SURVEY OF INSECTS AND BIOLOGY AND CONTROL OF CERTAIN INSECT PESTS OF THE BALPHAKRAM SANCTUARY, MEGHALAYA

Ray

ANUPAM KUMAR ROY M.Sc.
DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

SUBMITTED
IN
FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

To

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG

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Phone :
Gram : NEHU

Prof M K KHARE
MSc DPhil FNASc FRMS
Dean

SCHOOL OF LIFE SCIENCES
NORTH EASTERN HILL UNIVERSITY
SHILLONG 793 014
MEGHALAYA

July 11, 1988.

I certify that the thesis entitled "SURVEY OF INSECTS AND BIOLOGY AND CONTROL OF CERTAIN INSECT PESTS OF THE BALPHAKRAM SANCTUARY, MEGHALAYA" submitted by Mr. Anupam Kumar Roy for the Degree of Doctor of Philosophy of the North Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other University.

(M.K.KHARE)
Professor of Zoology
&
Dean, School of Life Sciences.

Forwarded

Head
Department of Zoology
School of Life Sciences
North Eastern Hill University
Shillong

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Date: 11/7/88
Shillong.

(ANUPAM KUMAR ROY)

CONTENTS

INTRODUCTION

The insects comprise approximately half (50.8%) of the total living species and 72% of all animals on this earth. In a forest system they occupy wide range of micro and macro habitats. They get food from the plant and interact with environmental influences and form an important element in a complex web of plant and animal life. Natuaally they have tremendous influence on the forest ecosystem. The insects may impair or enhance the aesthetic values of any system they occupy. Their attack on forest trees may increase chances of fire hazard.

Forest Entomology is a major branch of forest ecology. It deals with the problem of interactions of insects to the forest and forest produce. It includes mainly the study of forest insects and their population dynamics. Forest Entomology covers identification, forecasting, measurement of injurious insect population, assessment of insect causing damage, analysis of the causes of outbreak and evolving principles and procedures to protect the forests and forest products from insects (Graham, 1963).

Forest Entomologists have great task for understanding forest system and providing measures of control both for the benefit of the forest system as well as the insects. A knowledge of insect fauna of a forest have been felt to be of primary necessity in view of the increasing emphasis being laid in the creation of National Parks and Wild-life Sanctuaries and their maintenance.

Balphakram National Wild-life Sanctuary is situated in adjoining border areas of West Garo Hills District and West Khasi Hills District (290 sq. km.) of the Meghalaya State. It is a natural Sub-tropical semi-evergreen forest of mixed vegetation. The people of this area practise jhum or shifting cultivation. This forest is one of the last resorts of wild elephants and other wild lives in the North-eastern hills region in India. Till recent past Balphakram National Wild-life Sanctuary was a scientifically unexplored area.

The present investigation was started in 1979. During the first two years survey was conducted and after a thorough annual survey, two major insect pests of important forest trees were identified and investigations on their development, life-table and control measures were taken up.

This Thesis incorporates the study on three aspects :

(1) SURVEY OF INSECT FAUNA :

Reports on faunistic surveys of insects are scanty and limited to certain pockets only so far as North-eastern hills of India have is concerned though some reports on insects from India have been mentioned in Imms General Text Book of Entomology revised by Richards and Davis (1977). Forest Research Institute Dehradun India and Zoological Survey of India have conducted faunistic surveys in different parts of the Country from time to time. As insects form a major group of primary consumers, survey and identification of insect fauna is of fundamental importance in the management of any forest ecosystem. As there is no report on insect fauna of Balphakram National Wild-life Sanctuary the present investigation was undertaken. The description of the sanctuary has been provided in the Chapter 2. Some idea of its inhabitants and their living has been provided.

In our present survey insects were collected by sweeping net and by hand picking during day time and by light-trap during night time at monthly intervals from September, 1979 to October, 1981. Though many insects were collected during day time, the light-trap was found very convenient and the study on survey of the insects was based mainly on this technique. Hanna (1969) reported light-trap as a convenient tool for investigating insect fauna, its population dynamics and seasonal activity in any given area. Certain workers, such as, Falcon et al. (1967 a, b) have combined black light-trap with field sampling for detecting and assessing the attack of pests in certain crops. Similarly, black light-traps have been used in association with sex pheromones for the same purpose, (Ford, Wolf and Vaid, 1972). With the help of regular light-trap collection population dynamics of various insect groups can be studied. Some workers such as, Belts *et al*.(1971), Odiyo (1973) have used such data for fore-casting out-breaks of certain serious pests. Light-traps have been useful in taxonomic studies (James,1943; Back,1958; Linley, Evans and Evans, 1970; Kline and Axtell, 1976) as well as for analysis of population dynamics (Henneberry, Howland and Wolf, 1967; Alma, 1973; Reddy and Alfred, 1977).

The Light-trap experiments were conducted at the Balphakram Forest Beat Office varandah which is situated on a hill-top (862 m. a.s.l.), surrounded by thick deciduous forest. Insects attracted to light in between 17.00 hrs. to 05.00 hrs. were collected at hourly intervals. The analysis of insects collected has been carried out on hourly as well as monthly basis and a picture of their population dynamics has been provided in relation to atmospheric temperature, humidity and rainfall.

(2) BIOLOGY AND LIFE-TABLE OF MAJOR INSECT PESTS :

The outbreaks and population dynamics of the forest insect pests have always been a point of special concern (see Graham, 1963). The outbreaks are associated with the changes in the ecology and other envirenmental factors (Tinbergen, 1960; Sippell, 1962; Graham, 1963;

Furniss and Barr, 1967; Miller, 1970; Ives, 1976; Valentine and Talerico, 1980). For predicting the outbreaks and devising control measures it is necessary to have an idea of the biology and life table of the insect pests (Witter, Mattson and Kulman, 1975; Mason, 1976).

During the first year of survey we found 11 species of insects feeding on different trees and plants in large numbers. Out of these, Cyclosia panthona Cram. and Diaphania laticostalis Guene were found to be serious defoliators of Aporosa roxburghii Bull. and Holarrhena antidysentrica (Lin.), respectively. These trees grow abundantly in Balphakram forest. We conducted detailed investigations on biology and population dynamics of C. panthona Cram. and constructed its life tables and survivorship curves. Detailed biology of D. laticostalis Guene was also carried out. For the rest of the insects their host plants and period of occurrence have been recorded.

(3) RELATIVE TOXICITY EXPERIMENTS :

Chemical control measures are widely practised to control insect pests in agriculture as well as in forests. To select suitable insecticides, relative toxicity of candidate insecticides are performed. In the recent past certain workers such as, Saini and Sharma (1970), Teotia and Lal (1972), Takahashi and Kiritani (1973), Ciesla (1977), Singh and Gupta(1978) among others conducted experiments on relative toxicity of different insecticides in laboratory and evaluated their relative effectiveness to control the particular insect pest species. Based on the results of the laboratory, insecticides can be selected for use in the field. Keeping this in view 4 locally available insecticides (Nuvacron, Cythion, Ekalaux and Thiodan) have been tested in the present investigation to find out their relative toxicity against *Cyclosia panthona* and *Diaphania laticostalis* larvae. The findings presented in this thesis are expected to be of use to the Foresters as well as Government Departments in the management of insect fauna and control of major insect pests not only in Salphakram National Wild-life Sanctuary but also in the neighbouring forests.

STUDY SITE

LOCATION :

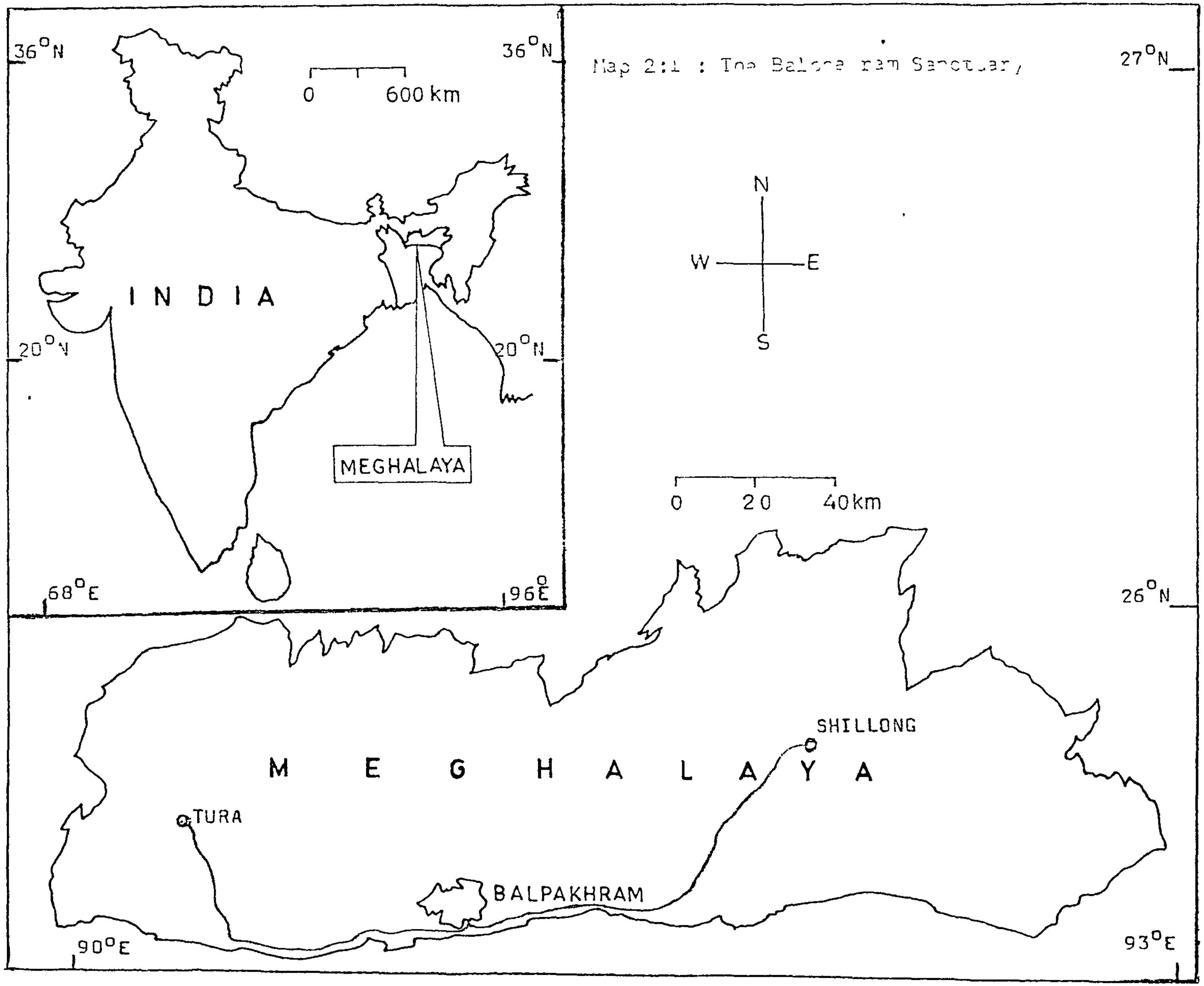
The Balphakram National Wild-life Sanctuary is situated in between latitudes 25°10' - 25°30'N and longitudes 90°37' - 90°58'E in the South-western part of the Meghalaya State of India. The two-thirds of the sanctuary is in the West Garo Hills District and one-third in the West Khasi Hills District. The total area of the sanctuary is about 290 sq. km (Maps 2.1, 2.2 and 2.3). The main study site was around the Balphakram Beat Office situated at about 860 m a.s.l.

The Eastern boundary of the sanctuary is marked by the Moheshkhola river and its tributary the Sohling stream and also the Dotinga stream of the Bytit river flowing from North to South.

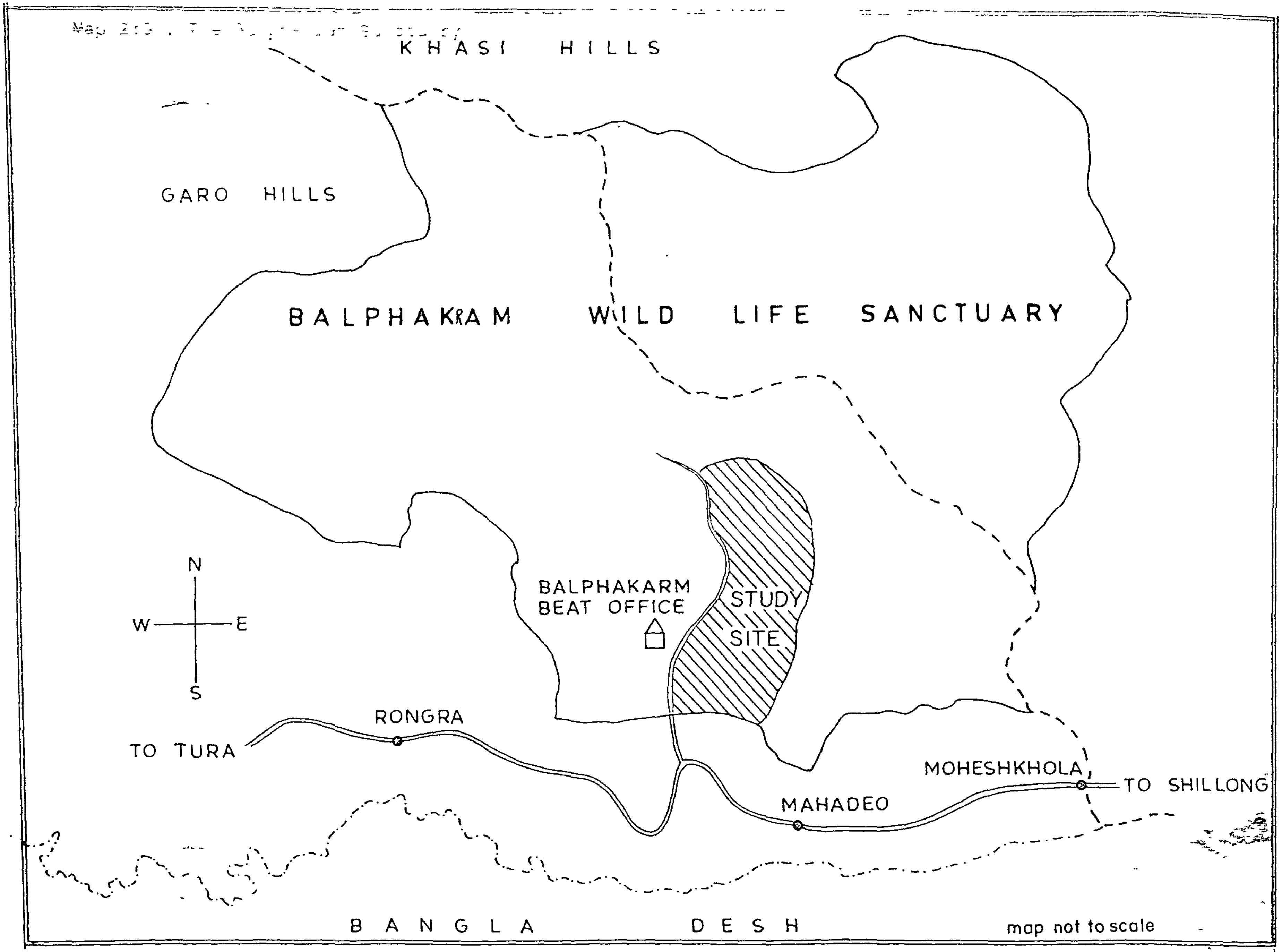
The Western boundary of the sanctuary is marked by the Rongrong stream of the Simsang river flowing from North to South and the Kailash (Chutmang) peak.

The Northern boundary of the sanctuary is marked by the Rongkhai stream and its tributary the Durek stream flowing into the Simsang river.

