36	142
Minimum number	05	12	40
Mean $\pm$ S.E.	15.33 $\pm$ 0.698	21.37 $\pm$ 0.782	63.71 $\pm$ 2.57

Table - 12

Incidence of I. javensis of Different Experimental Zones
at Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood		Second brood		Third brood		Fourth brood		Fifth brood		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	1	2	1	1	2	0	3	1	1	1	1.30 $\pm$ 0.261
Harian	1	0	1	1	0	1	1	1	0	1	0.70 $\pm$ 0.153
Panchagar	0	0	2	2	1	2	2	3	2	2	1.60 $\pm$ 0.306
Thakurgaon	1	1	1	1	1	1	2	2	2	1	1.30 $\pm$ 0.153
Setabganj	0	1	1	2	1	0	2	2	1	0	1.00 $\pm$ 0.258
Shyampur	2	1	0	2	2	3	1	2	2	2	1.70 $\pm$ 0.261
Mohimaganj	0	1	2	2	1	1	0	2	1	0	1.00 $\pm$ 0.258
Jaipurhat	0	1	1	1	2	2	1	2	2	0	1.20 $\pm$ 0.250
Mobarakganj	-	-	-	-	-	-	-	-	-	-	
Dorsona	-	-	-	-	-	-	-	-	-	-	
Jogati	-	-	-	-	-	-	-	-	-	-	

Table - 13

Incidence of E. zehntneri of different Experimental Zones
at Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood		Second brood		Third brood		Fourth brood		Fifth brood		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	2	4	3	5	5	5	4	8	4	4	4.40 $\pm$ 0.499
Harian	4	3	4	4	6	5	7	5	5	3	4.60 $\pm$ 0.400
Panchagar	6	5	4	4	8	8	9	10	6	5	6.50 $\pm$ 0.671
Thakurgaon	2	3	5	5	4	5	5	5	5	4	4.20 $\pm$ 0.389
Setabganj	2	3	4	4	4	5	5	6	4	4	4.10 $\pm$ 0.348
Shyampur	1	2	3	3	4	2	4	4	2	3	2.80 $\pm$ 0.327
Mohinaganj	3	3	5	4	5	5	5	6	4	5	4.50 $\pm$ 0.308
Jaipurhat	4	3	5	4	6	7	6	7	5	5	5.20 $\pm$ 0.417
Mobarakanj	1	4	5	3	5	4	6	5	4	2	3.90 $\pm$ 0.482
Dorsona	3	3	6	5	6	5	7	5	5	5	5.00 $\pm$ 0.395
Jogati	3	3	4	5	6	6	6	4	5	5	4.70 $\pm$ 0.367

Table - 14

Incidence of S. nicevillei of Different Experimental Zones
at Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood		Second brood		Third brood		Fourth brood		Fifth brood		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	2	1	2	3	2	5	3	2	2	2	2.40 $\pm$ 0.340
Harian	0	2	1	2	3	1	2	6	2	0	1.90 $\pm$ 0.547
Panchagar	3	1	2	4	4	3	3	5	3	2	3.00 $\pm$ 0.365
Thakurgaon	1	1	2	2	4	2	2	3	3	2	2.20 $\pm$ 0.291
Setabganj	1	0	2	2	3	3	2	5	2	2	2.20 $\pm$ 0.417
Shyampur	0	1	3	1	2	4	3	2	1	1	1.80 $\pm$ 0.389
Mohimaganj	1	1	0	0	2	4	3	4	2	2	1.90 $\pm$ 0.459
Jaipurhat	0	2	2	4	1	3	2	3	1	2	2.00 $\pm$ 0.365
Mobarakganj	0	1	2	2	3	3	4	6	2	4	2.70 $\pm$ 0.539
Dorsona	1	2	6	5	4	3	6	3	2	3	3.50 $\pm$ 0.543
Jogati	2	3	7	3	5	4	3	4	2	3	3.60 $\pm$ 0.476

Table - 15

Incidence of T. jokoahamensis of Different Experimental Zones
at Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood 1987-88, 1988-89		Second brood 1987-88, 1988-89		Third brood 1987-88, 1988-89		Fourth brood 1987-88, 1988-89		Fifth brood 1987-88, 1988-89		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	6	8	9	11	10	12	13	14	7	6	9.60 $\pm$ 0.910
Harian	7	6	10	7	12	11	14	8	8	10	9.30 $\pm$ 0.804
Panchagar	10	12	11	10	18	19	23	25	14	12	15.40 $\pm$ 1.74
Thakurgaon	5	6	9	10	11	9	12	13	10	9	9.40 $\pm$ 0.778
Setabganj	4	5	8	9	8	10	11	8	9	8	8.00 $\pm$ 0.667
Shyampur	3	4	7	6	8	5	10	9	6	7	6.80 $\pm$ 0.680
Mohimaganj	5	7	10	11	10	9	12	8	8	9	8.90 $\pm$ 0.641
Jaipurhat	5	9	8	12	10	13	13	14	10	9	10.30 $\pm$ 0.870
Mobarakganj	2	4	5	6	11	12	13	11	8	8	8.00 $\pm$ 1.17
Dorsona	4	5	7	9	4	8	6	12	9	10	7.40 $\pm$ 0.847
Jogati	4	6	9	9	11	11	14	15	12	10	10.10 $\pm$ 1.06

Table - 16

Incidence of *R. schoenobivorous* of Different Experimental Zones
at Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood		Second brood		Third brood		Fourth brood		Fifth brood		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	2	1	2	2	2	3	5	4	2	2	2.50 ± 0.373
Harian	2	2	3	2	3	3	4	3	2	2	2.60 ± 0.221
Panchagar	2	5	3	4	4	5	5	7	3	4	4.20 ± 0.443
Thakurgaon	1	2	2	3	3	4	3	3	2	3	2.60 ± 0.267
Setabganj	1	2	1	2	2	3	2	2	3	3	2.10 ± 0.234
Shyampur	0	1	2	1	2	1	3	2	1	2	1.50 ± 0.269
Mohimaganj	1	2	3	3	3	4	3	3	2	2	2.60 ± 0.267
Jaipurhat	4	2	3	2	4	3	2	3	3	3	2.90 ± 0.234
Mobarakganj	2	1	4	3	2	4	2	3	2	2	2.50 ± 0.305
Dorsona	1	2	3	4	4	2	4	3	3	3	2.90 ± 0.315
Jogati	2	2	3	3	3	3	4	6	2	2	3.00 ± 0.395

Table - 17

Incidence of A. flavipes of Different Experimental Zones at
Different Broods in the Year 1987-88 and 1988-89

Experimental Zones	First brood		Second brood		Third brood		Fourth brood		Fifth brood		Mean $\pm$ S.E.
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89	
Meherchandi	1	2	2	1	2	2	2	3	4	4	2.30 $\pm$ 0.335
Harian	2	1	2	2	2	3	3	3	1	1	2.00 $\pm$ 0.258
Panchagar	2	3	2	2	3	3	3	4	2	5	2.90 $\pm$ 0.315
Thakurgaon	0	1	1	2	1	1	2	2	1	1	1.20 $\pm$ 0.200
Setabganj	0	1	2	2	2	3	2	2	2	1	1.70 $\pm$ 0.261
Shyampur	0	1	2	1	1	2	1	2	2	1	1.30 $\pm$ 0.214
Mohimaganj	1	1	2	2	2	2	2	2	2	2	1.80 $\pm$ 0.133
Jaipurhat	0	0	0	0	0	0	0	0	0	0	---
Mobarakganj	-	-	-	-	-	-	-	-	-	-	---
Dorsona	-	-	-	-	-	-	-	-	-	-	---
Jogati	-	-	-	-	-	-	-	-	-	-	---

According to Khalequzzaman and Mannan (1982) those first 5 parasites prevailed at Rajshahi region. But in the present investigation, along with those 5 parasites reported by Khalequzzaman and Mannan (1982) one microgastrinae A. flavipes was recorded. Karim et al. (1977) also reported A. flavipes as a parasite of sugarcane borers. But R. scirpophagae was not found throughout the study areas as recorded by Rahman (1976).

Rahman (1976) and Khalequzzaman and Mannan (1982) reported I. javensis and S. nicevillei as the most common parasites. But these parasites, in the present findings were less common while T. jokohamensis was found to be the most common species. But Rahman (1976) and Khalequzzaman and Mannan (1982) recorded it to be less common.

4.72 Biology of the parasites:

i) Elasmus zehntneri Ferr.

This is a gregarious parasite. The newly hatched grub measured $.05 \pm 0.002$ cm. The eggs were generally laid on the host body. But if the eggs were laid, away from the host, the grubs when hatched out, glided on the smooth silken lining of the tunnel until they reached the host. Similar observation was reported by Cherian and Israel (1937). As many as 40-142 (63.71 ± 2.57) (Table - 11) grubs were observed attached to the body of one host caterpillar. They crawled over the host

and punctured its skin at some tender part of the cuticle and sucked the juice from the host's body. As a result, the host larva shrunk, became inactive and ultimately died. White, cylindrical and transparent parasitoid larvae congregated in the host body and consumed its body. They ultimately fed on the entire tissue of the host including the viscera. However a few of the parasitoid were found to remain aloof from the main attack. (Plate 16). A full-grown larva was 0.31 ± 0.01 cm in length. Cherian and Israel (1937) reported that a full-grown larva was $3\frac{1}{2}$ mm x 1 mm long.