The Southern boundary is marked by some villages which are from East to West , Sohling and Ranthangsora at the north of Moheshkhola; Thepthepa



Map 2:1 : The Balpakhram Sanctuary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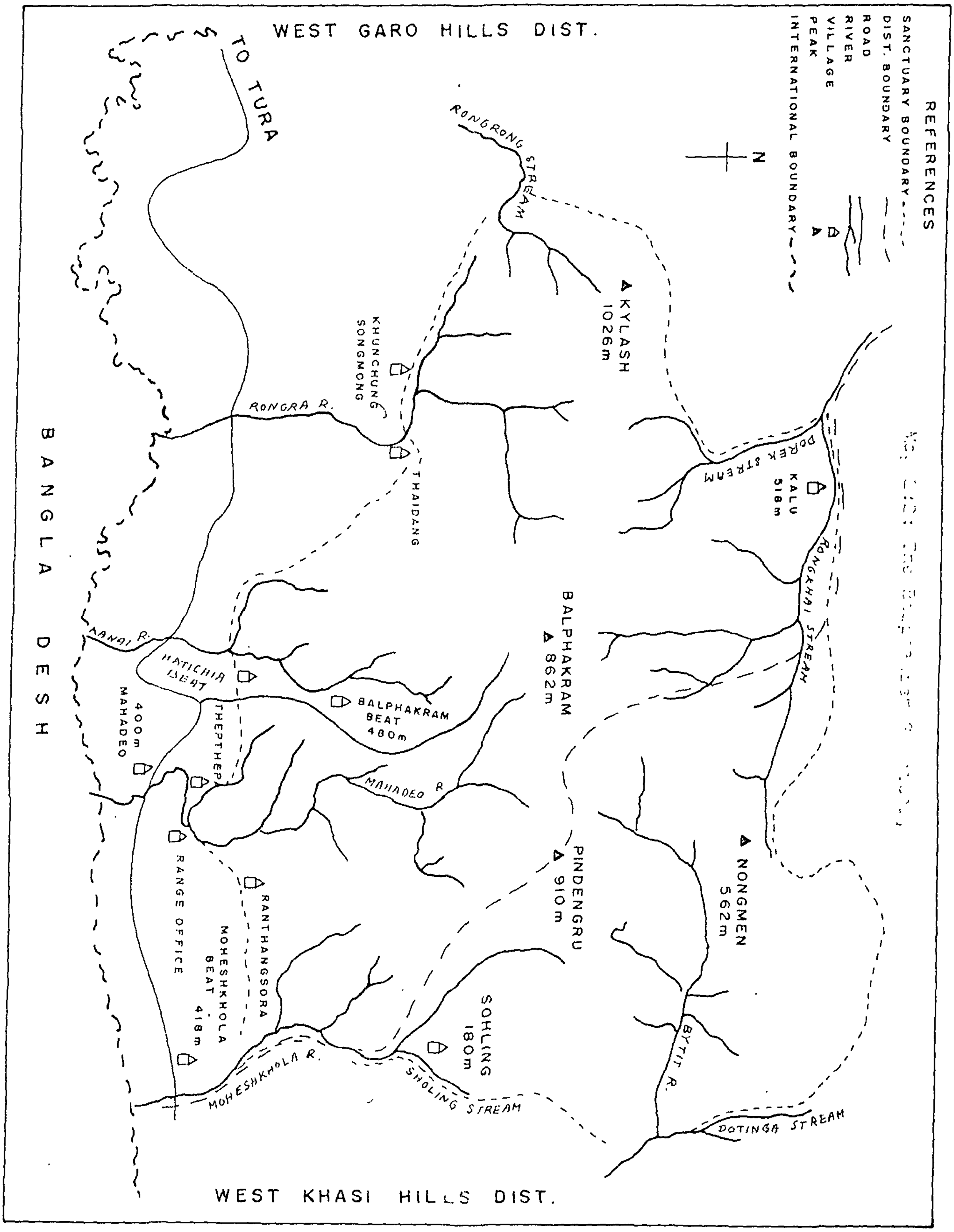
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ROAD
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N
RONGRONG STREAM
KYLASH 1026m
KHUNCHUNG SONGMONG
RONGRA R.
THAIDANG
DOREK STREAM
KALU 518m
RONGKHAI STREAM
BANGLA DESH
BALPHAKRAM 862m
KANAI R.
HATICHIA BEAT
BALPHAKRAM BEAT 480m
400m MAHADEO
THEPTHEP
MAHADEO R.
PINDENGRU 910m
NONGMEN 562m
RANGE OFFICE
RANTHANGSORA
MOHESHKHOLA BEAT 418m
SOHLING 180m
BYTIT R.
MOHESHKHOLA R.
SHOLING STREAM
DOTINGA STREAM
WEST KHASI HILLS DIST.

at the North of Mahadeu; Hatichia at the North of Khanai; Thaidang, Khonchek, Khunsung Songmong at the North of Rengra and Chutmung Gongret at the North of Phanda. Thepthepa village situated at the Southernmost tip of the sanctuary is only about 3 km. from the Indo-Bangladesh international boundary.

The Sanctuary is surrounded by Moheshkhola Adugiri range on the East; by Tura range on the West, by Arabella range on the North and by the Bangladesh plain on the South. The three main hill ranges within the Sanctuary from East to West are Pindengru (910 m. a.s.l.), Balphakram (860 m. a.s.l.) and Kailash or Chutmung (1025 m. a.s.l.).

MEANING OF BALPHAKRAM :

In Garo language "Balwa" means wind and "Phakram" means where it blows constantly. Thus, Balphakram means a place of continuous wind. The name of the sanctuary, Balphakram is derived from the Balphakram hill range situated at the central part of the sanctuary. It is a popular belief among the local Garo people that at the "Mitte Adalat" (Court of Ghost) there, the human souls account for the deeds and misdeeds of their life-time.

GEOLOGY :

Singh (1968) has described that Meghalaya plateau (and so also Balphakram) has a chequered geological history

Figure 21 : Author* with some of the inhabitants of Rongmun-siring village near Balphakram Beat Office.

of emergence, sub-emergence and peneplantation with several phases of erosion, sedimentation, diastropism, intrusion, movement of land and sea and emmissions. It is a fragment of the super Continent of Gondowana and contains the marks of peneplantation ranging from pre-Cambrian, sub-Recent and Recent periods. It was submerged partially by the encroaching sea during the Mesozoic and Tertiary times and was uplifted slowly from sea bed at the time when the Himalayas rose from the floor of the Tethis. This organic movement was so slow and free from buching that the sedimentary beds retained their horizontal character and gave rise to structural platforms which can clearly be seen in Cherrapunji area (Chatterji, 1968). Similar platforms are also seen in the Balphakram range with many marine fossils.

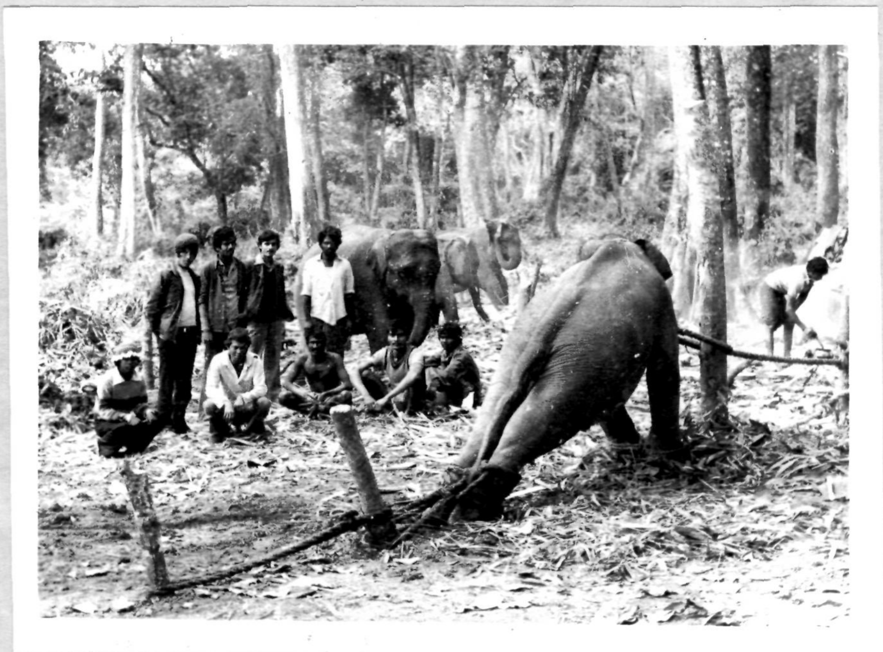
SOIL :

The soil of the Garo Hills is quite heavy clay containing about 10% organic matter with high nitrogen content as described by Zimba (1977). The soil of Balphakram sanctuary varies from sandy loam in Balphakram range to clay loam in Moheshkhola range with lime-stone in many pockets. The soil pH in Balphakram range was 6.3 and in Moheshkhola range was 5.8 in July, 1980, confirming high acidity in the region.

INHABITANTS :

There were 120 Garo families in 11 different villages with a total population of about 600 individuals within the sanctuary as per 1979 census (Figure 21). They

Figure 2.2 : Young wild Elephants caught from Garo Hills.



practice Jhum or Shifting (Slash and Burn) cultivation and grow paddy, maize, cucurbits, potatoes, chillies, pine apples, orange etc. Every family clears about 2 hectares of hill slopes every year for shifting cultivation with cycles of 5 to 15 years. Shifting cultivation causes soil erosion, savannah formation and decreases of vegetation cover required for wild-life in the sanctuary. The other sources of livelyhood of the people are collection of broom-stick, cane-stick, bambooes and Agar wood as cash-crops from the forest.

WILD-LIFE :

Balphakram National Wild-life Sanctuary is one of the last resorts for wild-lives in the North-Eastern part of India. It is famous for high elephant concentration of about 900 individuals out of a total of about 2500 wild elephants (Figure 1.2) reported to exist in Meghalaya (Gogoi and Chaudhury, 1981). Other mammals are Royal Bengal Tiger, Clouded Leopard, Red Panda, Golden Cat, Gaur, Barking Deer, Swamp Deer, Wild Buffalo, Wild Cat, Binturung, Civet, Hoolock, Macaque, Slow Lorris, Flying Squirrel etc. Among birds are Horn Bill, Wild Hen, Parrot, Dove, Parakeet, Night Jar, Owl, Drongo, Minivet and Black Breasted Robin are common. Among reptiles Monitor Lizard, Gecko, Cobra,Calotes etc. are common.

VEGETATION :

The forests in the sanctuary are diverse and rich in floristic compositions owing to congenial

Figure 23: Typical climax vegetation in Balphakram Hill Range.

ecological conditions (Figure 2). The vegetation can be classified as :

(1) TROPICAL EVERGREEN FORESTS :

These are dense forests at the lower part of the hills. The prominent trees of these forests are Catanopsis trubuloids, Dillenia indica, Aporosa roxburghii, Holarrhena antidysentrica, Quarcus spp., Terminalia spp., Aquillaria spp. and others.

(2) TROPICAL MOIST DECIDUOUS FORESTS :

Tropical moist deciduous forests cover the whole area of the sanctuary. In such forests most common trees are Kydia calycina, Eleocarpus florintroemia , Lagerstroemia parviflora, Albizia labbeck among others.

(3) BAMBOO FORESTS AND OTHER SECONDARY VEGETATIONS :

Such forests are found in jhum fallows with many secondary vegetations, such as, Dendrocalamus hamiltonii, D. sikimensis, Bambusa tulda, Bauhinia purpuria, Callicarpa arborea, Macaranga indica, Mikanea malabarica, Eupatorium odoratum among others.

(4) SAVANNAH AND GRASS LANDS :

Such pockets are mainly found in the elevated plateau with thin soil cover, which also represents a part of climax vegetation, prominently with Pterospermum lanceaefolium, Vernonia volkmerifolia, Phyllanthus emblica, Curcuma spp., Arundinella bengalensis, Panicum sp., Saccharum spp. among others (Kumar, 1984).

Fig. 2.4 : Study site of Light-trap the Balphakram Beat Office.

CLIMATE :

The sanctuary has warm Sub-tropical monsoon rainfed climate. In summer a maximum temperature of 31°C is recorded during the month of May. In winter minimum temperature of 14°C is recorded during the month of December. The annual rainfall recorded are 498 cm, 512 cm and 602 cm during 1979 -80, 1980 - 81 and 1981 - 82, respectively.

ROAD COMMUNICATION :

One can reach the Sanctuary from Shillong by a jeepable 225 km road via Mawchinram along Indo-Bangladesh border. The motorable road from Tura to Balphakram is about 160 km via Baghmara.

AREA OF SURVEY AND EXPERIMENTS :

The survey of insect fauna was carried out mostly around Balphakram Beat Office and in different pockets of the entire sanctuary area. The Light-trap experiments were conducted at the varanda of the Balphakram Beat Office building (Figure 24). Biology and life-table of the insect pests were studied in an area of about 20 sq. km near Balphakram Beat Office. Rearing and development of the two major insect pests, <u>Cyclosia panthona</u> Cram. and <u>Diaphania laticostalis</u> Guene and toxicological experiments on them were conducted in the laboratory of Developmental Biology at N.E.H.U., Shillong.

CHAPTER 3

REVIEW OF LITERATURE

REVIEW OF LITERATURE

SURVEY OF INSECT FAUNA :

Blandford (1881) was one of the first Entomologists to publish report on insect fauna of India, in his "Fauna of British India". According to him, Lepidoptera comprised of about 10,000 species in India. Among earlier workers of forest insect fauna mention can be made of Stebbing (1899) who published a pamphlet entitled "Injurious Insects of Indian Forests" in which he included about 100 species.

In the Northeastern India among important workers on insect fauna in the recent past the names of the following can be mentioned. Cantlie and Pearson (1948) compiled list of butterflies of Khasi and Jaintia Hills. Norman (1952, 1956) worked on the Lepidopteran fauna of Assam. Kapur (1958) reported Coleoptera species from Manipur. Recently, Rynth (1977) provided a list of 79 species of Lepidoptera grouped under 9 families from Garo Hills, Meghalaya.

LIGHT-TRAP FOR INSECT COLLECTION :

A number of insects are attracted to light sources. In recent years light-trap has been found to be useful in insect fauna analysis. Black-light lamp has been used to collect insects and determine the time of their appearance and seasonal abundance (Pfrimmer, Lukefahr and Hollingsworth, 1955; Stanley and Dominick, 1958; Apple, 1962; Gentry, Dickerson and Stanley, 1971 b). Long fourteen years of study on Western Bean cutworms both in field corn and dry bean growing area was reported by Hagen (1976).

LIGHT-TRAP AND POPULATION ESTIMATION :

Hanna (1969) used light-trap to study the occurrence and period of activity and seasonal fluctuation of insects. Falcon et al.(1967a, b) proposed the combination of black light-trap and field sampling as an effective means for detecting the onset of infestations and assessing population dynamics of Coleoptera, Lepidoptera, Orthoptera and Hemiptera in an island by black light-trap on wheat and maize in Pakistan.

It is difficult to ascertain the percentage of insect fauna caught in light-trap in comparison to the total population in a system. Some workers such as King and Hind (1960), Falcon et al.(1967a, b) among others attempted to estimate the field population with the help of light-trap catch. Use of paints, dyes or radio active markers on catch insects, release and recapture of these marked insects have been reported for population estimation (Henneberry, Howland and Wolf, 1967). The percentage of recapture of marked insects by light-trap suggest the probable percentage of these in the field population (Alma, 1973). Yates (1973) used light-trap for investigating the geographical distribution of insects that attack pine seeds and cones, in addition to knowing their activity period and relative abundance.

INFLUENCE OF ENVIRONMENTAL FACTORS IN LIGHT-TRAP :

Light-trap catches are influenced by different environmental factors, such as, time (Graham, Glick and Mertin, 1964), temperature (Sutherland, 1966), temperature and rainfall (King, 1966). Williams (1961) reported large collection of Diptera during heavy rain or rainy night. In tropics, rainfall was recorded as the most important factor which regulated the size of the insect population in light-trap (Owen, 1969). Hartstack, Ridgway and Copedge (1973) mentioned about the changes in the environmental factors, such as wind velocity, temperature and its effect on insect catch in short ranges of hours of a night or so. Frith (1975) was of the opinion that rainfall ~~was~~ or a marked increase in precipitation increased the Lepidoptera catch. Broersma, Barrett and Silling (1976) reported that in a field condition the influence of environmental factors can not be easily isolated because of complex interactions among various environmental variables. Reddy (1980) also found that rainfall and warm temperature had a positive effect in light-trap insect collection.

LIGHT-TRAP IN INDIA :

Light-trap is used as an important tool to study the insect population dynamics and sufficient progress have been made in the subject. However, in Indian condition such experiments are limited. Among others, Banerji and Basu (1951) used William's light-trap at Chinsura, West Bengal, to determine the effect of weather on the actevity of insects. Usman (1954a,b)

1956) did faunistic study with the help of light-trap catch in Bangalore. Kundu, Dasgupta and Rastogi (1967) and Kundu and Gupta (1971) used light-trap to examine the seasonal abundance of Hemiptera in Pilani, Rajasthan. Shull (1967) used light-trap to examine the seasonal abundance of Hemiptera at Surat, Gujrat. Naik and Kundu (1977) studied the activity of 6 species of Orthoptera of semi-arid region of Rajasthan in relation to weather conditions. In Northeast hill region Reddy (1980) appears to be the first worker to use light-trap to study the pine cone infesting insect pests attracted to light-trap in Riatkhuan forest, Shillong. He analysed the species composition of different consumer insect pests attracted to light-trap which are detrimental to pine forest in two years annual cycle to determine if these insects could be controlled by the use of suitable light-trap.

BIOLOGY OF FOREST INSECT PESTS :

Investigations on forest insects have been conducted much more extensively in North American Continent than in any part of the world. These studies deal mainly with their biology, outbreaks and population dynamics in relation to environmental factors. Among early contributors mention can be made of Hopkins (1909) who studied the biology of Scolytid beetles in North American forests. Nishigaya (1918) investigated the population dynamics of _Lymantria mathura_ caterpillars in Japan. Swaine, Craighead and Baily (1924) studied biology of Spruce bud-worm, _Cacoecia fumiferana_ in Canadian forests. Graham (1937) worked on defoliation of forest trees by the walking stick insects.

Detailed ecological investigations on forest insects seem to have started in 1940s. Thus, Clark (1947) made detailed ecological study of Australian Plaque locust, Chortoicetas terminifera Walk. and investigated its outbreak in New South Wales. Hopping and Beall (1948) worked on the relationship of Lodgepole diameter to the incidence of attack by bark beetle, Dendroctonus monticolae.

During 1960s, in addition to the investigations on out-breaks of forest insect pests and extent of damage, control measures were also investigated, such as control of insect pests in pine woods (Tinbergen, 1960), resistance of Oak to defoliation by Tortrix viridana (Satchell, 1962) and factors affecting reproduction and mortality of natural population of Pine looper, Bupalus piniarius L. (Klomp and Grays, 1965). Furniss and Barr (1967) investigated in detail the bionomics of Anacamptodes clivinaria protanata Guene on the mountain Mahogony, Cercocarpus ledifolius Nutt. in Idaho. They reported that adult insects emerged from the soil after dark during early June, eggs are laid in clusters under bark-scales on the main branches. The larvae of this insect also feed on other plants, such as, Snow-bush, Choke-Cherry, Bitter-cherry and Ceanothus. Pupation occurs in August and during subsequent period they undergo diapause. High temperature breaks their diapause by late fall. They also studied parasitic infections of these insects. Similar investigations have been conducted on many other insects, such as, Eastern Pine shoot borer, _Eucosema gloriola_ Heinrich of _Pinus banksiana_ Lamb (Wong and Capbell, 1967), developmental biology of 5 species of _Lyctus_ Coleoptera (Rosel, 1969) among others.

Increasing attention have been paid to various aspects of biology, ecology and control of forest insect pests from economic standpoint during the 1970s. Miller (1970) studied in detail the damage of the Spruce, _Picea engelmannii_ and the Fir, _Abies lasiocarpa_ (Hook) Nutt. in Northwest Colorado forests caused by the beetles.

Mason and Thompson (1971) investigated on the larvae of the Douglas-fir Tussock moth, _Hemerocampa pseudotsuga_ Mc Dunnough attacking White Fir, _Abies concolor_ in North California. They found that caterpillars feed more on new foliage and old needles were almost totally unacceptable to the early instars but were eaten by late instars. Mason and Thompson (1971) recorded that outbreak of Douglas Fir Tussock moth, _H. pseudotsuga_ collapsed due to virus diseases.

Watson and Johnson (1972) investigated on development, fecundity and longevity of the Cotton leaf purforator, _Bucculatrix thurberiella_ Busk. in Arizona and reported that when eggs hatch the small larvae enter the leaf and pass the first three instars as leaf miners. The larvae then emerge from the mine and feed freely during the 4th instar after which a web is formed and the larvae form the so called horse-shoe stage where they moult to the

5th instar. The larvae emerge from the web and feed freshly on the surface of the leaf and if larvae occur in large numbers the whole leaves are skeletonised. The pupal cocoon is formed on a roughened surface and subsequently the adult emerges from the small cocoon.

Wickman, Mason and Thompson (1973) investigated outbreak of Douglas Fir Tussock moth Orgyia pseudotsugata in California and reported that outbreaks appear to develop almost explosively and after a year or two they usually subside abruptly. Some outbreaks have persisted at low level for as long as four years. During a severe outbreak the caterpillars are found crawling over rocks, trees, branches, ground and animals. But once outbreak subsides it is usually difficult to find even one caterpillar. They reported that defoliation greatly retards the growth, kills and top kills many trees and also weakens many others that they are top or all-killed by other insects.

Ives (1976) worked on biology and population dynamics of Larch sawfly, Pristiphora erichsonii (Hartwig) in Southern Manitoba. He reported that parthenogenetic females deposit their eggs in the current shoots during June - July causing severe damage to the succulent tissues. Growth is inhibited on the damaged side of the shoot resulting curling of the shoot. The eggs hatch in 7 - 10 days and the larvae feed on the needles. After a limited amount of feeding the larvae move to the basal false wherl of the needles until they moult to the 2nd instar. Larvae feed gregariously although 5th instar larvae tend to wander and many feed in small group or singly, specially when defoliation is severe. After about 3 weeks of larval life it drops from the tree and spin leathery cocoon in the moss of duff. Pupation occurs the following spring and adult emerge in 7 - 10 days later. A small percentage of the larvae may remain in prolonged diapause and do not emerge until the following or subsequent years. Several mortality factors affect survival of the various stages, such as, predatory insects and birds, severe storms which may dislodge the larvae and larval stage parasites.

Schultz and Allen (1975) described larval stages and worked on biology of Cherry Scallop Shell moth, Hydria pruniverata (Ferguson) in New York. It is a colonial feeder on black Cherry, Prunus scotiana Ehrh. Pupae overwinter in the litter and adult emergence occurs from May through September. Eggs are laid in the foliage in a pyramid shaped masses 23 - 26 days after adult emergence. Eggs begin to hatch 4 days following oviposition and each of the four larval stages lasts 4 - 6 days, with one generation per year. The egg-parasite, Telenomus sp. is the principal mortality factor occurring in populations that have remained at outbreak levels for two or more years.

Kiziroglu (1976) worked on biology, ecology and control of Gracilaria syringella (F.) in Ashtru, Bavaria. He found that in all developmental stages the temperature proved to be the main ecological controlling factor. The weight of male pupae coming from larvae fed with *Fraxinus* were markedly smaller than those descended from larvae fed with *Syringa* or *Liqustrum*. Young Ash trees were relatively more attacked than older ones. He reported that in 1973 the two generations of this insect showed a decrease of egg density caused by mainly drying up. The reduction of the larval density of the 1st generation was caused by abiotic factors, parasites and predators as about equal shares, whereas the density of the 2nd generation was diminished mainly by predators, particularly, *Forficula auricularia*. The attack of the larvae cause a loss of the Ash wood and often result in the death of the young trees.

Valentine and Talerico (1980) worked on the Gypsy moth, *Lymantria dispar* larval growth and consumption on Red Oak. They found that the consumption rate of the foliage by the larvae was 6.68% of the average larval dry weight degree day (Threshold = 4.4^{o}C). Average larval day weight increased from 0.2 mg at the time of hatching after 646.7 degree days spanning 43 days. The average accumulative consumption of red Oak foliage was 1116.1mg per larva. Simple biological growth functions which are useful in modelling defoliation were developed to predict average larval dry weight growth and consumption.

Recently among others, Kindler and Spomer (1986) investigated on the biology of the blue grass Bill bug, <u>Sphenophorus parvulus</u> (Coleoptera : Curculionidae) in an Eastern Nebraska Sod field. They studied for two years their life stages, incubation periods etc. Adults are reported to become active in April, mated, laid eggs and died as new adults appeared in August. Highest densities of eggs were found in the greenest and thickest blue grass available. Adults were usually found above ground in dense areas with thick layer which apparently offered shades and protection. Overwintering was accomplished by adults burying themselves in the top soil. An unidentified larval Dipteran parasite was reportedly found inside some adult bugs, peak numbers occurring in late July and mid June.

LIFE-TABLES :

Life-table is considered as the convenient method for accounting inter generation changes in insect numbers and the mortality factors in a population. Life-table provides a systematic record of the living individuals in each stage and account for the numbers dying within these stages. As it is not possible to identify all the factors causing insect mortality a life-table is a speculative one based on the best information that can be accumulated (Mason and Wickman, 1976). Life-table is a useful technique in the study of population dynamics, provides a format for recording and accounting for all population changes in the life cycle of a species in its natural environment (Harcourt, 1969). Morris and Miller (1954) first described the value of life-table for the investigation of natural population of insects.

Witter, Kulman and Hodson (1972) worked extensively on the life-table of the forest tent caterpillar, Malacosoma distria Hubner (Lepidoptera: Lasiocampidae) in Northern Minesota. They found that the survival rate during the egg and the pupal stages differed considerably in 1968 and 1969. The differences in egg survival are reportedly attributed to fluctuations in rates of death of fully developed 1st stage larvae within eggs which ranged from 39% in 1968 to 3% in 1969. Egg parasitization and infertility were 7 - 10% and 1 - 3%, respectively, showing no important changes from year to year. The differences in pupal survival resulted from fluctuations in rates of pupal parasitization, mostly by Sarcophaga aldrichi Parker, from 74% in 1968 to 50% in 1969. Generation mortality was 99.3% and 97.8% in 1968 and 1969, respectively. Generation survival equations by plots for 1968 and 1969 are also presented.

Mason and Wickman (1976) investigated on the life-table of Douglas Fir Tussock moth, Orgyia pseudotsugata in the Fir forest in North America. They found that Tussock moth outbreaks in a forest stand usually follow a three year pattern. This is characterised by a year of "release" when the insect population increases rapidly to an outbreak level, a year when the population declines sharply again to a relatively low level. They recorded most severe damage to trees in the second year of the outbreak and in the third year just prior to the collapse of the population. As the phenology of the Tussock moth and its host tree is synchronous, bud brust has been increasingly used as a field indicator of the egg hatch.

Houseweart and Kulman (1976) constructed the life-tables of the yellowheaded Spruce Sawfly, Pikonema alaskensis (Rohwer) for use in selecting appropriate life stages for release of biological control agents. They recorded that overwintering predation by insects and mammals killed 66.43% of the Sawfly cocoons in the soil. Seven species of small mammals were present in the Spruce plantation habitat and the predominant species is replaced from Microtus to Sorex and Blarina after the larvae drop from the trees. Parasitism of the late instars ranged from 1.49% to 19.64%. No egg parasite could be recorded. Life-tables for the 1975 generation were given with a discussion of different survival rates according to the level in the tree. The egg and the early larval stages were the most appropriate points in the life cycle for the release of the biological control agents.

Mason (1976) investigated on the life-table for a declining population of Douglas Fir Tussock moth, Orgyia pseudotsugata in North Oregon. He found that the density of the larvae was extraordinarily high at the beginning of feeding in June, 1973. Thereafter, population either declined sharply or collapsed on all of the plots studied. Measureable larval populations of the subsequent generations were found only on six plots in June, 1974 , which had virtually disappeared by mid-summer. Rate of decline was variable under different conditions but appeared to be predictable from the level of past defoliation. The decline rate was faster on heavily or moderately defoliated plots than on lightly or previously undefoliated plots. Population collapse was the result of a multitude of natural factors operating in compensating ways against the high density outbreak. It was characteried by an increase in the effect of numerous mortality factors including virus disease, insect parasites, predators, starvation and larval dispersion, changes in population quality and structure resulting in lower fecundity, egg quality and changes in sex ratio. The largest proportion of mortality occurred early in the larval cycle and was probably due to losses from natural dispersion and predation.

Investigation on forest insects in Indian Sub-Continent are sporadic. Among the earlier workers name of Stebbing (1907) can be mentioned who reported insect pests of Sal, Shorea robusta in Assam along with their predators and parasites. Gardner (1938) studied the immature stages of Lymantridae insects of forests in India. Roonwal (1953, 1954, 1957, 1979) did extensive works on Indian forest insects, specially, the Sal defoliator, Lymantria mathura Moore. He described their egg-masses, population eruption, seasonal life history, nocturnal feeding activity etc. in the Sub-Himalayan forest regions.

Zethner (1973) investigated extensively on forest insect problem of Bangladesh and Pakistan and suggested protection measures against them. He found that the most important insect pests in forestry of the Indian Sub-Continent are found on logs and other felled materials, plantations and nurseries. Felled woods are reported to be destroyed by termites and wood boring beetles (Platipodidae and Bostrichidae).

Misra (1978) has investigated on the bionomics of the borer, Ailanthus excelsa in Siwalik forest division. He reported its another host plant as Acacia gageana .

Singh and Rawat (1980) studied biology, host-plants, seasonal activity and laboratory testing on chemical control of Pericallia ricini (Lepidoptera : Arctidae) at Jabalpur. In laboratory they found that females lay 360 - 1004 eggs (mean 641) in clusters on the underside of the leaves. The incubation, larval, pre-pupal and pupal periods lasted for 3.25±0.71, 27.66 ± 4.21, 3.00 ± 0.66 and 12.40 ± 2.06 days, respectively. The pest was active from June-July to December and entered pupal diapause in 4th generation for about seven months. The diapause broke in June - July of the next year after the onset of monsoon.

Khan and Maiti (1983) studied on the bio-taxonomy, biology and ecology of some Longicorn beetle borers (Coleoptera : Cerambicidae) of Andaman island.

Sen Sarma and Thakur (1986) have recently published a detailed list of insect pests of the

Dipterocarpaceae trees and their management. In their list of insect pests, among Cerambicid beetles which cause greatest economic damage to the living trees of Dipterocarpaceae are Batocera rufomaculata, Celosterna scabrator and Hoplocerambyx spinicornis. Among Curculionid beetle larvae Alcidodes crassus, Nanophes dipterocarpi and Sitophilus rugicollis which feed on seeds and fruits of Dipterocarpus spp. and render them non-viable. Among Lepidoptera, caterpillars are Blastobasis sp., Lyonetica eratopa and Pammene theristis which feed on fruits and seeds of Shorea robusta as well as its seedlings and young shoots in all Sal growing areas. Among Orthoptera, nymphs and adults of Chortogonus spp. and Oxyia velox which feed on folliage and seedlings of Shorea robusta as minor pests.

RELATIVE TOXICITY OF INSECTICIDES :

Various insecticides have been used for insect control for thousands of years. So far as the synthetic insecticides are concerned the discovery of DDT by Paul Muller in 1939 revolutionised insect control and marked the beginning of the development and application of modern synthetic organic insecticides. Hundreds of insecticides have since then been synthesised or discovered and new toxicants are tested year after year.

Insecticides are classified in different ways. From the origin point of view, they are classified as Organic, Inorganic and Synthetic insecticides. According to the mode of action, they are named as Stomach Poison, Contact Poison, Fumigants etc. Based on the effect on different stages of the target organisms, they are categorised as Ovicide, Larvicide and Adulticide (Romoser, 1973).

Though there are several methods of insect pest control, such as, mechanical, cultural, biological, pheromonal and integrated, insecticides are used as a convenient tool to control them. A number of insecticides are available in the market. It is however necessary to have a comparative idea of their toxicity on the target organisms. Investigations on relative toxicity of insecticides have been conducted from the time they were made available for use. We shall review here works of recent contributions in this context.

In the last decade, among others, Serghiou (1971) made a very exhaustive investigation on the relative toxicity of 12 insecticides on Spodoptera littoralis larvae in laboratory and in field on Leucerne. Bioassay in which all the field tested insecticides were included was performed in the laboratory to determine their effectiveness against 3rd and 5th instars. More than 90% mortality of both the instars was obtained with Cyolane 25EC. Field mortality of the mixed instars population was obtained with Monocrotophos 60EC at 1.47 kg, Cyolane 25EC at 0.78 kg, 1.49 kg and 1.11 kg and Gardone 75%WP at 1.46 kg per hectar. Monocrotophos 40EC at 1.11 kg gave 88.5% control.

Schwartz et. al. (1971) tested 5 contact insecticides on California Oak-worm, Phryganidia californica Pachward , in 3rd and 4th instars and found the decreasing order at LD_{50} : Pyrathrin, Zectran, DDT, Carbaryl and Malathion. At LD_{90}, the decreasing order became Pyrathrin, Zectran, DDT, Malathion and Carbaryl. A low slope of the regression curve for Carbaryl suggests that small gains in mortality would be achieved at the expense of large increments of dosage. Pyrathrin, Zectran and Malathion were found to be likely candidate for field testing.

Robertson (1972) investigated the toxicity of Zectran aerosol to the 5th instar Oak-worm, Phryganidia californica , its primary parasite , Itoplectis behrenskii (Cresson) and the hyper-parasite, Dibrachys cavus (Walk.). The descending order of tolerance of LD_{50} was : 5th, 4th, 3rd, 2nd, 1st instar of Oak-worms, parasites, hyperparasites.

Deane and Dunbar (1973) conducted experiments on two forest pests, the Gypsy moth, Porthetria dispar (L) and the Elm span-worm, Ennomos subsignarius (Hubner) and found that mist blower application of Acephate, Chlordimeform, Leptophos, Phosalone and Semivol gave excellent foliage protection, except Chlordimeform, which was not very toxic to either species. In laboratory, both the species were repelled equally well by foliage treated with Chlordimeform.

Whitlock (1973) reported the effects of 11 insecticides topically applied against the 3rd instar larvae of Heliothis armigera in South Africa. Methomyl was reported to be the most effective while Carbaryl proved most disappointing. The delayed action of Monocrotophos illustrated and compared with Parathion which is a fast acting insecticide.

Ragenovich and Coster (1974) evaluated Carbamate and Phosphate insecticides against the Southern Pine beetle, Dendroctonus frontalis and the Bark beetle, Ips grandicollis and I. calligraphus with Lindane as a reference. Lindane significantly reduced the established Southern Pine beetle broods. Phosmate caused high mortality of adult beetles within 24 hrs. after emergence from treated Pines. Propoxur and Carbaryl were effective in preventing I. grandis and I. calligraphus attack in Loblolly Pine logs.

Ciesla (1977) tested the effect of Sevin (Carbaryl), Dylox (Trichlorofon), Orthene (Acephate) and Dimilin (TH6040) on Douglas Fir Tussock moth, Orgyia pseudotsugata. He found that approximately 100% larval mortality occurred after 4 days with Sevin, Orthene and Pyrocite and after 14 days with Dimilin.

Debarr and Nard (1978) tested a large number of contact insecticides to the 2nd stage nymphs of Leptoglossus corculus, the leaf footed Pine seed bug, by topical application. Most of these insecticides had

LD_{50} values less than 5 µg/gm of body weight. Nine insecticides : Aldicarb, Aminocarb, Azinophos-methyl, Carbofuran, Dicrotophos, FMC 45498, Monocrotophos, Propoxur and SD 43775 had LD_{50} values of less than 1 µg/gm of body weight. They found that there was a good agreement between the relative toxicities of insecticides applied topically and in laboratory tests.

Roberton and Boelter (1979) determined the toxicity of 14 insecticides to the larval stages of the Douglas Fir Tussock moth, Orgyia pseudotsugata in laboratory by contact and feeding and concluded that the degree of exposure of the larvae to insecticides significantly affected mortality. The younger instars were more susceptible to the toxicants. They found significant difference in population responses from 1973 to 1977 as well. Spray volume, formulation and presence of Rohodamine B dye significantly affected the toxicites of Carbaryl and Trichlorfon.

Kay (1979) attempted to determine the tolerance level of 9 insecticides on Coccinella repanda larvae. They followed the topical application technique. Based on 48 hrs. of LD_{50} values the ascending order of toxicity to the larvae was Endosulfan, Pirimicarb, Thiometon, Formathion, Chlorpyrifos, Dermeton-S-methyl, Dimetheate, Phosphamidon and Monocrotophos. To the adults the order was Endosulfan, Pirimicarb, Thiometon,Formathion, Chlorpyrifos, Thiometon, Demeton-S-Methyl, Phosphamidon, Dimethoate and Monocrotophos. The study was conducted as an aid in developing pest management process for Therioaphis trifolii and Acyrthosiphon kondoi in Leucerne as Coccinella repanda is an important predator of aphids.

Retnakaran, Smith and Tomkins (1979) tested Dimilin for the control of forest Tent caterpillar, Malacosoma disstria on two trembling Aspen, Populas tremeloides stands heavily infested with Tent caterpillars. The insecticide was applied to 1st and 2nd instars and the trees were in starting to flush and reportedly achieved total control.

Parker, Kalley and Teilon (1979) investigated on the control of Maple leaf-cutter, Paracjemensis acerifolilla by Carbaryl in Vermont, U.S.A. All the three formulations tested, killed significant numbers of the insect pest and protected the Maple tree, Acer saccharum leaves. Sevin-4 oil had a larger residual effect and caused the highest percentage of mortality. Sevin and Sevin-80 sprayable resulted in fewer Maple leaf-cutter in the foliage.

Haverty and Wood (1981) investigated the residual toxicity of Carbaryl, Chlorpyrifos, Diazinon, Fenitrothion, Fenvalerate, Lindane, Methyl Parathion, Permathion and Resmethrin on the Mountain Pine cone beetle, Conophthorus monticolae . After 24 hrs. of exposure encapsulated Resmethrin and Fenvalerate were found to be most toxic with LD_{50} values to be 325 and 65 times as toxic, respectively, as the least toxic formulation was encapsulated Fenitrothion.