The larval periods of E. zehntneri have been represented in table 18. The periods on an average were 3.43 ± 0.14 and 3.69 ± 0.92 days for the 3rd and 4th brood respectively. Cherian and Israil (1937) reported it to be 2-4 days.

A freshly formed pupa was uniformly white and 2 days later the eyes became reddish brown and a day later they turned black. Ultimately the pupa became completely black. It was easy to separate the sexes as the males were distinctly smaller than the female pupae. The pupal periods were recorded 9.39 ± 0.49 and 9.70 ± 0.53 days (Table 18) for the 3rd and 4th brood respectively in the present study. According to Cherian and Israel (1937) the pupal period of E. zehntneri lasted for 7-10 days.

The adult wasp (Plate 17) was nearly black in colour with slightly reddish mark on the ventral part of the abdomen. It

could be easily distinguished by the triangular shape of the body and the abdomen. The slender abdomen was sharply jointed with thorax. The male and the female wasp could easily be identified (Plate 17).

Male.

It measured 0.23 ± 0.007 cm and was smaller than the female; abdomen pale yellow and the triangular black spots on the sides of the 2nd-5th segments broader; on 5th segment the spots joined above so that only the hind border remained yellow. Antennae were with long ramelli on 4th, 5th and 6th joints; 7th joints long, as long as two-thirds of 3rd ramellus; club was narrow.

Female.

The female was 0.29 ± 0.01 cm in length and its head and thorax were black with greenish shine. Head was short and narrow than the thorax. Abdomen was orange, antennae yellow, legs pale yellow, the tarsi somewhat brown and wings hyaline with yellow nerves. The ovipositor remained projected very little beyond tip of the abdomen. Antennae were with ten joints and legs were with coxae branched very much. Wings were with marginal nerve longer than sub-marginal ones.

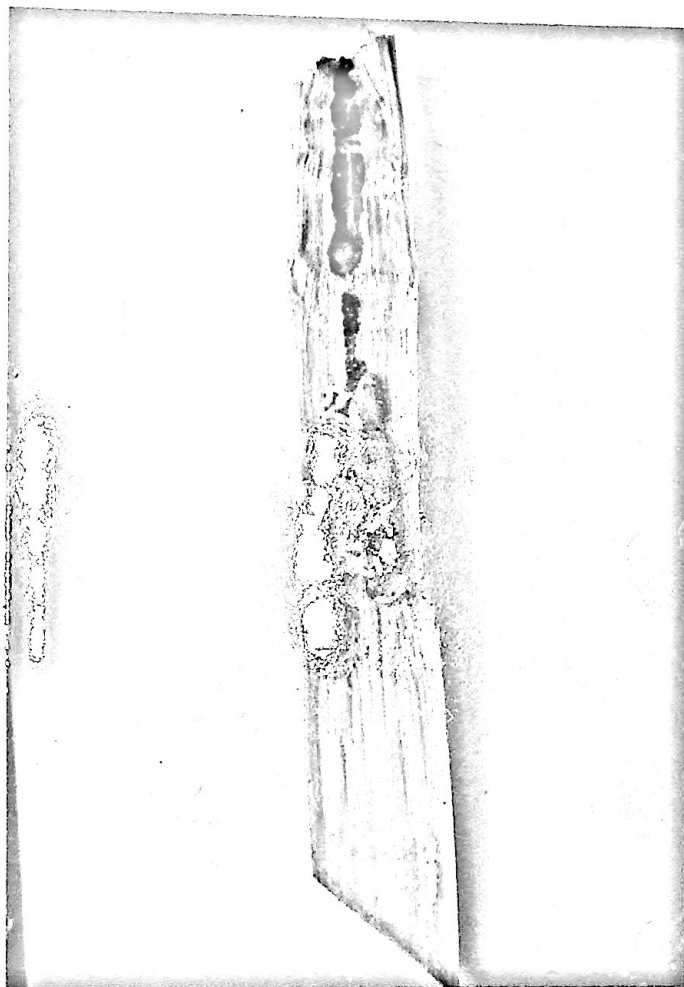


Plate - 16: Larvae of E. zehntneri away
from main attack.

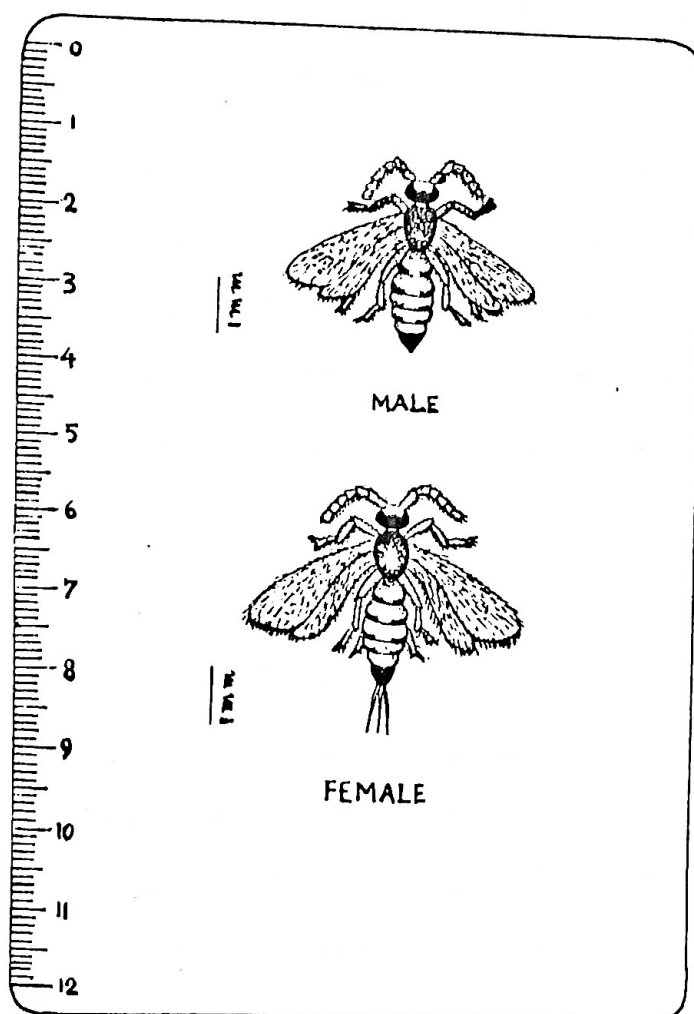


Plate - 17: Adults of E. zehntneri.

Cherian and Israel (1937) reported that without food both males and females did not live more than three days. But in the present findings, the males and the females lived for 7.76 ± 0.81 , 8.06 ± 0.75 and 11.39 ± 0.88 , 11.79 ± 0.79 days for the 3rd and 4th brood without any food.

The number of male and female adults with their sex ratios in third and fourth broods have been shown in Table 19. The sex ratios were 36.05:63.95 and 38.89:61.11 in the third and fourth brood respectively. The K^2 values of the ratios of both the broods were found significant at ($P < 0.01$) and ($P < 0.05$).

ii) Stenobracon nicevillei Bingham

This parasite is solitary in nature. The larva is golden in colour with slightly yellowish dorsal part. Both the anterior and posterior ends of the body were slightly tapered. The newly hatched larva measured $0.14 \pm .004$ cm. They crawled over the host while sucked the juice by turning the skin of the host body. The parasitoid failed to thrive when it was transferred to an unparalysed or artificially killed caterpillar. On the other hand, when a paralysed caterpillar was supplied to a freshly hatched parasitoid larva, it was found to thrive successfully. A full-grown parasitoid larva was 2.15 ± 0.03 cm long and 0.24 ± 0.008 cm broad. The larval periods have been shown in the Table 18. The periods

were 5.83 ± 0.31 and 5.80 ± 0.36 days for the 3rd and 4th brood respectively. Cherian and Israel (1937) observed that the larval period was 3 to 7 days.

A full-grown larva spun a white cocoon of silk, which is completed in a day. Then a larva underwent pupation inside that cocoon very close to the body of dead host (Plate 18B). The puparium looked white at the initial stage, but finally turned to golden colour. The pupal periods were 10.96 ± 0.56 and 11.29 ± 0.49 days for the 3rd and 4th brood (Table 18). But the pupal period was about 7 days (Cherian and Israel, 1937).

The adults (Plate 19) looked apparently yellowish with black head. The wing span was 2.40 ± 0.04 cm. There were 2 round black spots on each wing and the tip of the wing was also black. The antennae were quite long. The cerci were black. The ovipositor was white and it was nearly 1.77 ± 0.013 cm. in length. The females could easily be separated by their ovipositors. The longevity of the male and the female (Table 18) were 14.13 ± 0.75 , 15.30 ± 0.87 and 17.13 ± 0.77 , 18.09 ± 0.95 days for the 3rd and 4th period.