Vaughan and Turner (1984) conducted experiments with 7 insecticides on adults and late instars of Lesser Mealworms to determine the relative toxicity in Polystyrene painted and unpainted plywood. In the residual activity test, insecticide performance was altered by difference in formulations, surface type and the life stages of the insects. Wetable powder formulations were more effective on Polystyrene than were emulsifiable concentrate.

Stankovic, Sestovic and Peric (1985) tested the toxicity of some insecticides on Colorado beetle on the basis of probit regression and the highest efficacy for Chlorfenvinfos and the lowest for Carbaryl has been established. On the basis of potency the tested compounds were classified into two groups. Lindane, Carbaryl, Dioxacarb and Phosmet comprise the first group and Kelevan and Chlorfenvinfos the second group. Carbaryl has the least relative potency in the first group of insecticides. For achieving the same effect, out of the two insecticides in the the second group, a greater quantity of Kelevan than Chlorfenvinfos is needed.

In India the toxicological experiments have been conducted mainly on agricultural pests. As described above, we shall restrict here to the more important contributions only appeared in the last three decades.

Dale *et al.*(1966) investigating on the residual effect of some insecticides found that Aldrin and Heptachlor were more effective than DDT, BHC and Carbaryl on the maggot of the Melon fly, *Dacus cucurbitae*, which live in the soil.

Saini and Sharma (1970) tested the relative toxicity of 15 insecticides against the 5th instar larvae of Lemon butterfly, *Papilio demoleus* L. under Potter's tower. Mevinphos, Endrin, Parathion, Telodrin, Bidrin, Gamma BHC, Aldrin and BHC were found to be 7.85, 68.4 , 3.55, 2.41, 1.60, 1.50, 1.40 and 1.20 times, respectively, as toxic as DDT. Malathion, Dialdrin, Diazinon, Phosphamidon and Dimethoate 0.025% and Malathion 0.05% were found to be effective for control of the pest.

Singh and Pandey (1972) tested 6 insecticides for controlling the Mango leaf cutting weevil, Deporaus marginatus Pasc. and found that DDT, Nuvacron and Sevin were most effective. Sevin had the maximum effectiveness.

Teotia and Lal (1972) worked out the relative toxicity of the films of 10 insecticides against the full grown larvae of Til leaf and pod borer, Antigastria catalaunalis. They found the relative toxicity in the following descending order : Malathion, Fenitrothion, Mevinphos, Diazinon being about 2.15, 1.86, 1.78 and 1.64 times, respectively, as toxic as Lindane. Endrin, Carbaryl, Carbophenothion and Dimethoate proved less toxic and were about 0.95, 0.14 and 0.097 times, respectively, as toxic as Lindane.

Singh, Ramzan and Sidhu (1973) evaluated the relative toxicity of 14 insecticides for the control of the Cotton leaf-roller, Sylepta derogata larvae in the field. Fenitrothion 0.025% and Monocrotophos 0.025% along with Carbaryl 0.1%, DDT + BHC 0.1% each and Endosulfan 0.05% also proved effective causing 68 - 85% mortality. All other treatments, i.e., Dimethoate 0.025%, Malathion 0.07%, Methyl-O-Demeton 0.025%, Endrin 0.02%, Malathion 0.07% and Phosphamidon 0.025% were much less effective.

Singh and Gupta (1978) evaluated the relative toxicity of 20 contact insecticides in laboratory by

Potter's tower against the Teak skeletonizer, Pyrausta machaeralis. They found that the descending order of relative toxicity tested against the 3rd instar larvae were : Monocrotophos, Chlordimeform, Quinalfos, Anthio, Acephate, Carbaryl, Fenitrothion, Dichlorvos, Dieldrin, Dimethoate, Cythion, Endrin, Gamma BHC, Endosulfan, Leptophos, Malathion, Aldrin, Ambithion, DDT(WDP), DDT (WP). There is not much difference in the toxicity of Cythion, Endrin, Gamma BHC, Endosulfan, Leptophos, Malathion, Aldrin and Ambithion. Fenitrothion, Dichlorvos, Dieldrin and Dimethoate fall more or less in the same category of toxicity. Acephate and Carbaryl proved more toxic, being 15.315 and 8.544, respectively, than DDT(WP) as unit. Monocrotophos, Chlordimeform, Quinalfos and Anthio proved to be the most effective against the pest.

Gupta, Veer and Sen Sarma (1982) did laboratory evaluation of 21 insecticides against the 3rd instar larvae of Selepa celtis Moore (Lepidoptera : Noctuidae) under Potter's tower. Insecticides were : Monocrotophos 100EC, Chlordimeform 50EC, Quinalphos 55EC, Anthio 35EC, Carbaryl 50WP, Endosulfan 35EC, Pyrathrum 20EC, Gamma BHC 20EC, Dichlorvos 50WDP, Toxaphene 80EC, Leptophos 34EC, Malathion 50EC, Klophos 50EC, Fenitrothion 50EC, Dieldrin 18EC, Aldrin 30EC, Cythion 35EC, DDT 50WP, Accothion 100EC, Dimethoate 30EC and Endrin 20EC in different concentrations. Monocrotophos, Chlordimeform, Quinalphos and Anthio were more toxic than DDT while Ambithion, Dimethoate and Endrin were less toxic than DDT. The rest insecticides were in the following order of effectiveness in descending order : Carbaryl, Endosulfan, Pyrathrum, Gamma BHC, Dichlorvos, Toxaphene, Leptophos, Malathion, Klofos, Fenitrothion, Dieldrin, Aldrin, Cythion, DDT.

Gupta and Veer (1986) did laboratory bioassay of some insecticides as contact poison against the 3rd instar larvae of Glyphodes pyloalis Walker (Lepidoptera : Pyralidae) . They found the descending order of toxicity as : Chlordimeform, Formathion, Malathion (premium grade), Methyl-Parathion, Endosulfan, Malathion, Fenitrothion, Leptophos, Klofos, Dichlorvos, Endosulfan, DDT, Dimethoate, Pyrathrum, Chlordane, Gamma BHC. Monocrotophos, Formathion and Chlordimeform were 27 to 30 times more toxic than DDT.

CHAPTER 4

M A T E R I A L   A N D   M E T H O D S

MATERIAL AND METHODS

4.1 : SURVEY OF INSECT FAUNA :

The light-trap experiments ~~was~~ were performed at night time for the survey of insect fauna at the Balphakram Forest Beat Office, which is an Assam type building at a hill-top, surrounded by thick deciduous and semi-evergreen vegetation at the Southern part of the Balphakram National Wild-life Sanctuary.

A 24 watt bulb lighted by a 12 volt Exide Battery was set 15 cm above the floor in the varandah of the Beat Office. A set of 6 white enamelled trays (size 50X30X5 cm each) were placed on the floor below the lighted bulb. Each tray was filled-up with water to which 10 ml of Teepol was added. The Teepol acted as a good trap for insects falling in the water.

The experiment was conducted at monthly intervals in the new moon night from 17.00 hrs. in the evening to 05.00 hrs. in the morning. The insects thus trapped in the water were collected at hourly intervals and preserved in 70% Ethyl Alcohol, except Lepidoptera which were preserved in dry condition. The climatic parameters, such as, temperature, humidity and rainfall were noted along with every sample of collection.

The survey of diurnal insects was conducted every month from November, 1979 to October, 1981. During this period 7 days were spent each month in the forest for insect collection. The insects were collected by hand-picking and by forceps. Insects in flight, such as, butterflies etc. were caught by sweeping net. Smaller insects were preserved in 70% Ethyl Alcohol in bottles and labelled with date and place of collection. The larger insects, such as, Lepidoptera, Coleoptera, Hemiptera, Orthoptera etc. were preserved in dry condition.

The insects were identified at the Zoological Survey of India, Calcutta and its Eastern Regional Station at Shillong.

4.2 : BIOLOGY AND LIFE-TABLE OF MAJOR INSECT PESTS :

During the first year of survey 11 species of insect pests were recorded. Out of these, Cyclosia panthona Cram. was found to be a major defoliator of the tree Aporosa roxburghii Bull. which grow abundantly in the Balphakram forest. In the first year, nature of its occurrence and outbreak were noted, eggs, larvae, pupae and adults were collected and development was studied in the field as well as in the laboratory. During the second year, the density of the eggs and the larval populations were estimated and the life-tables were prepared. Another insect pest species, Diaphania laticostalis Guene which defoliates the medicinal tree, Holarrhena antidysentrica (L.) Wall was also investigated ~~of its biology~~ during the second year. For the rest 9 minor pest species, their occurrence and their host plants only have been described.

4.3 : RELATIVE TOXICITY EXPERIMENTS :

Relative toxicity experiments of 4 contact insecticides, namely, Thiodan 35EC (Endosulfan), Cythion 50EC (Cyanamid Malathion), Nuvacron 40EC (Monocrotophos) and Ekalaux 25EC(Quinalphos) were carried out on the advance stage (4th and 5th instars) larvae of Cyclosia panthona Cram. and Diaphania laticostalis Guene .

Of various techniques for relative toxicity experiment we adopted a simple technique, namely, Dry-film technique of Gupta and Rawlins (1966). Each insecticide was tested in 5 different concentrations, viz., 0.0025%, 0.005%, 0.01%, 0.02% and 0.04% in distilled water. A thin film of 0.5 ml of the required concentration of the insecticide was spread evenly on the bottom of the petri-dish. of 75 mm in diameter. The film was allowed to dry at room temperature (20°C to 25°C) for about 3 hrs. Ten numbers of advance stage larvae of uniform size were placed on each of the dried petri-dish with specific concentation and kept covered for mortality counting. For control only distilled water was used for making the dry film and ten numbers of uniform size larvae were placed in the petri-dish. Experiments were conducted with five replications for each concentration at room temperature ($14^{\circ}C$ to $20^{\circ}C$) and at 20% to 40% of relative humidity. Humidity was maintained within the range by sprinkling water in the laboratory. Mortality counts were noted at 1, 3, 6, 12, 24 and 48 hrs. of time intervals. Moribund insects were taken as dead.

STATISTICAL ANALYSIS :

Tables, Figures and Histograms have been provided in population dynamics and the insects collected have been analysed for co-relation co-efficient with environmental factors. In the study of the insect pests, Diagrams, Histograms and Life-tables have been provided. For the analysis of the relative toxicity experiments Tables, Figures and the help of Regression Equations and Regression Lines have been undertaken.

OBSERVATIONS

5.1 : LIST OF IDENTIFIED INSECTS :

The following is the list of 134 identified species of different Orders :

(1) Order : Lepidoptera

(2) Family : Nymphalidae

1. Pantoporia nefti.
   Occurrence : September - October.
2. Pantoporia sp.
   Occurrence : December - June.
3. Neptis heliodore.
   Occurrence : December - January.
4. Neptis nandina.
   Occurrence : December - January.
5. Precis hierta.
   Occurrence : November - January.
6. Precis villida (Junonia lemonias L.)
   Occurrence : June - December.
7. Precis almana (Junonia almana L.)
   Occurrence : June - December.
8. Precis atlites (L.)
   Occurrence : July - December.
9. Erias insulana (Ergolis merione).
   Occurrence : July - December.
10. Lethe confusa.
    Occurrence : July - December.

11. *Hypolimnus bolina*.

Occurrence : July - September.

12. *Cirrochroa aoris*.

Occurrence : September - October.

13. *Euthalia merta*.

Occurrence : January - February.

14. *Terionis* sp.

Occurrence : September - November.

15. *Limenitis* sp.

Occurrence : October - November.

(2) Family : Danaidae

16. *Danais aglea*.

Occurrence : Throughout the year.

17. *Danais plexipus*.

Occurrence : July - December.

18. *Danais genutia*.

Occurrence : November - January.

19. *Danaua hamata*.

Occurrence : October - November.

20. *Danaus limniace*.

Occurrence : June - July.

21. *Danaus* sp.

Occurrence : August - September.

22. *Euploea core*.

Occurrence : June - September.

23. *Euploea doubledayi*.

Occurrence : August - October.

24. Euploea diocletianus.

Occurrence : July - September.

25. Euploea deione.

Occurrence : July - September.

26. Euploea mulciber.

Occurrence : Throughout the year.

27. Xyleutes ceramicus Walk.

Occurrence : December - January.

(3) Family : Pieridae

28. Delias thysbe.

Occurrence : September - October.

29. Delias descombesi.

Occurrence : June - October.

30. Delias agalaia.

Occurrence : November - December.

31. Delias rosenbergi.

Occurrence : July - August.

32. Gonepteryx rhamni.

Occurrence : August - September.

33. Catopsilia pomona.

Occurrence : July - August.

34. Eurema hecabe.

Occurrence : June - November.

35. Ixias pyrene.

Occurrence : December - January.

36. Pieris brassicae.

Occurrence : November - February.

37. *Pieris napi*.

Occurrence : December - February.

38. *Appias* sp.

Occurrence : January - February.

(4) Family : Papilionidae

39. *Papilio memmon*.

Occurrence : July - August.

40. *Papilio fuscens*.

Occurrence : June - August.

41. *Papilio polytis*.

Occurrence : June - August.

42. *Papilio* sp.

Occurrence : June - August.

43. *Papilio* sp.

Occurrence : July - August.

44. *Pachlioptera* sp.

Occurrence : August - September.

45. *Graphium agamemmon*.

Occurrence : June - July.

46. *Hebromia glausippe*.

Occurrence : June - July.

(5) Family : Hesperidae

47. *Pelopidus assamensis*.

Occurrence : September - October.

48. *Pelopidus conjuncta*.

Occurrence : November - December.

49. *Notocrypta curvifascia.*

Occurrence : February - March.

50. *Suniana sunias.*

Occurrence : December - January.

51. *Udaspes folus.*

Occurrence : August - September.

(6) Sphingidae :

52. *Cephanodes hylus* L.

Occurrence : May - July.

53. *Macroglossum stallatarum.*

Occurrence : May - June.

54. *Theretra* sp.

Occurrence : August - September.

(7) Family : Saturnidae

55. *Actias selene* (Hubn.).

Occurrence : August - September.

56. *Attacus atlas* L.

Occurrence : May - July.

(8) Family : Lycanidae

57. *Nacaduba pavana.*

Occurrence : August - September

58. *Celastrina* sp.

Occurrence : August - September.

(9) Family : Cossidae

59. *Xyleutes ceramicus.*

Occurrence : August - September.

(10) Family : Brahmaeidae

60. Brahmaea wallichii Gray

Occurrence : July - August.

(11) Family : Agaristidae

61. Eusemia dentatrix.

Occurrence : July - September.

(12) Family : Syntomidae

62. Syntomis sperbius.

Occurrence : January - February.

(13) Family : Zygaenidae

63. Cyclosia panthona Cram.

Occurrence : March - April , October - November.

(14) Family : Pyralidae

64. Diaphania laticostalis Guene

Occurrence : March - April.

(2) Order : Coleoptera

(1) Family : Scarabaeidae

1. Cathersius molossus (L.)

Occurrence : July - August.

2. Xylotrupes gideon .

Occurrence : June - August.

3. Heliocopris bucephalus.

Occurrence : May - July.

4. Scarabaeus sacer.

Occurrence : April - July.

5. *Popilia cyanea*.

Occurrence : May - July.

6. *Oryctus rhinoceros*.

Occurrence : September - October.

(2) Buprestidae

7. *Chrysochroa bicolor* Fabr.

Occurrence : June - August.

8. *Chrysochroa chinensis* Cast.

Occurrence : June - July.

9. *Chrysochroa gratiosa* Deyr.

Occurrence : July - August.

10. *Sternocera aequisignata* Saund.

Occurrence : June - July.

11. *Sternocera laevigata*.

Occurrence : June - July.

(3) Family : Meloidae

12. *Mylabris phalerata* (Pallas)

Occurrence : May - July.

13. *Mylabris pustulata* Thunbera

Occurrence : May - July.

(4) Family : Coccinellidae

14. *Epilachna vigintioctopunctata*.

Occurrence : December - March.

15. *Chilomenes 6-maculata*.

Occurrence : December - March.

16. *Coccinella* sp.

Occurrence : January - March.

17. *Chilomenes* sp.

Occurrence : January - March.

(5) Family : Chrysomellidae

18. *Dicladispa armigera*.

Occurrence : October - December.

19. *Aulacophora foveicollis* Lucas

Occurrence : November - March.

(6) Family : Curculionidae

20. *Cyrtotrachelus longimanus*.

Occurrence : June - August.

21. *Protocerius* sp.

Occurrence : May - July.

(7) Family : Lucanidae

22. *Lucanus cantosi* Hope

Occurrence : July - August.

(8) Family : Gyrinidae

23. *Gyrinus* sp.

Occurrence : June - July.

(9) Family : Scaphidiidae

24. *Scaphidium* sp.

Occurrence : June - July.

(10) Family : Staphylinidae

25. Staphylinus sp.

Occurrence : September - October.

(11) Family : Cicindelidae

26. Cicindela sp.

Occurrence : March - May.

(12) Family : Dynastidae

27. Oryctes rhinoceros.

Occurrence : February - March.

(3) Order : Orthoptera

(1) Family : Acrididae

1. Oxyia velox.

Occurrence : Throughout the year.

2. Oxyia hyla hyla Serville

Occurrence : Throughout the year.

3. Oxyia sp.

Occurrence : Throughout the year.

4. Schistocera gregaria.

Occurrence :October - March.

5. Chondracris rosea (de Gur)

Occurrence : May - September.

6. Choroedocus oxypterus (Blanchard)

Occurrence : June - September.

7. Attractomorpha cremulata (Fabr.)

Occurrence : July - October.

8. Acrida exalta (Walk.)

Occurrence : May - October.

(2) Family : Tettigonidae

9. Holochlora indica Kirby

Occurrence : June - August.

10. Mecopoda elongata L.

Occurrence : June - July.

(3) Family : Gryllidae

12. Gryllus bimaculatus de Gur

Occurrence : June - August.

13. Brachytrypes orientalis (Burm.)

Occureence : May - July.

14. Teleogryllus mitratus (Burm.)

Occurrence : July - August.

15.

(4) Family : Gryllotalpidae

15. Gryllotalpa fossor.

Occurrence : April - August.