For longevity experiment, Cherian and Israel (1937) fed the wasps with honey-water and reported that the males and the females lived for 11-29 and 9-21 days respectively where the males lived more than the females.



Plate - 18: Late larva and pupae of S. nicevillei: Late larva (A), pupae of S. nicevillei close to the body of the host (B) and pupae of S. nicevillei (C).

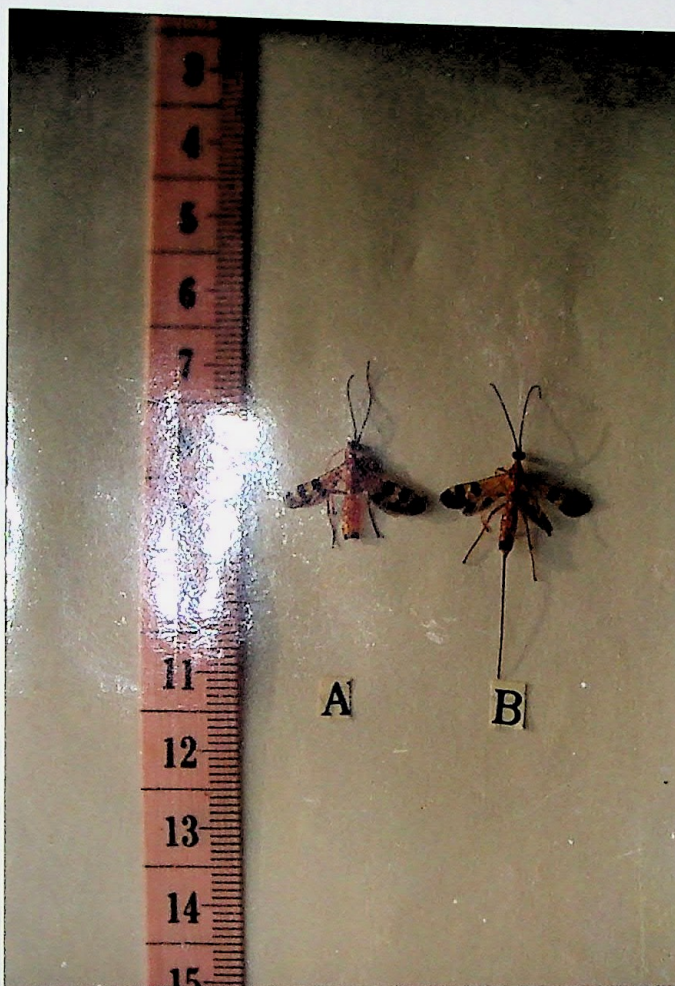


Plate - 19: Adults of S. nicevillei:
Male (A) and Female (B).

The sex ratios were 31.19:68.81 and 34.19:65.81 in the third and fourth brood respectively (Table 19). It was found that the K^2 values of the ratios of both the broods were significant at ($P < 0.001$) and ($P < 0.01$).

iii) Topobracon jokohamensis Cam.

This is also a solitary parasite. This parasite in its larval and adult forms looked almost similar to S. nicevillei. The larva was yellow golden in colour. It consumed the body tissue of the host larva leaving back only its cuticle and finally became full-grown. A full-grown larva was about 2.37 ± 0.035 cm. long and 0.24 ± 0.005 cm. broad. This full-grown larva made the puparium outside the host body (Plate 20C) and entered into pupation. The larval and pupal periods were 7.20 ± 0.39 , 13.10 ± 0.57 and 7.70 ± 0.54 , 13.33 ± 0.66 days for the 3rd and 4th brood respectively.

The adult was slightly larger in size than that of S. nicevillei. This parasite had also 2 black spots on the wings but the tip of the wing was less black. The ovipositor of the female of this species was shorter in comparison with that of S. nicevillei (Plate 21B) and it was 0.35 ± 0.011 cm. The cerci were also short. The longevity of the male and the female were 15.03 ± 1.22 , 15.86 ± 1.18 and 18.30 ± 1.61 , 17.40 ± 1.26 days for the 3rd and 4th brood respectively.

Table - 18

Larval, pupal periods and adult longevity of parasites
(E. zehntneri, S. nicevillei and T. jokohamensis)

Name	Broods	Larval period	Pupal period	Adult longevity male (♂)	Adult longevity female (♀)
<u>E. zehntneri</u>	3rd	3.43 ± 0.141	9.39 ± 0.497	7.76 ± 0.804	11.39 ± 0.881
	4th	3.69 ± 0.092	9.70 ± 0.530	8.06 ± 0.744	11.79 ± 0.786
<u>S. nicevillei</u>	3rd	5.83 ± 0.319	10.96 ± 0.558	14.13 ± 0.747	17.13 ± 0.771
	4th	5.80 ± 0.355	11.296 ± 0.491	15.30 ± 0.871	18.09 ± 0.948
<u>T. jokohamensis</u>	3rd	7.20 ± 0.342	13.10 ± 0.569	15.03 ± 1.215	18.30 ± 1.609
	4th	7.70 ± 0.538	13.33 ± 0.656	15.86 ± 1.179	17.40 ± 1.263

Table - 19

Sex ratio of E. zehntneri, S. nicevillei and T. jokohamensis

Name of the parasites	Broods	Sex	1987-88					1988-89					Total No. of the adults	Sex ratio	x ²
			No. of replications					No. of replications							
			1	2	3	4	5	1	2	3	4	5			
<u>E. zehntneri</u>	Third	♂	12	24	13	16	12	16	6	16	10	12	137	36.05	7.784 ^{***}
		♀	16	40	33	32	18	22	13	30	17	22	243	63.95	
	Fourth	♂	21	18	11	20	9	14	12	17	10	8	140	38.89	4.937 [*]
		♀	31	28	16	31	15	20	21	28	15	15	220	61.11	
<u>S. nicevillei</u>	Third	♂	3	4	3	2	5	3	2	4	2	6	34	31.19	14.153 ^{***}
		♀	9	5	4	8	11	5	7	7	6	13	75	68.81	
	Fourth	♂	5	3	2	5	4	3	4	6	3	5	40	34.19	9.998 ^{***}
		♀	10	5	4	9	10	5	9	10	6	9	77	65.81	
<u>T. jokohamensis</u>	Third	♂	8	12	6	8	6	6	8	6	5	6	71	35.68	8.202 ^{***}
		♀	16	20	16	10	8	9	15	11	10	13	128	64.32	
	Fourth	♂	8	7	8	10	5	7	4	6	4	9	68	32.85	11.765 ^{***}
		♀	19	12	16	18	10	13	13	10	11	17	139	67.15	

*, **, *** Significant at 5%, 1% and 0.1% respectively.



Plate - 20: Larvae and pupae of T. jokohamensis:
Larva outside the tunnel (A)
Larva attached to a host larva (B).

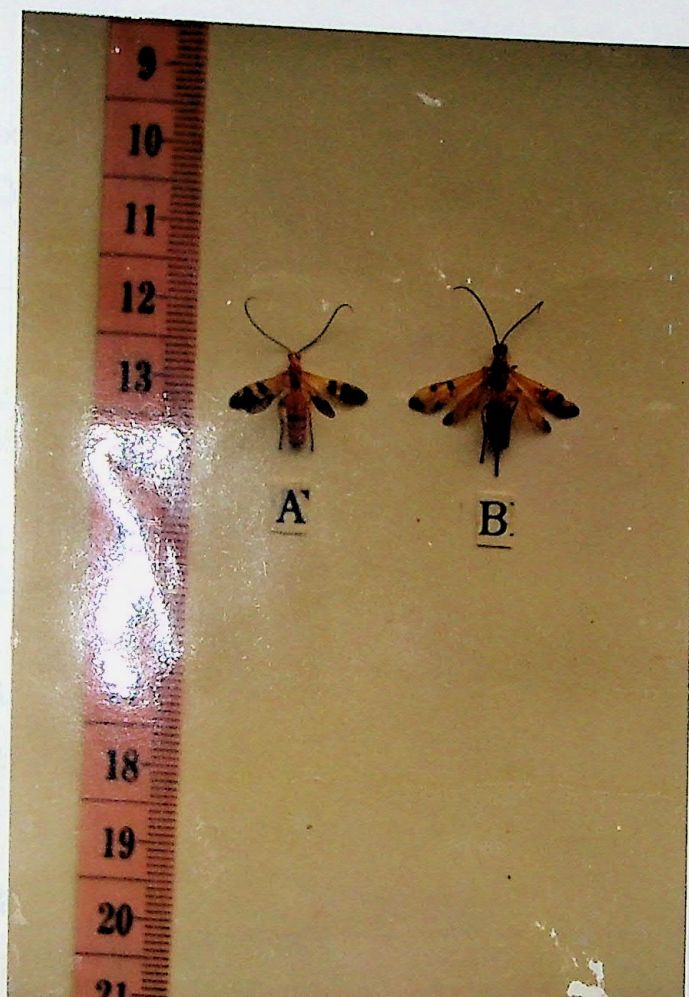


Plate - 21: Adults of T. jokohamensis:
Male (A) and Female (B).