(4) Order : Hemiptera

(1) Family :Pyrrhocoridae

1. Dysdercus cingulatus (Fabr.)

Occurrence : February - April.

(2) Family : Aphididae

2. Aphis sp.

Occurrence : January - April.

(3) Family : Jassidae

3. *Empoasca flavescens*.

Occurrence : February - March.

4. *Nephotettix bipunctatus*.

Occurrence : January - April.

(4) Family : Coreidae

5. *Leptocorixa varicornis*.

Occurrence : April - May.

(5) Family : Lygaeidae

6. *Lygaeus* sp.

Occurrence : February - March.

(5) Order : Hymenoptera

(1) Family : Bombidae

1. *Bombus* sp.

Occurrence : April - May.

(2) Family : Apidae

2. *Apis mellifica*.

Occurrence : February - May.

(3) Family : Formicidae

3. *Oecophylla smaragdina*.

Occurrence : April - August.

4. *Formica* sp.

Occurrence : February - September.

5. *Formica* sp.

Occurrence : Throughout the year.

(4) Family : Vespidae

6. *Vespa* sp.

Occurrence : April - June.

(5) Family : Braconidae

7. *Apanteles* sp.

Occurrence : March - May.

(6) Order : Diptera

(1) Family : Culicidae

1. *Aedes* sp.

Occurrence : February - May.

2. *Culex* sp.

Occurrence : February - July.

3. *Anopheles* sp.

Occurrence : May - June.

(2) Family : Muscidae

4. *Musca domestica*.

Occurrence : Throughout the year.

5. *Musca* sp.

Occurrence : Throughout the year.

(3) Family : Drosophilidae

6. *Drosophila* sp.

Occurrence : May - July.

(4) Family : Tachinidae

7. *Tachina* sp.

Occurrence : May - June.

(5) Family : Tipulidae

8. *Tipula* sp.

Occurrence : May - June.

(7) Order : Dictyoptera

(1) Family : Blattidae

1. *Blatta orientalis*.

Occurrence : Thoroughout the year.

2. *Periplaneta americana*.

Occurrence : Thoroughout the year.

(8) Order : Dermaptera

(1) Family : Forficulidae

1. *Forficula auricularia*.

Occurrence : May - July.

(9) Order : Ephemeroptera

(1) Family : Baetidae

1. *Baetis* sp.

Occurrence : April - June and September - November.

2. *Cloeon* sp.

Occurrence : September - October.

(10) Order : Phasmida

(1) Family : Phyllidae

1. *Phyllium* sp.

Occurrence : April - May.

(2) Family : Bacteriidae

2. *Tenodera* sp.

Occurrence : April - June.

5.2 : ANALYSIS OF INSECTS IN LIGHT-TRAP :

The analysis of the light-trap insect catches is presented under the following sub-headings : Monthwise Analysis, Hourly Analysis and Population Dynamics.

5.21 : MONTHWISE ANALYSIS :

The data on monthwise analysis of insects collected in light-trap belonging to different orders have been shown in Tables 5.1, 5.2 and Figures 5.1,5.2.

During the first year the collection percentage of different insect orders in descending order were as follows : Diptera 42.05%, Coleoptera 16.68%, Lepidoptera 12.91%, Hemiptera 11.66%,Hymenoptera 10.62%, Orthoptera 3.74%, Ephemeroptera o.87%, Dictyoptera 0.70%, Dermaptera 0.47%, Isoptera 0.17%, Plecoptera 0.13% and Odonata 0.02%.

During the second year the percentage in descending order were as follows : Diptera 47.43%, Coleoptera 13.33%, Lepidoptera 6.16%, Orthoptera 4.58%, Ephemeroptera 0.73%, Dictyoptera o.70%, Trichoptera 0.55%, Isoptera 0.48% = Dermeptera 0.48%, Plecoptera 0.46% and Odonata 0.01%.

Total number of all the insects collected in the first year was 9211 and in the second year was 6895.

Table 5.1 : Monthwise total Insect collection of thirteen different Orders in Light-trap from November, 1979 to October, 1980.

Months	NV	DC	JA	FB	MR	AP	MY	JN	JL	AG	SP	OC	Annual Total	Annual Percentage
Orders														
Dip	108	2	2	8	5	19	34	312	393	346	623	2022	3874	42.05
Lep	14	9	10	7	12	121	154	164	183	119	135	262	1190	12.91
Hym	23	5	6	10	10	96	122	167	215	20	276	29	979	10.62
Hem	302	15	5	5	6	62	92	51	68	27	40	355	1028	11.16
Col	161	20	10	3	19	130	162	121	142	30	20	719	1537	16.68
Dic	1	0	0	0	0	16	25	5	3	5	7	3	65	0.70
Ort	11	8	3	7	47	17	27	26	23	10	12	154	345	3.74
Eph	11	0	0	0	0	3	18	10	5	4	8	22	81	0.87
Ple	1	0	0	0	0	0	1	2	3	1	3	1	12	0.13
Tri	3	0	0	0	0	2	1	7	4	6	4	11	38	0.41
Iso	0	0	0	3	0	0	3	0	4	6	0	0	16	0.17
Der	0	0	0	0	0	4	13	3	2	3	4	15	44	0.47
Odo	0	0	0	0	0	0	0	0	1	1	0	0	2	0.02
M.T.	635	59	36	43	99	470	652	868	1046	578	1132	3593	9211	
M.P.	6.89	0.64	0.39	0.46	1.07	5.15	7.07	9.42	11.35	6.27	12.28	39.00		

Dip = Diptera
Lep = Lepidoptera
Hym = Hymenoptera
Hem = Hemiptera
Col = Coleoptera
Dic = Dictyoptera
Ort = Orthoptera

Eph = Ephemeroptera
Ple = Plecoptera
Tri = Trichoptera
Iso = Isoptera
Der = Dermaptera
Odo = Odonata

M.T. = Monthly Total
M.P. = Monthly percentage

NV = November
DC = December
JA = January
FB = February
MR = March
AP = April

MY = May
JN = June
JL = July
AG = August
SP = September
OC = October

Table 5.2 : Monthwise total Insect collection of thirteen different Orders in Light-trap from November, 1980 to October, 1981.

Months / Orders	NV	DC	JA	FB	MR	AP	MY	JN	JL	AG	SP	OC	Annual Total	Annual Percentage
Dip	68	1	4	10	7	12	24	323	292	280	591	1658	3270	47.43
Lep	10	8	11	7	11	27	29	39	47	65	112	59	425	6.16
Hym	27	6	5	9	11	95	84	139	209	29	227	39	880	12.76
Col	65	2	9	8	10	108	150	129	164	48	26	200	919	13.33
Dic	2	0	0	0	4	5	8	6	5	7	5	6	48	0.70
Ort	8	9	5	6	21	24	34	26	27	7	10	139	316	4.58
Eph	8	0	0	0	0	3	6	5	3	4	6	15	50	0.73
Ple	1	0	0	0	0	2	4	6	4	2	4	9	32	0.46
Tri	4	0	0	0	0	4	3	4	5	6	7	5	38	0.55
Iso	0	0	0	6	0	0	7	0	9	11	0	0	33	0.48
Der	0	0	0	0	0	4	6	5	3	4	5	6	33	0.48
Odo	0	0	0	0	0	0	0	0	0	1	0	0	1	0.01
M.T.	465	40	38	52	83	334	445	726	832	488	1019	2373	6895	
M.P.	6.74	0.58	0.55	0.75	1.20	4.90	6.45	10.52	12.06	7.07	14.77	34.41		

Dip = Diptera
Lep = Lepidoptera
Hym = Hymenoptera
Hem = Hemiptera
Col = Coleoptera
Dic = Dictyoptera
Ort = Orthoptera

Eph = Ephemeroptera
Ple = Placoptera
Tri = Trichoptera
Iso = Isoptera
Der = Dermaptera
Odo = Odonata

M.T. = Monthly Total
M.P. = Monthly Percentage

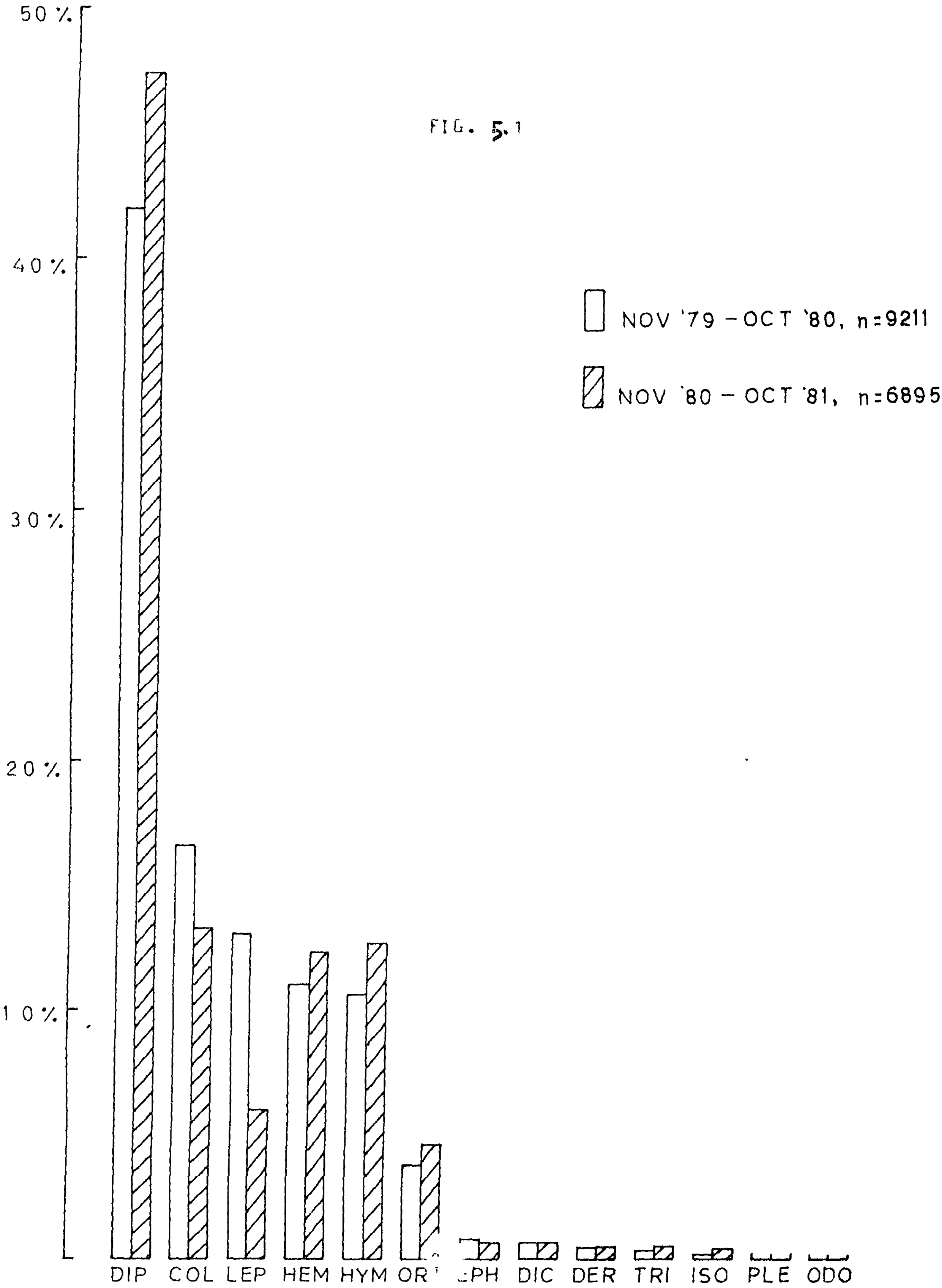
NV = November
DC = December
JA = January
FB = February
MR = March
AP = April

MY = May
JN = June
JL = July
AG = August
SP = September
OC = October

Figure 5.1 : Percentage of 13 Insect orders of the total Annual Insect Collection by Light-trap in the first year (November, 1979 to October, 1980) and in the second year (November, 1980 to October, 1981)

DIP = Diptera
LEP = Lepidoptera
HYM = Hymenoptera
EPH = Ephemeroptera
DER = Dermaptera
ISO = Isoptera
ODO = Odonata
COL = Coleoptera
HEM = Hemiptera
ORT = Orthoptera
DIC = Dictyoptera
TRI = Trichoptera
PLE = Plecoptera

FIG. 5.1



50 %
40 %
30 %
20 %
10 %
NOV '79 - OCT '80, n=9211
NOV '80 - OCT '81, n=6895
DIP
COL
LEP
HEM
HYM
EPH
DIC
DER
TRI
ISO
PLE
ODO

Figure 5.2 : Monthwise Insect Collection Percentage of the total Annual Insect Collection by Light-trap in the first year (November, 1979 to October, 1980) and in the second year (November, 1980 to October, 1981).

N	=	November	D	=	December
JA	=	January	F	=	February
MR	=	March	AP	=	April
MY	=	May	JN	=	June
JL	=	July	AG	=	August
S	=	September	O	=	October

FIG. 5.2

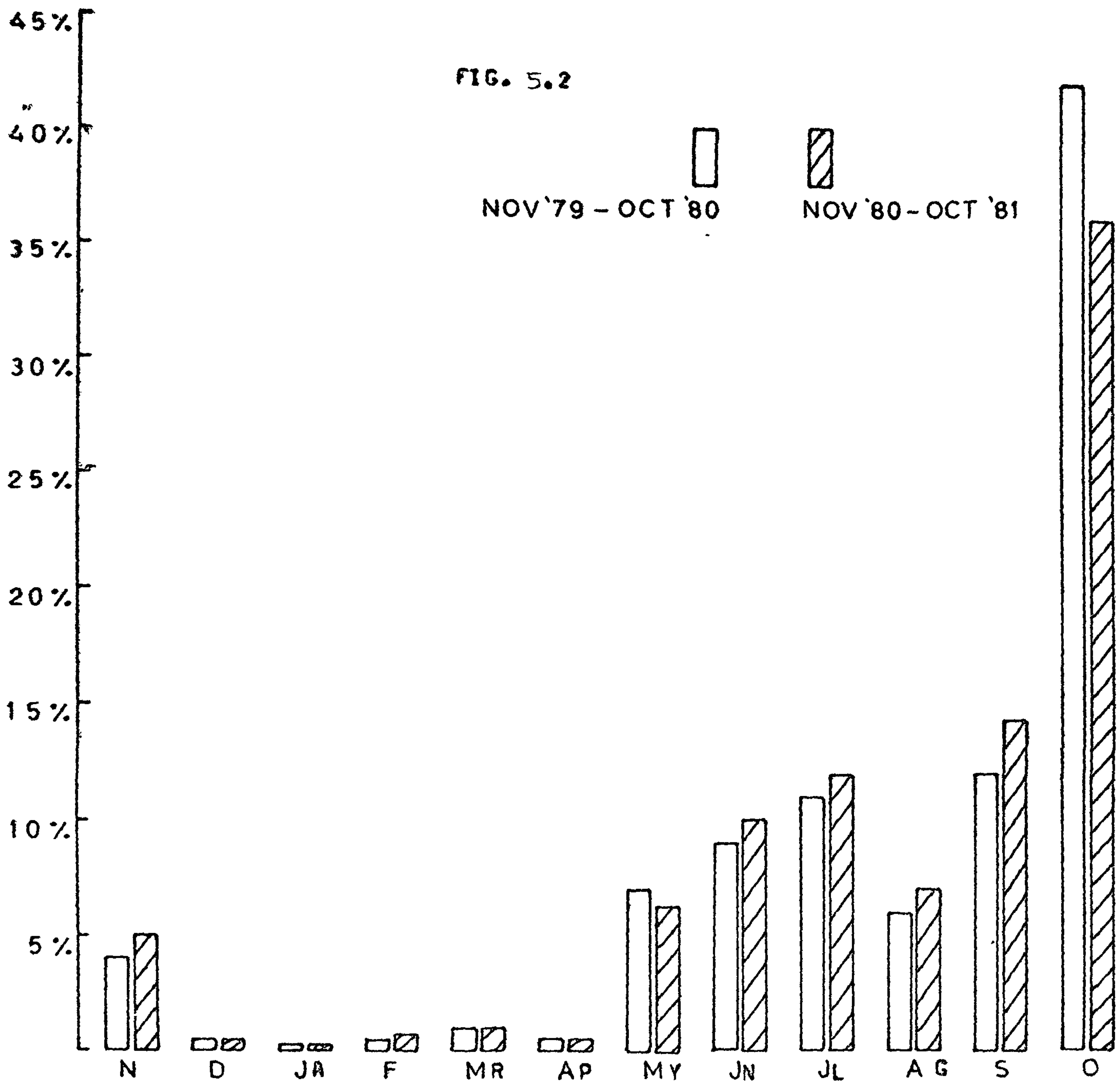

45%
40%
35%
30%
25%
20%
15%
10%
5%
NOV'79 – OCT'80
NOV'80 – OCT'81
N
D
JA
F
MR
AP
MY
JN
JL
AG
S
O

Table 5.3 : Correlation Co-efficient of Orderwise Insect collection in Light-trap between the corresponding months of the first year and the second year.

Insect Orders	Correlation Coefficient (r)	Degree of Freedom	Significance $P < 0.01$	Significance $P < 0.05$
Diptera	0.76573	10	S	S
Lepidoptera	0.64608	10	NS	S
Hymenoptera	0.98880	10	S	S
Hemiptera	0.97682	10	S	S
Coleoptera	0.49561	10	NS	NS
Dictyoptera	0.24516	10	NS	NS
Orthoptera	0.97733	10	S	S
Ephemeroptera	0.95717	10	S	S
Plecoptera	0.60311	10	NS	S
Trichoptera	0.80611	10	S	S
Isoptera	0.94204	10	S	S
Dermaptera	0.80608	10	S	S
Odonata	0.67556	10	S	S
Total Insects	0.99074	10	S	S

S = Significant

NS = Not Significant

A comparison of the above data of the two years reveal that Diptera was the highest, Coleoptera was the second highest and Odonata was the lowest in the light-trap collection.

The percentage of monthwise total insect catch during the first year was in the following descending order : October 39.00%, September 12.28%, July 11.35%, June 9.42%, May 7.07%, November 6.89%, August 6.27%, April 5.15%, March 1.07%, December 0.64%, February 0.64% and January 0.39%.

During the second year, the percentage of monthwise total insect catch was in the following descending order : October 34.41%, September 14.76%, July 12.06%, June 10.52%, August 7.07%, November 6.74%, May 6.45%, April 4.90%, March 1.20%, February 0.75%, December 0.58% and January 0.55%.

Above data reveal that insect catch percentage was highest in October and lowest in January during both the years.

The relationship between the monthly abundance of different insect orders for both the years is presented in the Table53. A positively significant relationship is revealed at 0.01% level for Orthoptera,

Table 5.4 : Correlation Coefficient between the Orderwise monthly total Insect collection in Light-trap and and monthwise Temperature, Humidity and Rainfall from November, 1979 to October, 1980.

Insect Orders	Min. Temp.	Max. Temp.	Min. Rel. Hum.	Max. Rel. Hum.	Rainfall
Diptera	0.365708 NS	0.461894 NS	0.379316 NS	0.122666 NS	0.379316 NS
Lepidoptera	0.013633 NS	0.822395 **	0.754436 **	0.342416 NS	0.754436 **
Hymenoptera	0.674595 *	0.688747 *	0.694147 *	0.252790 NS	0.694147 *
Hemiptera	0.287366 NS	0.354423 NS	0.070546 NS	0.065005 NS	0.070546 NS
Coleoptera	0.329678 NS	0.394685 NS	0.225057 NS	0.120914 NS	0.225057 NS
Dictyoptera	0.522605 NS	0.379342 NS	0.281682 NS	0.189831 NS	0.281682 NS
Orthoptera	0.034139 NS	0.313545 NS	0.174339 NS	0.849665 **	0.174339 NS
Ephemeroptera	0.267428 NS	0.319778 NS	0.212556 NS	0.105087 NS	0.212556 NS
Plecoptera	0.784747 **	0.872512 **	0.807264 **	0.259390 NS	0.807264 **
Trichoptera	0.630928 *	0.699020 *	0.634019 *	0.212416 NS	0.634019 *
Isoptera	0.307740 NS	0.251553 NS	0.433422 NS	0.226914 NS	0.433422 NS
Dermaptera	0.526604 NS	0.535534 NS	0.345917 NS	0.198185 NS	0.345917 NS
Odonata	0.410646 NS	0.361765 NS	0.627091 *	0.264899 NS	0.627091 *
Total Insects	0.467309 NS	0.548647 NS	0.416622 NS	0.148225 NS	0.416622 NS

Min. Temp. = Minimum Temperature   Min. Rel. Hum. = Minimum Relative Humidity

Max. Temp. = Maximum Temperature   Max. Rel. Hum. = Maximum Relative Humidity

NS = Not Significant

* = Significant at P 0.05

** = Significant at P 0.01

Table 5.5 : Correlation Coefficient between the Orderwise monthly total Insect collection in Light-trap and monthwise Temperature, Humidity and Rainfall from November, 1980 to October, 1981.

Insect Orders	Min. Temp.	Max. Temp.	Min. Rel. Hum.	Max. Rel. Hum.	Rainfall
Diptera	0.39723 NS	0.39436 NS	0.02809 NS	0.26485 NS	0.19429 NS
Lepidoptera	0.67365 *	0.69994 *	0.03575 NS	0.46816 NS	0.45105 NS
Hymenoptera	0.68054 *	0.63933 *	0.57954 *	0.59848 *	0.56300 NS
Hemiptera	0.28713 NS	0.26546 NS	0.21130 NS	0.18903 NS	0.09540 NS
Coleoptera	0.62359 *	0.53174 NS	0.52181 NS	0.65602 *	0.35989 NS
Dictyoptera	0.87884 **	0.84796 **	0.79505 **	0.76515 **	0.50688 NS
Orthoptera	0.29726 NS	0.24265 NS	0.06979 NS	0.24664 NS	0.01356 NS
Ephemeroptera	0.22686 NS	0.18359 NS	0.05600 NS	0.12447 NS	0.08272 NS
Plecoptera	0.71927 **	0.66591 **	0.50295 NS	0.62267 *	0.46543 NS
Trichoptera	0.87180 **	0.86355 **	0.46881 NS	0.52424 NS	0.55815 NS
Isoptera	0.40008 NS	0.44510 NS	0.53854 NS	0.59193 *	0.42175 NS
Dermaptera	0.82598 **	0.71835 **	0.67283 *	0.71267 **	0.45944 NS
Odonata	0.28298 NS	0.37056 NS	0.24452 NS	0.27253 NS	0.37189 NS
Total Insects	0.54200 NS	0.52148 NS	0.15622 NS	0.36435 NS	0.27122 NS

Min. Temp. = Minimum Temperature   Min. Rel. Hum. = Minimum Relative Humidity
Max. Temp. = Maximum Temperature   Max. Rel. Hum. = Maximum Relative Humidity

NS = Not Significant
* = Significant at P< 0.05
** = Significant at P< 0.01

Hymenoptera, Hemiptera, Ephemeroptera, Diptera, Trichoptera, Isoptera, Dermaptera and Odonata for the total catch. The relationship is positively significant at 0.05% level for Lepidoptera, Orthoptera, Hymenoptera, Hemiptera, Ephemeroptera, Diptera, Trichoptera, Plecoptera, Isoptera, Dermaptera and Odonata. No relationship is found for Coleoptera and Dictyoptera at 0.01% and 0.05% levels.

The relationship between the environmental factors (temperature, humidity and rainfall) and the total numbers of insects collected for the two years have been shown in Tables 5.4 and 5.5, respectively.

During the first year, relationship with minimum temperature at 0.01% level with Plecoptera, at 0.05% level with Hymenoptera and Trichoptera; with maximum temperature at 0.01% level with Lepidoptera and Plecoptera, at 0.05% level with Hymenoptera and Trichoptera were found to be significant.Relationship with minimum relative humidity at 0.01% level with Lepidoptera and Plecoptera, at 0.05% level with Hymenoptera, Trichoptera and Odonata; with maximum relative humidity at 0.01% level with Orthoptera were found to be significant. Relationship with rainfall at 0.01% level with Lepidoptera and Plecoptera; at 0.05% level with Hymenoptera, Trichoptera and Odonata were found to be significant.

During the second year, relationship with minimum temperature at 0.01% level with Dictyoptera, Trichoptera, Plecoptera and Dermaptera; at 0.05% level with

Lepidoptera, Hymenoptera and Coleoptera; with maximum temperature at 0.01% level with Dictyoptera, Trichoptera and Dermaptera; at 0.05% level with Lepidoptera, Hymenoptera and Plecoptera were found to be significant. Relationship with minimum relative humidity at 0.01% level with Dictyoptera, at 0.05% level with Hymenoptera and Dermaptera; with maximum relative humidity at 0.01% level with Dictyoptera and Dermaptera, at 0.05% level with Hymenoptera, Coleoptera, Plecoptera and Isoptera were found to be significant. Rainfall had no significance at 0.01% and 0.05% levels in the second year.

5.22 : HOURLY ANALYSIS :

The hourly analysis of the total insect catch is presented in Tables 5.6 and 5.7 for the two years, respectively.

The percentage of hourly insect catch during the first year in the ascending order were as follows : 05.00 - 06.00 hrs. (1.11%), 04.00 - 05.00 hrs. (2.19%), 02.00 - 03.00 hrs. (4.28%), 17.00 - 18.00 hrs. (4.74%), 03.00 - 04.00 hrs. (4.76%), 01.00 - 02.00 hrs. (5.78%), 23.00 - 24.00 hrs. (5.86%), 22.00 - 23.00 hrs. (10.81%), 18.00 - 19.00 hrs. (11.69%), 19.00 - 20.00 hrs. (13.85%), 21.00 - 22.00 hrs. (16.96%), 20.00 - 21.00 hrs. (17.91%). During the second year the percentage of hourly catch in ascending order were as follows : 05.00 - 06.00 hrs. (0.79%), 04.00 - 05.00 hrs. (1.81%), 03.00 - 04.00 hrs. (2.71%), 02.00 - 03.00 hrs. (3.29%), 17.00 -

Table 5.6 : Total numbers and percentage of Insect Orders collected by Light-trap at one hourly intervals during November, 1979 to October, 1980.

The top figure represents the actual number of Insects while the figure immediately below it represents the percentage of Insect Order collected in that hour.

1 = 17.00-18.00 hrs	7 = 23.00-24.00 hrs
2 = 18.00-19.00 hrs	8 = 24.00-01.00 hrs
3 = 19.00-20.00 hrs	9 = 01.00-02.00 hrs
4 = 20.00-21.00 hrs	10 = 02.00-03-00 hrs
5 = 21.00-22.00 hrs	11 = 03.00-04.00 hrs
6 = 22.00-23.00 hrs	12 = 04.00-05.00 hrs

Table 5.6

Insect Orders	1	2	3	4	5	6	7	8	9	10	11	12
Diptera	284 7.33	768 19.82	699 18.04	675 17.42	610 15.74	346 8.93	148 3.82	151 3.89	67 1.72	65 1.67	39 1.00	22 0.56
Lepidoptera	33 2.77	75 6.30	136 11.42	262 22.01	181 15.21	125 10.50	73 6.13	90 7.56	68 5.71	60 5.04	55 2.26	32 2.68
Hymenoptera	40 4.08	62 6.33	85 8.68	164 16.75	121 12.35	72 7.35	47 4.80	63 6.43	52 5.31	195 19.91	46 4.69	32 3.26
Hemiptera	38 3.69	73 7.10	114 10.11	100 9.72	207 20.13	180 17.50	92 8.94	58 5.64	80 7.78	50 4.86	40 3.89	6 0.58
Coleoptera	19 1.23	42 2.73	148 9.62	355 23.09	352 22.90	203 13.20	133 8.65	129 8.39	91 5.92	36 2.34	13 0.84	6 0.39
Dictyoptera	3 4.61	9 13.84	12 18.48	13 20.00	12 18.46	1 1.53	1 1.53	4 6.15	6 9.23	4 6.15	0 0.00	0 0.00
Orthoptera	11 3.18	19 5.50	57 16.52	54 15.65	55 15.94	51 14.78	38 11.01	23 6.66	23 6.66	10 2.89	3 0.86	1 0.28
Ephemeroptera	4 4.93	12 14.81	13 16.04	11 13.58	7 8.64	8 9.87	3 3.70	7 8.64	4 4.93	9 11.11	2 2.46	1 1.23
Plecoptera	0 0.00	3 25.00	4 33.33	0 0.00	3 25.00	2 16.66	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Trichoptera	1 2.63	2 5.26	6 15.78	7 18.42	4 10.52	3 7.89	2 5.26	0 0.00	0 0.00	7 18.42	4 10.52	2 5.26
Isoptera	3 18.75	7 43.75	2 12.50	0 0.00	2 12.50	0 0.00	1 6.25	0 0.00	0 0.00	0 0.00	0 0.00	1 6.25
Dermaptera	1 2.27	4 9.09	8 18.18	7 15.90	7 15.90	4 9.09	2 4.54	7 15.90	2 4.52	2 4.54	0 0.00	0 0.00
Odonata	0 0.00	0 0.00	1 50.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1 50.00	0 0.00	0 0.00	0 0.00
Total Insects	437 4.74	1076 11.69	1275 13.85	1648 17.91	1561 16.96	995 10.81	540 5.86	532 5.78	394 4.28	438 4.76	202 2.19	103 1.11

Table 5.7 : Total numbers and percentage of Insect Orders collected by Light-trap at one hourly intervals during November, 1980 to October, 1981.

The top figure represents the actual number of Insects while the figure immediately below it represents the percentage of Insect Orders collected in that hour.

1 = 17.00-18.00 hrs	7 = 23.00-24.00 hrs
2 = 18.00-19.00 hrs	8 = 24.00-01.00 hrs
3 = 19.00-20.00 hrs	9 = 01.00-02.00 hrs
4 = 20.00-21.00 hrs	10 = 02.00-03.00 hrs
5 = 21.00-22.00 hrs	11 = 03.00-04.00 hrs
6 = 22.00-23.00 hrs	12 = 04.00-05.00 hrs

Table 5.7

Insect Orders	1	2	3	4	5	6	7	8	9	10	11	12
Diptera	96 2.93	384 11.74	740 22.62	639 19.54	582 17.79	278 8.50	208 6.36	116 3.54	102 3.11	52 1.59	50 1.52	23 0.70
Lepidoptera	22 5.17	63 14.82	74 17.41	84 19.76	72 16.94	40 9.41	16 3.76	15 3.52	13 3.05	14 3.29	9 2.11	3 0.70
Hymenoptera	37 4.20	66 7.50	88 10.00	189 21.47	164 18.63	98 11.13	36 4.09	52 5.90	41 4.65	59 6.70	35 3.97	15 1.70
Hemiptera	26 3.05	68 8.00	106 12.47	126 14.82	203 23.88	95 11.17	84 9.88	63 7.41	33 3.88	28 3.29	11 1.29	7 0.82
Coleoptera	32 3.48	54 5.87	132 14.36	272 29.59	188 20.45	75 8.16	53 5.76	45 4.89	27 2.93	20 2.17	14 1.52	7 0.76
Dictyoptera	4 8.33	9 18.75	7 14.58	11 22.91	6 12.50	7 14.58	0 0.00	0 0.00	2 4.16	2 4.16	0 0.00	0 0.00
Orthoptera	15 4.74	27 8.54	36 11.39	41 12.97	77 24.36	45 14.24	32 10.12	20 6.32	8 2.53	10 3.16	5 1.58	0 0.00
Ephemeroptera	3 6.00	13 26.00	13 26.00	9 18.00	6 12.00	3 6.00	1 2.00	2 4.00	0 0.00	0 0.00	0 0.00	0 0.00
Plecoptera	0 0.00	5 15.62	7 21.87	7 21.87	6 18.75	3 9.37	3 9.37	0 0.00	1 3.12	0 0.00	0 0.00	0 0.00
Trichoptera	2 5.26	8 21.05	9 23.68	9 23.68	5 13.15	4 10.52	1 2.63	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Isoptera	7 21.21	10 30.30	10 30.30	3 9.09	2 6.06	0 0.00	1 3.03	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Dermaptera	3 9.09	8 24.24	6 18.18	3 9.09	7 21.21	2 6.06	1 3.03	0 0.00	0 0.00	2 6.06	1 3.03	0 0.00
Odonata	0 0.00	0 0.00	0 0.00	1 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Total Insects	247 3.58	715 10.36	1228 17.81	1394 20.21	1318 19.11	650 9.42	436 6.32	313 4.53	227 3.29	187 2.71	125 1.81	55 0.79

18.00 hrs. (3.58%), 01.00 - 02.00 hrs. (4.53%), 23.00 - 24.00 hrs. (6.32%), 22.00 - 23.00 hrs. (9.42%), 18.00 - 19.00 hrs. (10.36%), 19.00 - 20.00 hrs. (17.81%), 21.00 - 22.00 hrs. (19.11%), 20.00 - 21.00 hrs. (20.21%).

During the first year the catch percentage was minimum at 04.00 - 05.00 hrs. (1.11%) and maximum at 20.00 - 21.00 hrs. (17.91%). Durning the second year the catch percentage was minimum at 04.00 - 05.00 hrs. (0.79%) and maximum at 20.00 - 21.00 hrs. (20.21%).

The data showing the percentage analysis of the catch by dividing the night into halves and quarters have been presented in Table 58 for the entire study period. The data show that the catch was maximum (46.14%) in the second quarter of the night between 20.00 - 23.00 hrs., followed by the first quarter (38.02%) between 17.00 - 20.00 hrs. and third quarter (10.62%) between 23.00 - 03.00 hrs. Average 84.30% insect catch was recorded in the first half of the night between 17.00 - 23.00 hrs.,while it was 15.36% catch in the second half of the night between 23.00 - 06.00 hrs.

Hourly analysis, however, shows some variations in insect catch percentage in different months. During the first year, maximum insect catch percentage was between 17.00 - 20.00 hrs. in December, January, February, March and September and between 20.00 - 23.00 hrs. in April, May, June, July, August, October and November.

Table 5.8 : Percentage composition of Insects collected by Light-trap in different quarters of the night in different months from November, 1979 to October, 1981.

Months	1st Quarter 17.00-20.00hrs	2nd Quarter 20.00-23.00hrs	3rd Quarter 23.00-03.00hrs	4th Quarter 03.00-06.00hrs	1st Half 17.00-23.00hrs	2nd Half 23.00-06.00hrs
Nov '79	22.34	69.41	7.97	0.26	91.75	8.24
Dec	76.08	23.91	0.00	0.00	100.00	0.00
Jan '80	89.28	10.71	0.00	0.00	100.00	0.00
Feb	60.46	37.20	0.00	2.32	97.67	2.32
Mar	51.51	41.41	4.04	3.03	92.92	7.07
Apr	16.17	60.21	18.29	5.31	76.38	23.61
May	18.09	57.05	18.25	6.59	75.15	24.84
Jun	21.56	54.42	18.99	5.01	75.99	24.00
Jul	19.42	57.51	17.51	5.55	80.38	23.06
Aug	40.58	43.17	9.49	6.73	83.76	16.23
Sep	32.77	28.26	9.18	29.77	61.04	38.95
Oct	36.59	41.80	12.12	3.47	78.40	21.59
Nov	27.22	60.74	11.17	0.28	87.96	11.46
Dec	58.33	38.88	2.77	0.00	97.22	2.77
Jan '81	34.48	44.82	6.89	0.00	79.31	6.89
Feb	55.76	42.30	1.92	0.00	98.07	1.92
Mar	45.78	42.16	10.84	1.20	87.95	12.04
Apr	23.65	50.29	20.95	8.08	73.95	29.04
May	25.67	53.60	15.31	5.40	79.27	20.72
Jun	26.66	54.44	14.02	4.86	81.11	18.88
Jul	23.74	61.75	9.71	4.79	85.49	14.50
Aug	36.68	48.97	9.83	4.50	85.65	14.34
Sep	34.57	40.07	12.86	12.47	74.65	25.34
Oct	35.04	44.17	16.82	3.94	79.22	20.77
Total Percentage	38.02	46.14	10.62	4.73	84.30	15.36

During the second year, maximum insect catch percentage was between 17.00 - 20.00 hrs. in December, February and March and between 20.00 - 23.00 hrs. in April, May, June, July, August, September, October, November and January. Minimum percentage of insects were collected between 23.00 - 03.00 hrs. in September during the first year and in December, January and February during the second year. While for the rest of the months minimum percentage was between 03.00 - 06.00 hrs. in both the years.