The sex ratio of male and female in third brood was 35.68:64.32 and it was 32.85:67.15 in case of the fourth brood (Table 19). The K^2 values of the ratios were found significant at ($P < 0.01$) and ($P < 0.001$).

Mannan (1979) reported that the larva of T. jokohamensis was about 2.5 cm in length and they pupated outside the host body. He also reported the female had a ovipositor of one cm. in length.

4.73 Description of the less common parasites:

i) I. javensis Rohw

This is a solitary larval as well as pupal parasite. The parasitoid larva bored through the cuticle of the host larvae and entered into it. The ash coloured young larva became nearly white at the full-grown stage, with ash coloured broad line on the dorsal side of the body. The larva fed the body tissue and became mature. The mature larva was about 1.21 ± 0.017 cm. in length with almost pointed anterior end and slightly blunt posterior end. The parasitoid passed its pupal stage inside the body of the host. The puparium of the parasitoid was almost white in the beginning but it turned into dark brown colour later on. The change of the colour became apparent antero-posteriorly. The length of the puparium was 1.19 ± 0.024 cm.

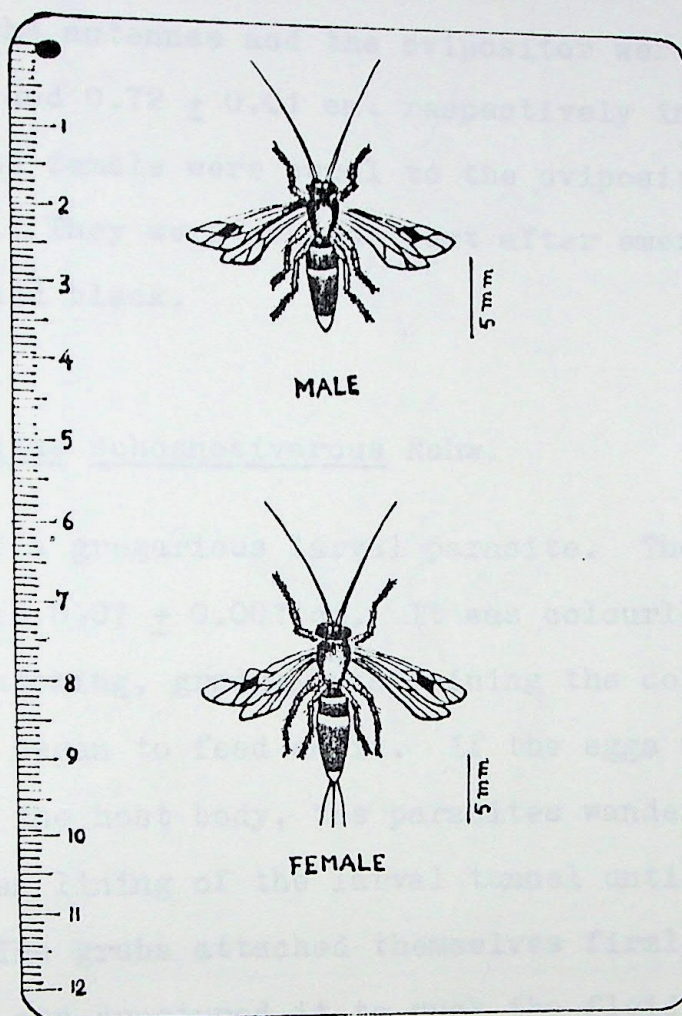


Plate - 22: Adults of I. javensis

The adult could easily be identified. The head region was nearly black. The thorax was slightly reddish in colour. The dorsal part of the abdomen was black with a few white bands but the ventral part was nearly white, with black spots. The wing span, the antennae and the ovipositor were 1.39 ± 0.02 , 1.22 ± 0.01 and 0.72 ± 0.01 cm. respectively in length. Two cercii of the female were equal to the ovipositor in size (Plate 22). They were greyish just after emergence but finally turned black.

ii) Rhaconotus schoenobivorous Rohw.

This is a gregarious larval parasite. The newly-hatched grub measured 0.07 ± 0.001 cm. It was colourless and transparent on hatching, gradually attaining the colour of the host, as it began to feed on it. If the eggs were not laid properly on the host body, the parasites wandered about on the smooth silken lining of the larval tunnel until they reached the host. The grubs attached themselves firmly to the body of the host and punctured it to suck the fluid food material. Black circular demarcations due to puncture were clearly seen on the body of the host. The parasitoids actively fed on the host and reached their maximum size of $0.39 \pm 0.02 \times 0.14 \pm 0.01$ cm.

The grubs then spinned cigar-shaped, white silken cocoons, within which they pupated. The freshly formed pupa

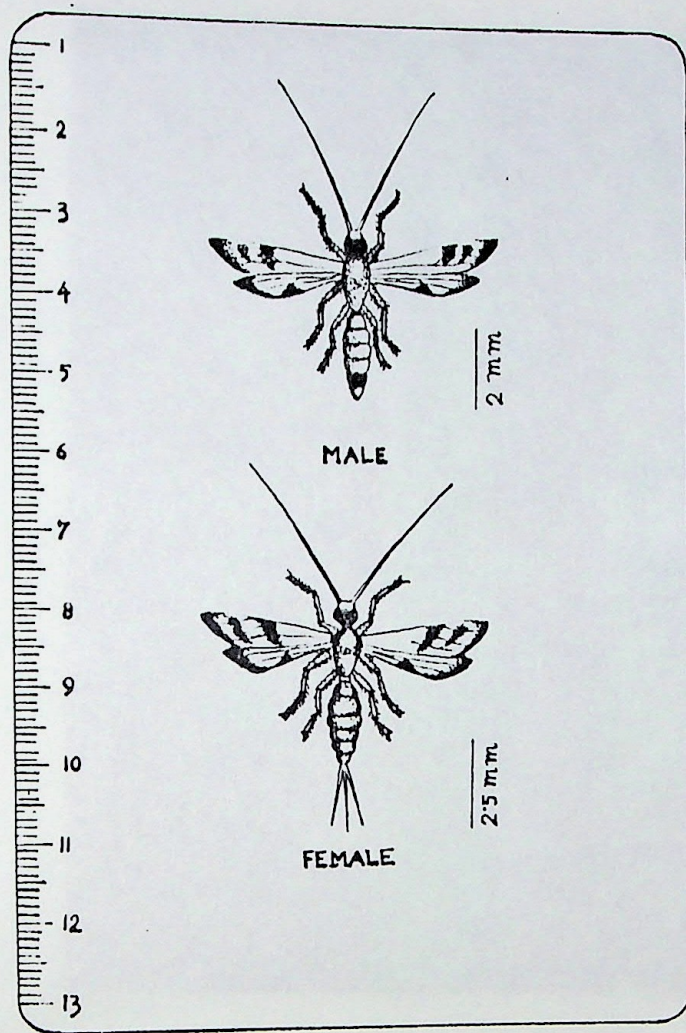


Plate - 23: Adults of R. schoenobivorous.



Plate - 24: Larvae and cocoons of R. schoenobivorous:
 Larvae (A), Larvae close to a host larva (B)
 and cocoons of R. schoenobivorous (C).

was white and measured $0.49 \pm 0.01 \times 0.13 \pm 0.008$ cm. All the pupae became brownish prior to adult emergence.

The dorsal part of the abdomen of the adult was slightly reddish while the ventral part was creamy. The adult was $0.18 \pm 0.005 \times 0.05 \pm 0.002$ cm in size. The female possessed a short ovipositor which measured 0.04 ± 0.002 cm. (Plate 23).

iii) A. flavipes Cam.

This species is gregarious in habit. A single host larva supported 12-36 (21.37 ± 0.78) such individuals. A parasitoid larva was composed of 13 body segments and its large head was sclerotized. The full grown larvae pupated out of the host body and the cocoons were irregularly deposited together (Plate 24C).

The adult was almost black in colour. It was 0.24 ± 0.005 and 0.05 ± 0.002 cm. in length and breadth respectively. Head was small and punctate. Leg was black and hind legs were longer than fore legs (Plate 25). Mouth had membranous labium. Small thorax had two pairs expanded transparent wings. Wing veins and stigma were brown. Stigma was shorter than metacarp. The head as well as the last abdominal part was black. But the rest part in between the head and the anal tip was yellowish.

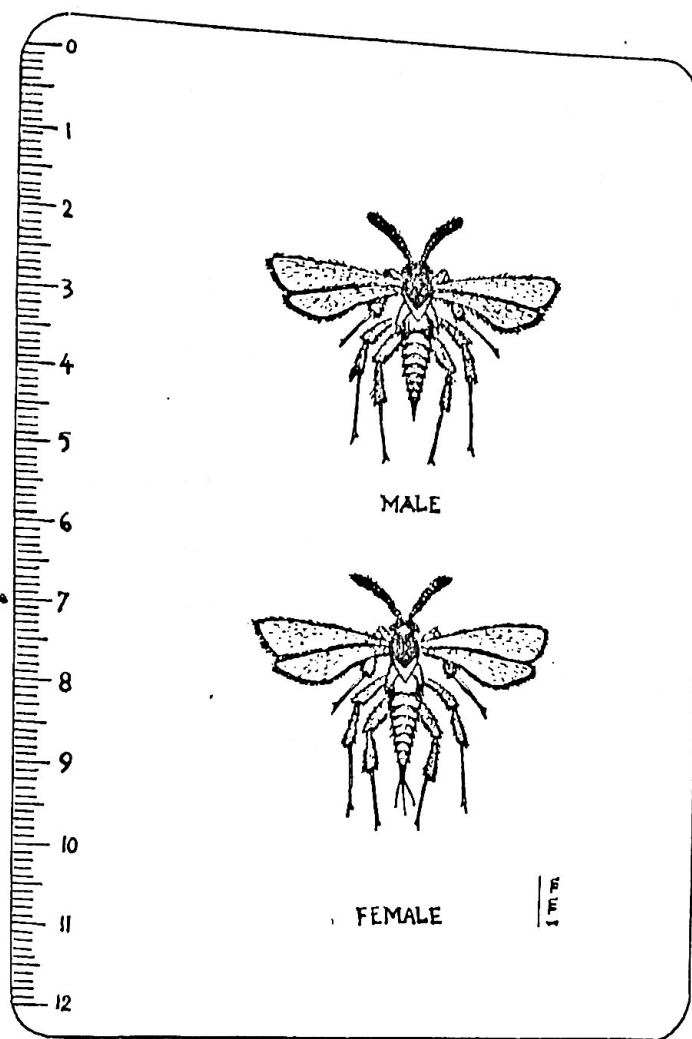


Plate - 25: Adults of A. flavipes.

4.74 Behaviour of the adult parasites:

The adult parasites emerged by cutting small holes through the lid of the exit hole constructed by the host larva before its pupation. Generally the adults were active immediately after emergence and mating took place on the same or on the subsequent days. The female parasite, after locating a host larva inside the stem, waited till the larva began to construct the lid i.e., it then came within the reach of her ovipositor. Now she thrust her ovipositor through the lid, stung the caterpillar and laid eggs in clusters either on the host or attached to the inner circumference of the tunnel. This was a common habit exhibited by all the adult parasitoids.

CHAPTER-5



CONCLUSION

CONCLUSION

On the basis of the results obtained from the experiments of the research project, "Bionomics of the sugarcane top shoot borer, Tryporyza nivella (Fab.)" carried out during 1987-1990 in the Department of Zoology, Rajshahi University and 11 sugar mill zones of north-western Bangladesh, the following conclusions can be made:

i) Although the pest has been identified to be T. nivella (Fab.) and the different 'morphs' have been considered as 'phase' (seasonal) variations, it should be investigated further cytogenetically and genetically.

ii) Since the incidence and development of the pest are influenced by temperature and relative humidity, these factors of the environment of a particular region must be considered to develop any model for surveillance, monitoring and forecasting of the pest.

iii) No cultivar of the crop is immune to the attack of the pest, but some sort of resistance and tolerance have been observed to different degrees in different varieties. These have been inferred from the incidence, loss assessment and recovery percentage. The mechanism is yet to be found out.

To recommend a cultivar to be more profitable, the performance of the variety against the pest must be brought into consideration from both the agronomic and industrial points of view.

iv) Regarding the control measures the pest can be controlled completely by mechanical and biological methods. Mechanical control is to be executed properly under efficient and intensive care at the earlier stage (From March to May) of the crop. The effectiveness of different indigenous natural enemies is regional and seasonal. The number, density and efficacy of these natural enemies are very much encouraging. Growers' and managers' awareness are very much essential regarding these farmer's friendly insects for their augmentation, and their activities must be boosted up. Legislative measures in these aspects are also suggested.

CHAPTER-6



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6. LITERATURE CITED

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CHAPTER-7

APPENDICES

Appendix table - I

Analysis of Variance of Pre-oviposition Period Between Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs (ni)	Total (Ti)	Mean [*]
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	1.50	1.25	1.09	1.13	1.38	1.13	1.21	1.50	1.04	1.75	10	12.98	1.298 ^a
Second	1.25	1.13	1.50	1.09	1.04	1.04	1.38	1.25	1.09	1.13	10	11.90	1.190 ^a
Third	1.04	1.25	1.09	1.22	1.13	1.13	1.00	1.17	1.25	1.09	10	11.37	1.137 ^a
Fourth	1.25	1.00	1.75	1.04	1.38	1.09	1.21	1.50	1.32	1.13	10	12.67	1.267 ^a
Fifth	1.38	1.75	1.13	1.50	1.25	1.21	1.54	1.25	1.45	1.32	10	13.78	1.378 ^{ab}
Total											50	62.70	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(62.70)^2}{50} = 78.626$$

$$\text{Total sum of squares, TSS} = \sum \sum x_{ij}^2 - \text{C.F.} = 80.611 - 78.626 = 1.885$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 78.974 - 78.626 = 0.348$$

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between broods	4	0.348	0.087	2.547 [*]
Error	45	1.537	0.034	(P < 0.05)
Total	49	1.885		

^{*}Mean having the same digit shows no significant differences.

The result is significant

$$\text{L.S.D.} = t_{0.05}^{45} \times \text{S.E.} = 2.021 \times 0.082 = 0.166$$

$$\text{S.E.} = \sqrt{\frac{2 \times 0.034}{10}} = 0.082$$

Analysis of Variance of Oviposition Period between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	0.87	1.16	1.46	1.66	2.12	0.96	1.16	1.46	1.87	2.16	10	14.88	1.488 a
Second	1.50	1.62	2.46	2.62	2.79	1.46	1.75	2.66	2.79	2.91	10	22.56	2.256 abc
Third	1.79	2.16	2.33	2.58	2.83	1.66	2.37	2.46	2.62	3.04	10	23.84	2.384 bc
Fourth	1.91	2.20	2.62	2.70	3.29	1.83	2.33	2.46	2.66	3.75	10	25.75	2.575 c
Fifth	1.08	1.37	1.70	2.08	2.37	1.16	1.46	1.62	1.41	2.75	10	17.00	1.70 ab
Total											50	104.03	

$$\text{Correction factor, C.F. } G^2/N = \frac{(104.03)^2}{50} = 216.445$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 237.604 - 216.445 = 21.159$$

$$\text{Brood sum of squares, SS} = \sum T_i^2 / n_i - \text{C.F.} = 225.083 - 216.445 = 8.638$$

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between broods	4	8.638	2.160	7.761 ***
Error	45	12.521	0.278	(P < 0.001)
Total	49	21.159		

The result is highly significant

$$\text{S.E.} = \sqrt{\frac{2 \times 0.278}{10}} = 0.236$$

$$\text{L.S.D.} = t^{45} \times \text{S.E.} = 3.551 \times 0.236 = 0.838$$

0.001

Analysis of Variance of Fecundity Between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	68	96	126	158	227	72	88	105	132	223	10	1295	129.50 c
Second	57	94	117	136	154	70	93	111	131	142	10	1105	110.50 b
Third	52	62	80	108	145	52	80	108	113	130	10	930	93.00 ab
Fourth	42	67	76	82	118	42	67	76	82	97	10	749	74.90 a
Fifth	54	74	96	132	148	67	96	105	132	148	10	1052	104.20 abc
Total											50	5131	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(5131)^2}{50} = 526543.22$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 606402.44 - 526543.22 = 79859.78$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 543065.50 - 526543.22 = 16522.28$$

ANOVA

Source of Variation	D.F.	SS	MS	F-value
Between broods	4	16522.28	4130.57	2.935 [*]
Error	45	63337.50	1407.50	(P < 0.05)
Total	49	79859.78		

The result is significant

$$\text{L.S.D.} = t_{0.05}^{45} \times \text{S.E.} = 2.021 \times 16.778 = 33.908$$

$$\text{S.E.} = \sqrt{\frac{2 \times 1407.50}{10}} = 16.778$$

Appendix table - IV

Analysis of Variance of Incubation Period Between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	8.12	8.41	8.50	9.20	9.32	8.04	8.16	8.41	8.50	9.00	10	85.66	8.566 b
Second	7.12	7.41	8.04	8.20	8.50	7.00	7.08	7.16	7.20	7.24	10	74.95	7.495 a
Third	7.28	7.50	8.54	8.54	9.20	7.16	7.28	7.32	7.36	8.12	10	78.30	7.830 ab
Fourth	7.16	7.50	9.04	9.04	9.16	7.20	7.32	8.00	8.04	8.12	10	80.58	8.058 ab
Fifth	9.12	7.28	8.20	8.20	8.54	7.32	7.36	8.20	8.36	8.40	10	80.98	8.098 ab
Total											50	400.47	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(400.47)^2}{50} = 3207.524$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 3231.594 - 3207.524 = 24.070$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 3213.696 - 3207.524 = 6.172$$