5.23 : POPULATION DYNAMICS:

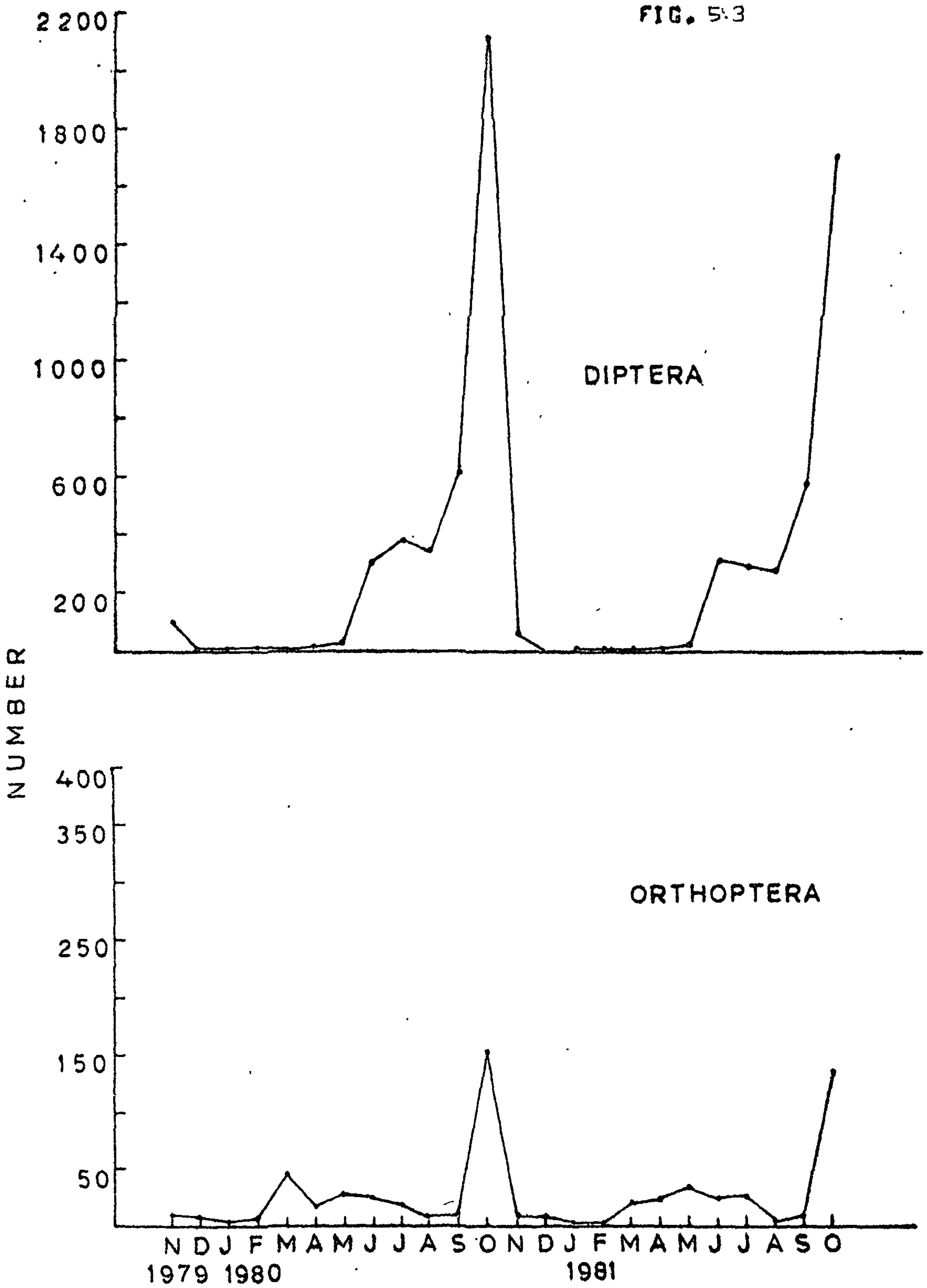
DIPTERA :

Diptera was the most dominant order in the light-trap collection in both the years, with 3874 and 3270 of numbers of individuals, respectively. During the first year the order constituted 42.05% and during the second year it was 47.43% of the total catches (Tables 5.1, 5.2). The monthly fluctuation of Diptera has been shown in the Figure 5.3.

During the first year the monthwise total collection and its percentage of the total annual Catch were as follows : November 108 (2.79%), December 2 (0.05%), January 2 (0.05%), February 8 (0.21%), March 8 (0.21%), April 19 (0.49%), May 34 (0.88%), June 312 (8.05%), July 393 (10.14%), August 346 (8.93%), September 623 (16.08%) and October 2022 (52.19%). During the second year the monthwise collection and its percentage of the total

Figure 5.3: Monthwise total collection of Diptera and Orthoptera in Light-trap from November, 1979 to October, 1981.

FIG. 5.3


2200
1800
1400
1000
600
200
DIPTERA
NUMBER
400
350
250
150
50
ORTHOPTERA
N D J F M A M J J A S O N D J F M A M J J A S O
1979 1980
1981

annual catch were as follows : November 68 (2.08%), December 1 (0.05%), January 4 (0.12%), February 10 (0.31%), March 7 (0.21%), April 12 (0.37%), May 24 (0.73%), June 323 (9.88%), July 292 (8.93%), August 280 (8.56%) and September 591 (18.07%) and October 1658 (50.70%).

The relative abundance of Diptera was minimum in December and January with 2 (0.05%) in each month and maximum in October with 2022 (52.19%) in the first year. During the second year the relative abundance was minimum in December with 1 (0.05%) and maximum in October with 1658 (50.70%). There were three peaks of catch in February 8 (0.21%), July 393 (10.14%) and October 2022 (52.19%) in the first year. During the second year the three peaks were in February 10 (0.31%), June 323 (9.88%) and October 1658 (50.70%). Thus, during both the years of investigation the relative abundance of Diptera showed similarity.

The relationship between the monthly relative abundance of Diptera and certain environmental factors is presented in Tables 4.4, 4.5 for both the years. In both the years, average minimum and maximum temperature, humidity and monthly total rainfall did not show any significant relationship with the monthly total Diptera catch at 0.01% and 0.05% levels.

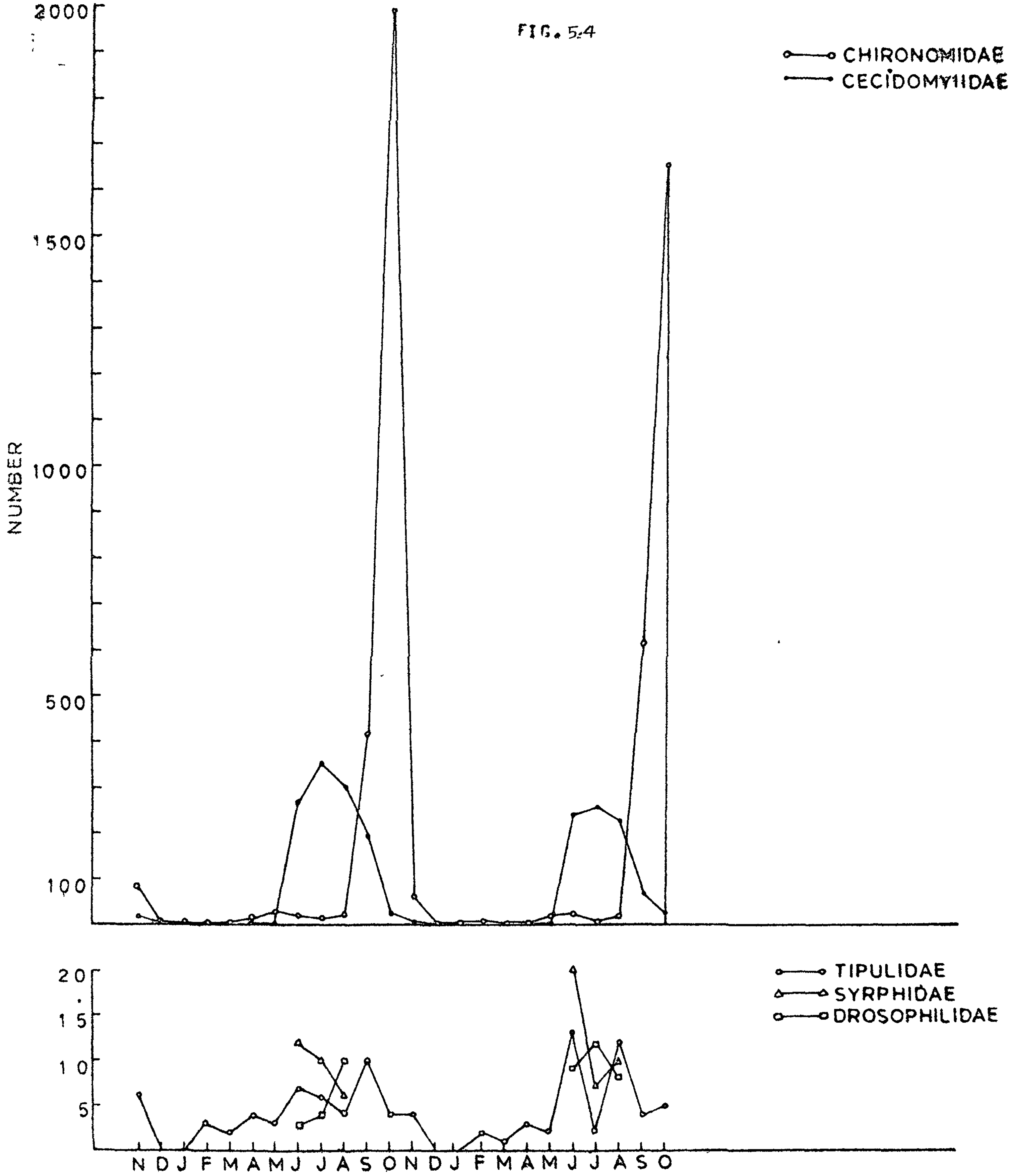
The identification of the order reveals that the collected samples comprised of five families, namely, Chironomidae, Cecidomyiidae, Tipulidae, Syrphidae and Drosophilidae. The monthwise fluctuation of different families has been shown in Figure 5.4. During the first year the numbers and percentage composition of these families were as follows : Chironomidae 2605 (67.24%), Cecidomyiidae 1175 (30.33%), Tipulidae 49 (1.26%), Syrphidae 28 (0.72%) and Drosophilidae 17 (0.43%). During the second year the numbers and percentage composition of the families were as follows : Chironomidae 2290 (70.03%), Cecidomyiidae 866 (26.48%), Tipulidae 48 (1.46%), Syrphidae 37 (1.13%) and Drosophilidae 29 (0.88%).

The relative abundance of different families of Diptera were as follows :

1. Chironomidae -- It was the most dominant family and comprised of 2605 numbers with 67.24% of the total Diptera catch of the first year and 2290 numbers with 70.03% of the total Diptera catch of the second year.

During the first year the monthly total catch and percentage to the total annual catch were as follows : November 86 (3.30%), December 2 (0.08%), January 2 (0.08%), February 5 (0.19%), March 3 (0.12%), April 12 (0.46%), May 28 (1.07%), June 19 (0.73%), July 16 (0.61%), August 22 (0.84%), September 418 (16.05%) and October 1992 (76.47%). During the second year the monthly total catch and percentage to the total annual catch were as follows : November 57 (2.49%), December 1 (0.04%), January 4(0.17%),

FIG. 5.4


CHIRONOMIDAE
CECIDOMYIIDAE
NUMBER
2000
1500
1000
500
100
TIPULIDAE
SYRPHIDAE
DROSOPHILIDAE
20
15
10
5
N D J F M A M J J A S O N D J F M A M J J A S O

February 8(0.35%), March 6 (0.26%), April 4 (0.17%), May 18 (0.79%), June 23 (1.00%), July 10 (0.44%), August 20 (0.87%), September 518 (22.62%) and October 1621 (70.79%).

The relative abundance of the Chironomidae was minimum in December and January with 2 (0.08%) in each month and maximum in October with 1992 (76.47%) in the first year. During the second year the relative abundance was minimum in December with 1 (0.04%) and maximum in October with 1621 (70.79%). There were three peaks of catch in the first year in February 5 (0.19%), May 28 (1.07%) and October 1992 (76.47%). In the second year the three peaks were in February 8 (0.35%), June 23 (1.00%) and October 1621 (70.79%).

During September and October in the entire study period most of the Chironomids were found to be with internal Nematode, latter brust out from the abdomen of the insect as soon as it falls down the water of the Light-trap.

2. Cecidomyiidae :- In the first year the family comprised of 1175 numbers with 30.33% of the total annual Diptera catch. In the second year it comprised of 866 numbers and 26.48% of the total annual Diptera catch.

During the first yearthe monthly total catch and percentage to the total annual catch of the family were as follows : November 16 (1.36%), December 0 (0.00%), January 0(0.00%), February 0 (0.00%), March 0 (0.00%), April 3 (0.26%), May 3 (0.26%), June 271 (23.06%), July

357 (30.38%), August 304 (25.87%), September 195 (16.60%). and October 26 (2.21%). During the second year the monthly total catch and its percentage to the total annual catch were as follows : November 7 (0.81%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 5 (0.58%), May 4 (0.46%), June 258 (29.79%), July 261 (30.14%), August 230 (26.56%), September 69 (7.97%) and October 69 (7.97%).

During the first year there was no catch in December, January, February and March and minimum catch was in April and May with 3 (0.26%) in each month and maximum catch was in July with 357 (30.38%). There was no catch in December, January, February and March; minimum catch was in May with 4 (0.46%) and maximum catch was in July with 261 (30.14%) in the second year. There was a single peak of catch in July 357 (30.38%) in the first year. In the second year there were two peaks of catch in April 5 (0.58%) and July 261 (30.14%).

3. Tipulidae -- In the first year the family comprised of 49 numbers and 1.26% of the total annual Diptera catch. In the second year it comprised of 48 numbers and 1.46% of the total annual Diptera catch.

During the first year monthwise total catch and its percentage to the total annual catch were as follows : November 6 (12.24%), December 0 (0.00%), January 0 (0.00%), February 3 (6.12%), March 2 (4.08%), April 4 (8.16%), May 3 (6.12%), June 7 (14.29%), July 6 (12.24%), August 4 (8.16%), September 10 (20.41%) and October 4 (8.16%). During the second year month-wise total catch and its percentage to the total annual catch were as follows : November 4 (8.33%), December 0 (0.00%), January 0 (0.00%), February 2 (4.17%), March 1 (2.08%), April 3 (6.25%), May 2 (4.17%), June 13 (27.08%), July 2 (4.17%), August 12 (25.00%), September 4 (8.33%) and October 5 (10.42%).

There was no catch in December and January, minimum catch was in March with 2 (4.08%) and maximum catch was in September with 10 (20.41%) in the first year. In the second year there was no catch in December and February, minimum catch was in March with 1 (2.08%) and maximum catch in June with 13 (27.08%). There were four low peaks of catch in the first year in February 3 (6.12%), April 4 (8.16%), June 7 (14.29%) and September 10 (20.41%). In the second year there were five low peaks of catch in February 2 (4.17%), April 3 (6.25%), June 13 (27.08%), August 12 (25.00%) and October 5 (10.42%).

4. Syrphidae -- In the first year the family comprised of 28 numbers and 0.72% of the total annual Diptera catch. In the second year it comprised of 37 numbers and 1.13% of the total annual Diptera catch.

Figure 5.5: Monthwise total collection of Coleoptera, Lepidoptera, Hemiptera and Hymenoptera in Light-trap from November, 1979 to October, 1981.