ANOVA

Source of Variation	D.F.	SS	MS	F-value
Between broods	4	6.172	1.543	3.879 ²²
Error	45	17.898	0.398	(P < 0.01)
Total	49	24.070		

The result is highly significant

$$\text{L.S.D.} = t^{45} \times \text{S.E.} = 2.704 \times 0.01 = 0.763$$

$$\text{S.E.} = \sqrt{\frac{2 \times 0.398}{10}} = 0.282$$

Appendix table - V

Analysis of Variance of Larval Period Between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	24.16	26.32	28.12	29.16	30.40	24.12	26.16	28.00	28.32	30.08	10	274.84	27.484a
Second	22.16	23.50	24.46	25.28	26.50	21.12	23.24	24.12	25.12	26.12	10	241.62	24.162a
Third	22.24	22.32	24.37	25.12	26.16	20.08	23.20	24.08	25.12	25.20	10	237.89	23.789a
Fourth	23.04	25.41	28.12	29.04	30.46	23.12	24.32	26.00	28.20	29.04	10	266.75	26.675 a
Fifth	105.12	112.08	126.20	129.37	133.37	110.20	122.04	124.08	130.12	131.04	10	1223.62	122.362 b
Total											50	2244.72	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(2244.72)^2}{50} = 100775.35$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 176930.14 - 100775.35 = 76154.79$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 175891.03 - 100775.35 = 75115.68$$

ANOVA

Source of Variation	D.F.	SS	MS	F-value
Between broods	4	75115.68	18778.92	213.292 xxx
Error	45	1039.11	23.09	(p < 0.001)
Total	49	76154.79		

The result is highly significant

$$\text{L.S.D.} = t^{45} \times \text{S.E.} = 3.551 \times 2.149 = 7.631$$

$$\text{S.E.} = \sqrt{\frac{2 \times 23.09}{10}} = 2.149$$

Appendix table - VI

Analysis of Variance of Pupal Period Between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	12.50	11.75	11.58	10.41	8.95	9.32	10.32	11.20	12.12	12.40	10	110.55	11.055 a
Second	13.20	12.16	11.91	10.58	9.75	10.16	11.20	12.16	13.04	13.12	10	117.28	11.728 a
Third	12.75	11.91	10.46	9.12	8.32	8.28	9.12	10.04	11.12	11.40	10	102.52	10.252 a
Fourth	17.20	15.58	15.08	14.46	11.46	12.12	14.24	15.08	16.20	17.00	10	148.42	14.842 b
Fifth	22.12	21.08	19.20	18.12	16.12	17.04	18.00	20.12	21.16	21.32	10	194.28	19.428 c
Total											50	673.05	

$$\begin{aligned} \text{Correction factor, C.F.} &= G^2/N = \frac{(673.05)^2}{50} = 9059.93 \\ \text{Total sum of squares, TSS} &= \sum \sum X_{ij}^2 - \text{C.F.} = 9745.24 - 9059.93 = 685.31 \\ \text{Brood sum of squares, SS} &= \sum T_i^2/n_i - \text{C.F.} = 9625.95 - 9059.93 = 566.02 \end{aligned}$$

ANOVA

Source of Variation	D.F.	SS	MS	P-value
Between broods	4	566.02	141.505	53.380 ***
Error	45	119.29	2.651	(P < 0.001)
Total	49	685.31		

The result is highly significant
 $S.E. = \sqrt{\frac{2 \times 2.651}{10}} = 0.728$

$L.S.D. = t_{0.001}^{45} \times S.E. = 3.551 \times 0.728 = 2.585$

Appendix table - VII

Analysis of Variance of male Adult Longevity Between
Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	2.46	3.50	3.62	2.91	3.12	2.50	3.04	3.12	3.32	3.54	10	31.13	3.113a
Second	3.70	3.95	3.32	3.58	2.75	2.65	3.08	3.32	3.65	4.00	10	34.00	3.400a
Third	4.70	3.95	3.62	4.16	4.37	3.66	4.04	4.08	4.12	4.32	10	41.02	4.102b
Fourth	4.95	4.70	4.16	4.28	3.75	3.46	4.12	4.32	4.66	4.82	10	43.22	4.322b
Fifth	2.50	3.20	2.90	2.87	3.16	2.40	2.82	3.12	3.32	3.42	10	29.71	2.971a
Total											50	179.08	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(179.08)^2}{50} = 641.39$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 663.26 - 641.39 = 2.87$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 655.84 - 641.39 = 14.45$$

ANOVA

Source of Variation	D.F.	SS	MS	F-value
Between broods	4	14.45	3.613	21.909***
Error	45	7.42	0.165	(P = < 0.001)
Total	49	21.87		

The result is highly significant

$$\text{L.S.D.} = t_{0.001}^{45} \times \text{S.E.} = 3.551 \times 0.182 = 0.646$$

$$\text{S.E.} = \sqrt{\frac{2 \times 0.165}{10}} = 0.182$$

Appendix table - VIII

Analysis of Variance of Female Adult Longevity
Between Different Broods of T. nivella

Broods	1987-88					1988-89					No. of obs. (n _i)	Total (T _i)	Mean
	No. of replication					No. of replication							
	1	2	3	4	5	1	2	3	4	5			
First	2.20	2.12	2.50	2.00	3.75	2.04	2.12	2.20	2.50	3.08	10	24.51	2.451ab
Second	2.83	2.66	2.95	2.16	2.37	2.08	2.32	2.50	2.81	3.04	10	25.72	2.572abc
Third	2.32	3.10	2.83	3.37	3.28	2.41	2.76	3.20	3.46	3.66	10	30.39	3.039 bc
Fourth	3.32	2.91	3.16	3.75	2.70	2.41	2.78	3.20	3.46	3.66	10	31.35	3.135 c
Fifth	2.08	2.16	2.24	2.12	2.54	2.08	2.20	2.32	2.40	2.58	10	22.72	2.272 a
Total											50	134.69	

$$\text{Correction factor, C.F.} = G^2/N = \frac{(134.69)^2}{50} = 362.828$$

$$\text{Total sum of squares, TSS} = \sum \sum X_{ij}^2 - \text{C.F.} = 376.088 - 362.828 = 13.260$$

$$\text{Brood sum of squares, SS} = \sum T_i^2/n_i - \text{C.F.} = 368.481 - 362.828 = 5.653$$

ANOVA

Source of Variation	D.F.	SS	MS	F-value
Between broods	4	5.653	1.413	8.360 ^{***}
Error	45	7.607	0.169	(P < 0.001)
Total	49	13.260		

The result is highly significant

45

$$\text{L.S.D.} = t \times \text{S.E.} = 3.551 \times 0.184 = 0.653$$

0.001

$$\text{S.E.} = \sqrt{\frac{2 \times 0.169}{10}} = 0.184$$

Appendix table - IX

t-test of adult longevity (days) between the male and female T. nivella of different broods.

First Brood		Second Brood		Third Brood		Fourth Brood		Fifth Brood	
Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2.46	2.20	3.75	2.83	4.70	2.32	4.95	3.32	2.50	2.08
3.50	2.12	3.95	2.66	3.95	3.10	4.70	2.91	3.20	2.16
3.62	2.50	3.32	2.95	3.62	2.83	4.16	3.16	2.90	2.24
2.91	2.00	3.58	2.16	4.16	3.37	4.28	3.75	2.87	2.12
3.12	3.75	2.75	2.37	4.37	3.28	3.75	2.70	3.16	2.54
2.50	2.04	2.65	2.08	3.66	2.41	3.46	2.41	2.40	2.08
3.04	2.12	3.08	2.32	4.04	2.76	4.12	2.78	2.82	2.20
3.12	2.20	3.32	2.50	4.08	3.20	4.32	3.20	3.12	2.32
3.32	2.50	3.65	2.81	4.12	3.46	4.66	3.46	3.32	2.40
3.54	3.08	4.00	3.04	4.32	3.66	4.82	3.66	3.42	2.58

$$\begin{array}{llllll} \bar{x}_1 = 3.11 & \bar{x}_2 = 2.45 & \bar{x}_1 = 3.40 & \bar{x}_2 = 2.57 & \bar{x}_1 = 4.10 & \bar{x}_2 = 3.04 & \bar{x}_1 = 4.32 & \bar{x}_2 = 3.14 & \bar{x}_1 = 2.97 & \bar{x}_2 = 2.27 \\ S = 0.488 & t = 13.81 & S = 0.406 & t = 10.22 & S = 0.389 & t = 13.63 & S = 0.456 & t = 12.94 & S = 0.27 & t = 12.96 \\ P < 0.001 & & P < 0.001 & & P < 0.001 & & P < 0.001 & & P < 0.001 & \end{array}$$

Appendix table - X

Analysis of variance of incidence of T. nivella (Fab.)
infested canes in different sugar mill zones under
different conditions of mechanical control.

Condition	Experimental zones	Broods					Total	Mean
		First	Second	Third	Fourth	Fifth		
Usual mechanical control practice	Meherchandi	6.80	9.20	14.80	19.40	9.40		
	Panchagarh	5.80	9.00	15.20	20.40	7.20		
	Thakurgaon	5.20	7.20	11.20	16.20	6.00		
	Setabganj	3.60	4.60	9.20	12.20	6.60		
	Shyampur	3.20	5.00	7.00	7.60	6.40		
	Mohimaganj	3.40	5.20	7.80	9.40	7.40		
	Jaipurhat	3.80	5.00	8.00	10.80	9.00		
	Mobarakganj	3.80	4.40	12.20	15.60	8.80		
	Darsona	5.40	6.20	7.80	10.60	9.20		
	Jogoti	6.20	6.40	9.20	10.20	8.40		
	Harian	3.80	6.80	10.60	15.60	7.80		
	Average of the above zones	4.64	6.27	10.27	13.45	7.84	42.47	8.495 a
Proper mechanical control practice	Harian	4.20	5.40	6.60	9.20	4.60	30.00	6.00 a
Without mechanical control practice (control)	Grower's plot at Harian	4.80	15.20	35.40	55.80	28.40	139.60	27.92 b

Correction factor, C.F. = 2998.25
Total sum of squares, TSS = 3034.03
Control measures sum of squares, CSS = 822.59
Brood sum of squares, BSS = 1440.12

ANOVA

Source of variation	D.F.	S.S.	M.S.	F-value
Between broods	4	822.59	205.648	2.133
Between control measures	2	1440.12	720.06	7.468* (P 0.05)
Error	8	771.32	96.415	
Total:	14	3034.03		

$$S.E. = \sqrt{\frac{2 \times 96.415}{5}} = 6.210$$

$$L.S.D. = t_{0.05}^8 \times S.E. = 2.306 \times 6.210 = 14.320$$

t-test of length, circumference and weight between infested and non-infested canes (ISD-16 and ISD-17)

ISD-16				ISD-17							
Length (m)		Circumference (cm)		Weight (kg)		Length (m)		Circumference (cm)		Weight (kg)	
Non-infes- ted (x_1)	Infested (x_2)	Non-infes- ted (x_1)	Infested (x_2)	Non-infes- ted (x_1)	Infested (x_2)	Non-infes- ted (x_1)	Infested (x_2)	Non-infes- ted (x_1)	Infested (x_2)	Non-in- fested (x_1)	Infes- ted (x_2)
1.96	1.59	7.81	7.93	4.60	3.80	2.49	1.18	7.23	6.39	4.50	2.00
2.55	1.24	7.50	8.21	6.20	3.40	2.43	1.31	7.22	6.50	5.00	1.90
2.73	1.29	7.50	8.50	5.30	3.00	2.25	1.77	6.60	6.73	4.10	2.50
2.59	1.38	7.36	7.98	5.80	3.20	2.33	1.66	6.85	6.53	3.20	2.00
2.87	1.47	7.58	7.87	5.00	3.00	2.21	1.21	6.54	6.65	3.40	2.15
2.62	1.35	7.06	8.23	5.20	3.10	2.38	1.18	6.97	6.29	4.50	2.20

$\bar{x}_1 = 2.553, \bar{x}_2 = 1.387$ $\bar{x}_1 = 7.47, \bar{x}_2 = 8.12$ $\bar{x}_1 = 5.35, \bar{x}_2 = 3.25$ $\bar{x}_1 = 2.35, \bar{x}_2 = 1.39$ $\bar{x}_1 = 6.90, \bar{x}_2 = 6.52$ $\bar{x}_1 = 4.12, \bar{x}_2 =$
 $S = \pm 0.239, t = 14.651$ $S = \pm 0.245,$ $S = \pm 0.459,$ $S = \pm 0.200$ $S = \pm 0.239$ $S = 2.13, S = \pm 0.515$
 $P < 0.001$ $t = 7.967$ $t = 13.739$ $t = 14.414$ $t = 4.775$ $t = 11.604$
 $P < 0.001$ $P < 0.001$ $P < 0.001$ $P < 0.001$ $P < 0.001$ $P < 0.001$

Appendix table - XII

t-test of length, circumference and weight between infested and non-infested canes (ISD-2/54 and L.J.C.)

ISD-54/2									
Length (m)		Circumference (cm)		Weight (kg)		Length (m)		Circumference (cm)	
						L.J.C.			
Non-infested (x_1)	Infested (x_2)	Non-infested (x_1)	Infested (x_2)	Non-infested (x_1)	Infested (x_2)	Non-infested (x_1)	Infested (x_2)	Non-infested (x_1)	Infested (x_2)
2.17	1.41	6.89	6.33	3.10	2.00	2.10	0.95	6.85	7.23
1.99	1.14	6.52	6.88	3.50	2.50	2.03	1.17	6.89	7.40
2.00	1.03	6.93	6.91	3.00	1.80	2.16	1.13	7.05	7.20
2.10	0.98	6.87	6.69	3.20	1.75	2.05	0.97	6.83	6.91
2.20	1.29	6.86	7.07	3.80	2.10	2.17	1.22	7.24	7.26
1.88	1.22	6.03	6.51	3.10	2.00	2.02	1.00	6.66	6.87

$\bar{x}_1 = 2.06, \bar{x}_2 = 1.18$	$\bar{x}_1 = 6.68, \bar{x}_2 = 6.73$	$\bar{x}_1 = 3.28, \bar{x}_2 = 2.03$	$\bar{x}_1 = 2.09, \bar{x}_2 = 1.07$	$\bar{x}_1 = 6.92, \bar{x}_2 = 7.15$	$\bar{x}_1 = 3.57, \bar{x}_2 = 1.77$
$S = \pm 0.145$	$S = \pm 0.317$	$S = \pm 0.288$	$S = \pm 0.92$	$S = \pm 0.204$	$S = \pm 0.446$
$t = 18.225$	$t = 0.472$	$t = 13.034$	$t = 33.294$	$t = 3.386$	$t = 12.120$
$P < 0.001$	The result is not significant.	$P < 0.001$	$P < 0.001$	$P < 0.01$	$P < 0.001$

Appendix table - XIII

Analysis of variance of incidence of T. nivella between different broods and different study areas of the variety Isd- 16

Stations	Broods					Total	Mean
	First	Second	Third	Fourth	Fifth		
Meherchandi	2.90	3.90	4.60	6.20	4.10	21.70	4.34
Harian	2.30	5.00	6.00	7.10	4.50	24.90	4.98
Panchagarh	3.40	5.50	8.70	10.00	5.80	33.40	6.68
Thakurgaon	2.30	3.50	4.30	5.40	2.90	18.40	3.68
Setabganj	2.10	2.90	3.90	5.90	3.70	18.50	3.70
Shyampur	2.00	2.70	5.20	6.30	4.50	20.70	4.14
Mohimaganj	1.30	2.90	5.80	7.50	4.80	22.30	4.46
Jaipurhat	1.60	2.70	5.30	8.70	6.10	24.40	4.88
Mobarakganj	2.20	3.00	7.10	7.80	6.80	26.90	5.38
Dorshona	3.20	4.50	5.80	7.20	7.10	27.80	5.56
Jogoti	3.00	3.50	7.50	8.20	6.40	28.60	5.72
Total	26.30	40.10	64.20	80.30	56.70	267.60	53.52
Mean	2.39	3.65	5.84	7.30	5.15	24.33	4.865

Correction factor, CF = 1302.00
 Total sum of squares, T.SS = 231.80
 Station sum of squares, S.SS = 42.56
 Brood sum of squares, B, SS = 160.22

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between stations	10	42.56	4.256	5.866*** (P < 0.001)
Between broods	4	160.22	40.055	55.210*** (P < 0.001)
Error	40	29.02	0.7255	
Total	54	231.80		

$$\text{S.E. (Station)} = \sqrt{\frac{2 \times 0.7255}{5}} = 0.5387$$

$$\text{S.E. (Brood)} = \sqrt{\frac{2 \times 0.7255}{11}} = 0.3632$$

$$\text{L.S.D.} (= t_{0.001}^{40} \times \text{S.E.})$$

$$\text{L.S.D. (Station)} = 3.551 \times 0.5387 = 1.913$$

$$\text{L.S.D. (Brood)} = 3.551 \times 0.3632 = 1.290$$

Appendix table - XIV

Analysis of variance of incidence of T. nivella between different broods and different study areas of the variety Isd- 17

Stations	Broods					Total	Mean
	First	Second	Third	Fourth	Fifth		
Meherchandi	3.50	4.80	5.50	6.60	5.00	25.40	5.08
Harian	2.80	5.50	6.70	7.60	4.70	27.30	5.46
Panchagarh	3.60	5.90	9.20	11.20	6.20	36.10	7.22
Thakurgaon	2.90	4.00	5.20	6.10	3.70	21.90	4.38
Setabganj	2.60	3.20	4.60	6.30	4.70	21.40	4.28
Shyampur	2.20	3.30	5.60	6.70	4.80	22.60	4.52
Mohimaganj	1.90	3.60	6.10	7.90	5.50	25.00	5.00
Jaipurhat	2.10	3.10	6.30	9.60	6.70	27.80	5.56
Mobarakganj	2.50	5.40	6.50	9.60	8.00	32.00	6.40
Darsona	4.00	5.10	7.30	8.30	7.50	32.20	6.44
Jogoti	3.60	3.50	8.50	8.80	7.10	31.00	6.20
Total	31.70	47.40	71.00	88.70	63.90	302.70	60.54
Mean	2.88	4.31	6.45	8.06	5.81	27.52	5.504

Correction factor, CF = 1665.95

Total sum of squares, T, SS = 253.10

Station sum of squares, S, SS = 46.39

Brood sum of squares, B, SS = 174.37

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between stations	10	46.39	4.639	5.738*** (P < 0.001)
Between broods	4	174.37	43.593	53.918*** (P < 0.001)
Error	40	32.34	0.8085	
Total	54	253.10		

$$\text{S.E. (Station)} = \sqrt{\frac{2 \times 0.8085}{5}} = 0.5687$$

$$\text{S.E. (Brood)} = \sqrt{\frac{2 \times 0.8085}{11}} = 0.3834$$

$$\text{L.S.D.} = t_{0.001}^{40} \times \text{S.E.}$$

$$\text{L.S.D. (Station)} = 3.551 \times 0.5687 = 2.019$$

$$\text{L.S.D. (Brood)} = 3.551 \times 0.3834 = 1.361$$

Appendix table - XV

Analysis of variance of incidence of T. nivella between different broods and different study areas of the variety Isd- 2/54

Stations	Broods					Total	Mean
	First	Second	Third	Fourth	Fifth		
Meherchandi	4.00	6.40	8.80	10.50	6.20	35.90	7.18
Harian	3.50	6.40	8.60	13.10	6.60	38.20	7.64
Panchagarh	5.30	7.60	14.00	16.20	8.50	51.60	10.32
Thakurgaon	3.90	5.20	10.60	11.80	4.70	36.20	7.24
Setabgonj	3.20	3.90	7.30	8.80	5.80	29.00	5.80
Shyampur	2.50	3.80	6.50	7.30	5.20	25.30	5.06
Mohimaganj	2.60	3.90	6.90	8.90	6.70	29.00	5.80
Jaipurhat	3.10	4.60	7.70	11.00	8.30	34.70	6.94
Mobarakganj	3.10	3.70	8.80	10.60	8.40	34.60	6.92
Darsona	5.10	5.60	8.40	9.70	8.70	37.50	7.50
Jogoti	5.90	5.60	10.30	11.40	9.10	42.30	8.46
Total	42.20	56.70	97.90	119.30	78.20	394.30	78.86
Mean	3.84	5.15	8.90	10.85	7.11	35.85	7.169

Correction factor, CF = 2826.77

Total sum of squares, T, SS = 499.46

Station sum of squares, S, SS = 101.21

Brood sum of squares, B, SS = 348.49

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between stations	10	101.21	10.121	8.136*** (P < 0.001)
Between broods	4	348.49	87.123	70.034*** (P < 0.001)
Error	40	49.76	1.244	

$$\text{S.E. (Station)} = \sqrt{\frac{2 \times 1.244}{5}} = 0.7054 \quad \text{L.S.D.} = t_{0.001}^{40} \times \text{S.E.}$$

$$\text{S.E. (Brood)} = \sqrt{\frac{2 \times 1.244}{11}} = 0.4756 \quad \text{L.S.D. (Station)} = 3.551 \times 0.7054 = 2.505$$

$$\text{L.S.D. (Brood)} = 3.551 \times 0.4756 = 1.689$$

Appendix table - XVI

Analysis of variance of incidence of T. nivella between different broods and different study areas of the variety L.J.C.

Stations	Broods					Total	Mean
	First	Second	Third	Fourth	Fifth		
Meherchandi	5.10	7.20	12.00	15.60	7.40	47.30	9.46
Harian	4.10	7.00	9.50	14.60	7.10	42.30	8.46
Panchagarh	5.60	8.10	14.30	17.00	9.00	54.00	10.80
Thakurgaon	4.50	6.20	10.10	13.50	5.60	39.90	7.98
Setabganj	3.40	4.90	8.20	10.70	6.40	33.60	6.72
Shyampur	2.70	4.30	6.90	7.70	6.00	27.60	5.52
Mohimaganj	2.90	4.80	8.10	9.70	7.10	32.60	6.52
Jaipurhat	3.50	5.10	8.60	12.60	9.10	38.90	7.78
Mobarakganj	3.50	4.10	10.10	10.60	9.10	37.40	7.48
Darsona	5.80	7.30	9.00	10.70	9.20	42.00	8.40
Jogoti	5.90	5.60	10.30	10.80	9.10	41.70	8.34
Total	47.00	64.60	107.10	133.50	85.10	437.30	87.46
Mean	4.27	5.87	9.74	12.14	7.74	39.75	7.951

Correction factor, CF = 3476.93

Total sum of squares, T.SS = 595.74

Station sum of squares, S.SS = 103.66

Brood sum of squares, B.SS = 424.60

ANOVA

Source of variation	D.F.	SS	MS	F-value
Between stations	10	103.66	10.366	6.145 ^{***} (P < 0.001)
Between broods	4	424.60	106.150	62.922 ^{***} (P < 0.001)
Error	40	67.48	1.687	
Total	54	595.74		

$$S.E. (Station) = \sqrt{\frac{2 \times 1.687}{5}} = 0.8216$$

$$L.S.D. = t_{0.001}^{40} \times S.E.$$

$$S.E. (Broods) = \sqrt{\frac{2 \times 1.687}{11}} = 0.5538$$

$$L.S.D. (Station) = 3.551 \times 0.8216 = 2.916$$

$$L.S.D. (Broods) = 3.551 \times 0.5538 = 1.967$$

Appendix table - XVII

Multiple regression of incidence of T. nivella (Y)
with temperature (x_1) and relative humidity (x_2)
at different study areas

**** Multiple regression ****

Equation number 1 Dependant variable ... Y

Y	x_1	x_2	
6.58	26.56	76.47	Variable(s) entered on step number
6.57	25.39	72.87	1 .. x_2
5.13	25.68	78.60	2 .. x_1
6.29	25.56	75.98	Multiple R .32718
6.55	27.17	77.67	R square .10705
7.08	26.44	77.07	Adjusted R square - .48825
			Standard error 35.83175

Analysis of variance

	DF	Sum of square	Mean square
Regression	2	461.75756	230.87878
Residual	3	3851.74244	1283.91415
F = .17982		Signif F = .8438	

..... Variable in the equation

Variable	B	SEB	Beta	T	SigT
		I			
x_2	3.71237	9.33418	.24981	.398	.7174
x_1	5.09374	26.42301	.12109	.193	.8594
(constant)	-362.40260	705.58024		-.514	.6430

$$\therefore Y = -362.40 + 5.09x_1 + 3.71x_2$$

Appendix table - XVIII

Analysis of variance of incidence of parasites
between different broods in different study areas.

Stations	Broods					Total	Mean
	First	Second	Third	Fourth	Fifth		
Meherchandi	16.00	21.00	25.00	31.00	16.50	109.90	21.90b
Harian	15.00	19.50	25.00	30.00	17.50	107.00	21.40b
Panchagarh	24.00	25.50	39.00	49.50	29.00	167.00	33.40c
Thakurgaon	12.00	21.50	23.00	27.00	21.50	105.00	21.00a
Setabganj	10.00	19.50	22.00	24.50	19.50	95.50	19.10a
Shyampur	8.00	15.50	18.00	21.50	14.50	77.50	45.50ab
Mohimaganj	13.00	22.00	24.00	25.00	18.50	102.50	20.50a
Jaipurhat	15.00	21.00	25.50	26.50	20.00	108.00	21.60b
Mobarakganj	7.50	15.00	22.00	24.00	17.00	85.50	17.10a
Darsona	10.50	22.50	21.00	24.00	20.00	98.00	19.60a
Jogoti	12.50	21.50	24.50	28.00	20.50	107.00	21.40b
Total	143.50	224.50	269.00	311.00	214.50	1162.50	
Mean	13.045a	20.410b	24.450c	28.272c	19.50b		

Correction factor, C.F. = 24571.02

Total sum of squares, T, SS = 2732.73

Station sum of squares, S, SS = 1031.63

Brood sum of squares, B, SS = 1436.68

ANOVA

Source of variation	D.F.	S.S.	M.S.	F-value
Between stations	10	1031.63	103.163	15.605*** (P < 0.001)
Between broods	4	1436.68	359.17	54.329*** (P < 0.001)
Error	40	264.42	6.611	
Total	54	2732.73		

$$\text{S.E. (station)} = \sqrt{\frac{2 \times 6.611}{5}} = 1.626$$

$$\text{L.S.D.} = t_{40}^{0.001} \times \text{S.E.}$$

$$\text{S.E. (Brood)} = \sqrt{\frac{2 \times 6.611}{11}} = 1.096$$

$$\text{L.S.D. (station)} = 3.551 \times 1.626 = 5.774$$

$$\text{L.S.D. (Brood)} = 3.551 \times 1.096 = 3.892$$