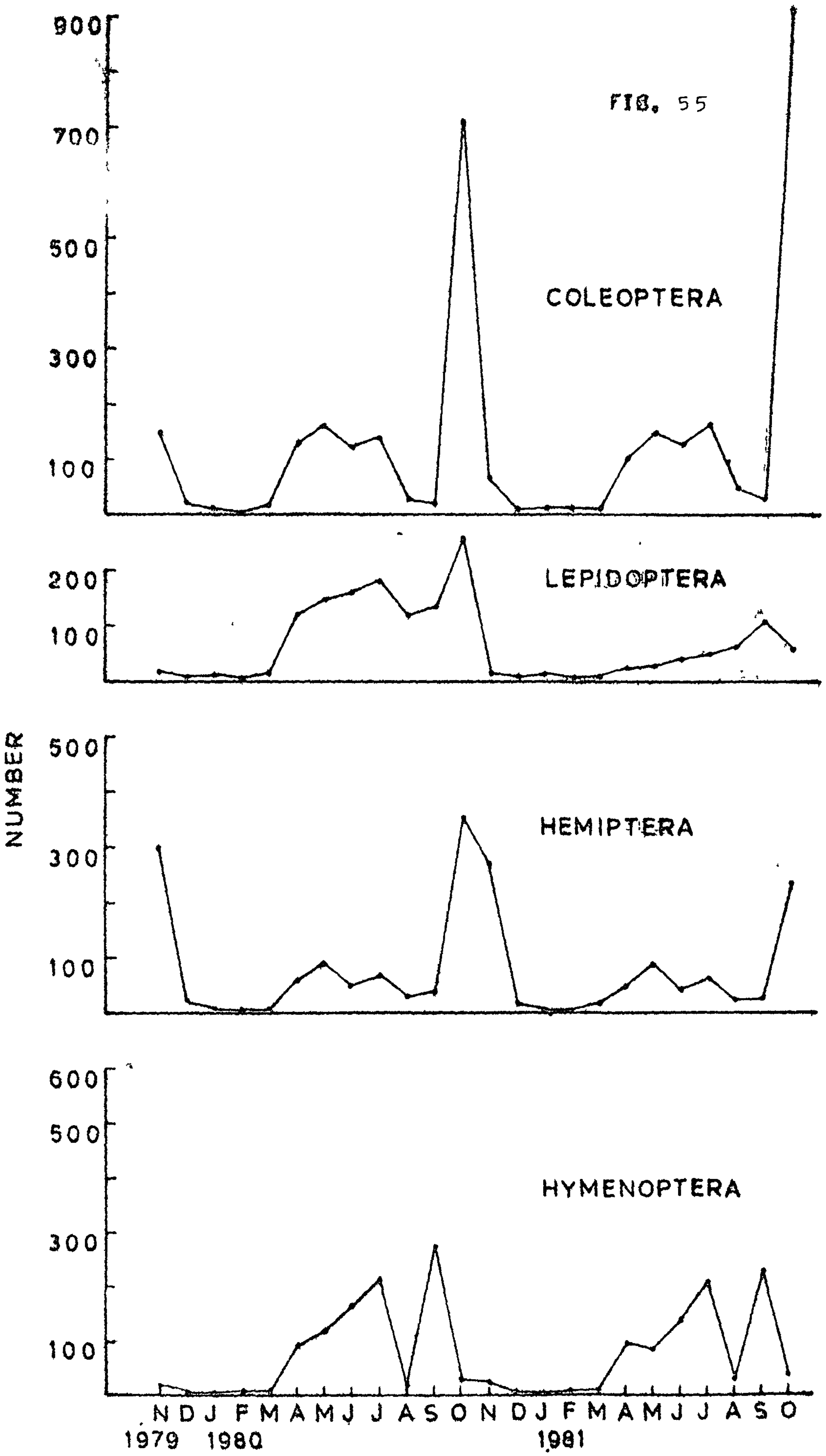


FIG. 55
COLEOPTERA
LEPIDOPTERA
HEMIPTERA
HYMENOPTERA
NUMBER
900
700
500
300
100
200
100
500
300
100
600
500
300
100
N D J F M A M J J A S O N D J F M A M J J A S O
1979 1980
1981

During the first year monthwise total catch and its percentage to the total annual catch were as follows : June 12 (42.86%), July 10 (35.71%), August 6 (21.43%) and were absent for the rest of the months. During the second year monthwise total catch and its percentage to the total annual catch were as follows : June 20 (54.05%), July 7 (18.92%), August 8 (21.62%) and were absent for the rest of the months.

5. Drosophilidae -- The family comprised of 17 numbers and 0.43% of the total annual Diptera catch during the first year. During the second year it comprised of 29 numbers and 0.88% of the total annual Diptera catch.

During the first year monthwise total catch and its percentage to the total annual catch were as follows : June 3 (17.65%), July 4 (23.53%), August 10 (58.82%) and were not found in the samples of the rest of the months. During the second year monthwise total catch and its percentage to the total annual catch were as follows : June 9 (31.03%), July 12 (41.38%), August 8 (27.59%) and were absent for the rest of the months.

LEPIDOPTERA :

During the first year the order comprised of 1190 numbers and 12.91% of the total annual insect catch. During the second year it comprised of 425 numbers and 6.16% of the total annual insect catch. (Tables 5.1, 5.2 and Figures 5.1, 5.2). Monthly fluctuation of Lepidoptera for the entire study period has been shown in Figure 5.5.

During the first year the monthwise total collection and its percentage to the total annual Lepidoptera collection were as follows : November 14 (1.18%), December 9 (0.76%), January 10 (0.84%), February 7 (0.59%), March 12 (1.01%), April 121 (10.17%), May 154 (12.94%), June 164 (13.78%), July 183 (15.38%), August 119 (10.00%), September 135 (11.34%) and October 262 (22.02%). During the second year monthwise total collection and its percentage to the total annual Lepidoptera collection were as follows : November 10 (2.35%), December 8(1.88%), January 11 (2.59%), February 7 (1.65%), March 11 (2.59%), April 27 (6.35%), May 29 (6.82%), June 39 (9.18%), July 47 (11.06%), August 65 (15.29%), September 112 (26.35%) and October 59 (13.88%).

The relative abundance of Lepidoptera was minimum in February with 7 (0.59%) and maximum in October with 262 (22.02%) during the first year. During the second year the relative abundance was minimum in February with 7 (1.65%) and maximum in September with 112 (26.35%). In the first year there were three peaks of catch in January 10 (0.84%), July 183 (15.38%) and October 262 (22.02%). There were two peaks of catch in January 11 (2.59%) and September 112 (26.35%) in the second year.

The relationship between the monthly relative abundance of Lepidoptera and certain environmental factors have been presented in Tables 5.4 and 5.5 for first and second year, respectively. During the first year average monthly minimum temperature did not show any significant relationship while average monthly maximum temperature showed significant positive relationship at 0.05% level; average monthly minimum relative humidity showed significant positive relationship at 0.05% level while average monthly maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels. During the second year average monthly minimum and maximum temperature showed significant positive relationship at 0.01% level; average monthly minimum and maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

The identificantion of the order reveals that the collected samples consist of nine families, namely, Pyralidae, Noctuidae, Geometridae, Notodontidae, Cossidae, Syntomidae, Yponomentidae, Zygaenidae and Sphingidae. The monthwise fluctuation of different families has been shown in Figure 5.6 .

During the first year the total catch of each family and their percentage to the total annual Lepidoptera catch were as follows : Pyralidae 441 (37.05%), Noctuidae 337 (28.31%), Geometridae 309 (25.96%), Notodontidae 41 (3.44%), Cossidae 29(2.43%), Syntomidae 14 (1.17%), Yponomentidae 13 (1.09%), Zygaenidae 5 (0.42%) and Sphingidae 1 (0.08%). During the second year the total catch of each family and their percentage to the total annual Lepidoptera catch were as follows : Pyralidae 157 (36.94%), Noctuidae 131 (30.82%), Geometridae 98 (23.05%), Notodontidae 18 (4.23%), Syntomidae 6 (1.41%), Cossidae 6 (1.41%), Zygaenidae 5 (1.17%) and Yponomentidae 4 (0.94%).

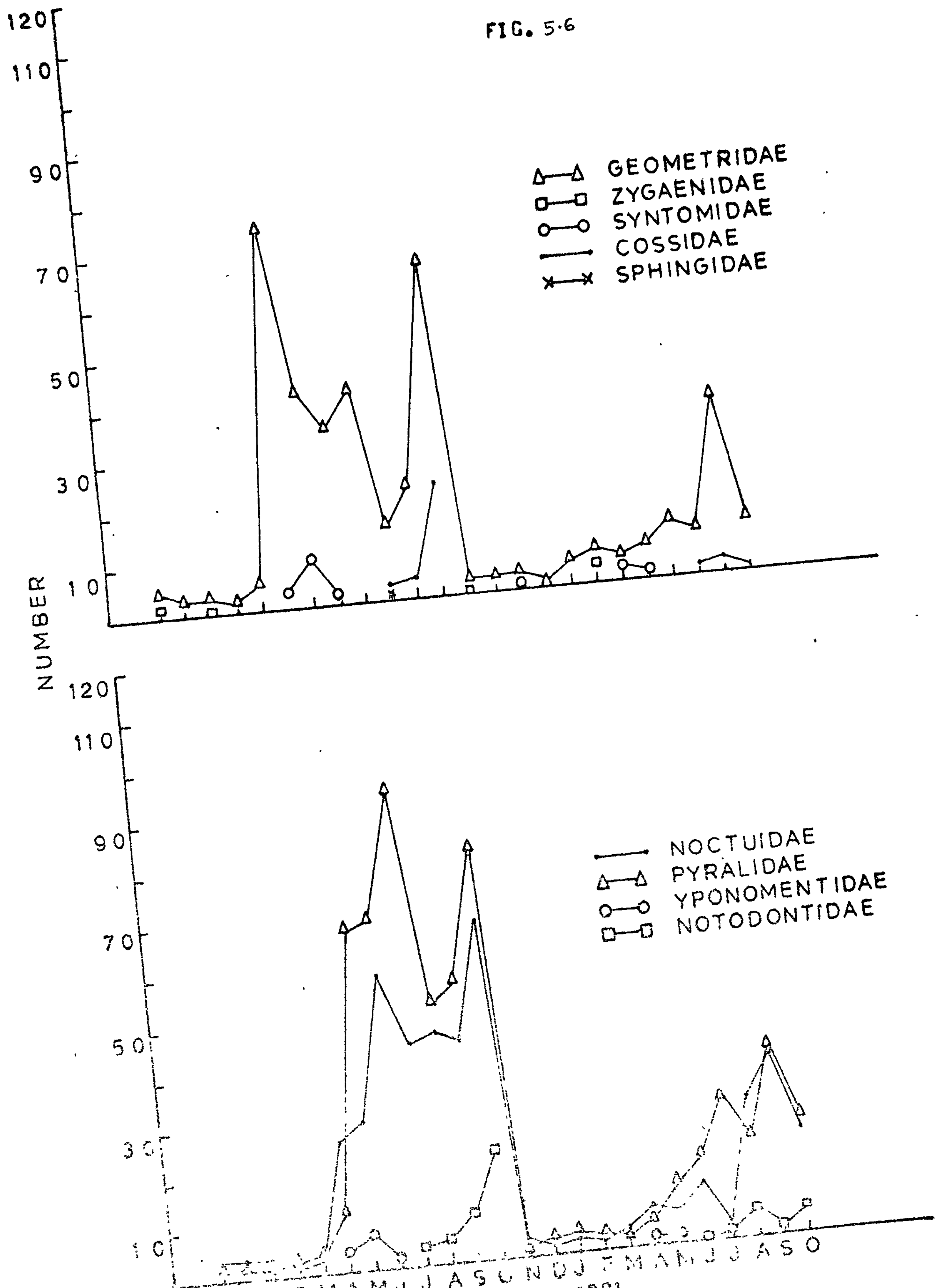
The relative abundance of different families were as follows :

1. Pyralidae -- It was the most dominant family during the entire experimental period among the Lepidoptera.

During the first year monthwise total catch and its percentage to the total annual catch were as follows : November 3 (0.68%), December 2 (0.45%), January

Figure 5.6: Monthwise total collection of Pyralidae, Noctuidae, Geometridae, Notodontidae, Cossidae, Syntomidae, Zygaenidae and Sphingidae in Light-trap from November, 1979 to October, 1981.

FIG. 5·6



120
110
90
70
50
30
10
NUMBER
GEOMETRIDAE
ZYGAENIDAE
SYNTOMIDAE
COSSIDAE
SPHINGIDAE
120
110
90
70
50
30
10
NOCTUIDAE
PYRALIDAE
YPONOMENTIDAE
NOTODONTIDAE
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1981

2 (0.45%), February 3 (0.68%), March 4 (0.91%), April 12 (2.72%), May 67 (15.19%), June 68 (15.42%), July 94 (21.32%), August 50 (11.34%), September 55 (12.47%) and October 81 (18.37%). During the second year monthwise total catch and its percentage to the total annual catch were as follows : November 2 (1.27%), December 3 (1.91%), January 4 (2.55%), February 3 (1.91%), March 3 (1.91%), April 6 (3.82%), May 12 (7.64%), June 17 (10.83%), July 29 (18.47%), August 20 (12.74%), September 38 (24.20%) and October 20 (12.74%).

The relative abundance of Pyralidae was minimum in December and January with 2(0.45%) in each month and maximum in July with 94 (21.32%) during the first year. During the second year the relative abundance was minimum in November with 2 (1.27%) and maximum in September with 38(24.20%). During the first year there were two peaks of catch in July 94 (21.32%) and October 81 (18.37%). During the second year there were three peaks of catch in January 4 (2.55%), July 29 (18.47%) and September 38 (24.20%).

2. Noctuidae -- During the first year monthwise total catch and its percentage to the total annual catch were as follows : November 4 (1.19%), December 4 (1.19%), January 4 (1.19%), February 2 (0.59%), March 3 (0.89%), April 26 (7.72%), May 30 (8.90%), June 68 (17.21%), July

44 (13.06%), August 46 (13.65%), September 44 (13.06%) and October 72 (21.36%). During the second year monthwise total catch and its percentage to the total annual catch were as follows : November 4 (3.05%), December 2 (1.53%), January 3 (2.29%), February 2 (1.53%), March 3 (2.29%), April 8 (6.11%), May 7 (5.34%), June 12 (9.16%), July 4 (3.05%), August 28 (21.37%), September 37 (28.24%) and October 21 (16.03%).

The relative abundance of Noctuidae was minimum in February with 2 (0.59%) and maximum in October with 72 (21.36%) during the first year. During the second year the relative abundance was minimum in December and February with 2 (1.53%) in each month and maximum in September with 37 (28.24%). There were three peaks of catch in June 58 (17.21%), August 46 (13.65%) and October 72 (16.03%) during the first year. During the second year there were four peaks of catch in January 3 (2.29%), April 8 (6.11%), June 12 (9.16%) and September 37 (28.24%).

3. Geometridae -- The monthwise total Geometridae catch and its percentage to the total annual catch during the first year were as follows : November 5 (1.62%), December 3 (0.97%), January 3 (0.97%), February 2 (0.65%), March 5 (1.62%), April 74 (23.95%), May 41 (13.27%), June 34 (11.00%), July 41 (13.27%), August 14 (4.53%), September 22 (7.12%)

and October 65 (21.04%). During the second year monthwise total catch and its percentage to the total annual catch were as follows : November 3 (3.06%), December 3 (3.06%), January 3 (3.06%), February 1 (1.02%), March 5 (5.10%), April 7 (7.14%), May 5 (5.10%), June 11 (11.22%), July 9 (9.18%), August 9 (9.18%), September 34 (34.69%) and October 10 (10.20%).

The relative abundance of Geometridae was minimum in February with 2 (0.65%) and maximum in April with 74 (23.95%) during the first year. During the second year the relative abundance was minimum in February with 1 (1.02%) and maximum in September with 34(34.69%). There were three peaks of catch in April 74 (23.95%), July 41 (13.27%) and October 65 (21.04%) during the first year. During the second year the three peaks of catch were in April 7 (7.14%), June 11 (11.22%) and September 34 (34.69%).

4. Notodontidae -- The monthwise total catch of Notodontidae and its percentage to the total annual catch in the first year were as follows : July 4 (9.76%), August 5 (12.20%), September 10 (24.39%) and were absent in the samples of the rest of the months. During the second year the monthwise total catch and its precentage to the total annual catch were as follows : June 1

(5.56%), July 3 (16.67%), August 6 (33.33%), September 2 (11.11%), October 6 (33.33%) and were absent in the samples for the rest of the months.

5. Cossidae -- The monthwise total catch of Cossidae and its percentage to the total annual catch in the first year were as follows : August 3 (10.34%), September 4 (13.79%), October 22 (75.86%) and were absent in the samples of the rest of the months. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : August 2 (33.33%), September 3 (50.00%), October 1 (16.67%) and were absent in the samples of the rest of the months.

6. Syntomidae -- The monthwise total catch of the family and its percentage to the total annual catch during the first year were as follows : April 3 (21.43%), May 9 (64.29%), June 2 (14.29%) and were not found in the samples of the rest of the months. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : January 1 (16.67%), May 3 (5.00%), June 2 (33.33%) and were not found in the samples of the rest of the months.

7. Yponomentidae -- The monthwise total catch of the family and its percentage to the total

annual catch were as follows : April 4 (30.77%), May 7 (53.85%), June 2 (15.38%) and were not found in the samples of the rest of the months. during the first year. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : April 2 (50.00%), May 2(50.00%) and were not found in the samples of the rest of the months.

8. Zygaenidae -- The monthwise total catch of the family and its percentage to the total annual catch during the first year were as follows : November 2 (40.00%), January 1 (20.00%), April 2 (20.00%) and were absent in the samples of the rest of the months. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 1 (20.00%), April 4 (80.00%) and were absent in the samples of the rest of the months.

9. Sphingidae -- This family was represented by a single catch in August during the first year. During the second year no Sphingidae was caught.

HYMENOPTERA :

The order comprised of 979 numbers of individuals and 10.76% of the total annual insect collection in the first year. In the second year the order comprised of 880 numbers of individuals and 12.76% of the total annual insect catch in that year. The monthly fluctuation of Hymenoptera for the entire study period has been shown in Figure 5.5.

During the first year monthwise total collection of Hymenoptera and its percentage to the total annual collection were as follows : November 23 (2.35%), December 5 (0.51%), January 6(0.61%), February 10 (1.02%), March 10 (1.02%), April 96 (9.81%), May 122 (12.46%), June 167 (17.06%), July 215 (21.96%), August 20 (2.02%), September 276 (28.19%) and October 29 (2.96%). During the second year monthwise total collection and its percentage to the total annual collection were as follows: November 27 (3.03%), December 6 (0.68%), January 5 (0.57%), February 9 (1.02%), March 11 (1.25%), April 95 (10.80%), May 84 (9.55%), June 139(15.80%), July 209 (23.75%), August 29 (3.30%), September 227 (25.80%) and October 39 (4.43%).

During the first year the relative abundance of Hymenoptera was minimum in December with 5 (0.51%) and maximum in September with 276 (28.19%). The relative abundance during the second year was minimum in January with 5 (0.57%) and maximum in September with 227 (25.80%). In the first year there were two peaks of catch in July 215 (21.96%) and September 276 (28.19%). In the second year also, the two peaks of catch were in July 209 (23.75%) and September 227 (25.80%).

The relationship of the total Hymenoptera catch and certain environmental factors have been shown in Tables 5.1 and 5.2 for the two years, respectively. During the first year the monthly average minimum and maximum temperature, monthly average minimum relative humidity showed significant positive relationship at 0.05% level; while the monthly average maximum relative humidity and the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels. During the second year the monthly average minimum and maximum temperature, the monthly average minimum and maximum relative humidity showed significant positive relationship at 0.05% level while the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

The collected Hymenoptera consist of three families, namely, Formicidae, Cynipidae and Vespidae. Monthwise fluctuation of each family for the entire study period has been shown in Figure 5.7.

Total catch of each family and its percentage to the total annual Hymenoptera catch during

Figure 5.7: Monthwise fluctuation of Cynipidae, Vespidae and Formicidae in Light-trap from November, 1979 to October, 1981.

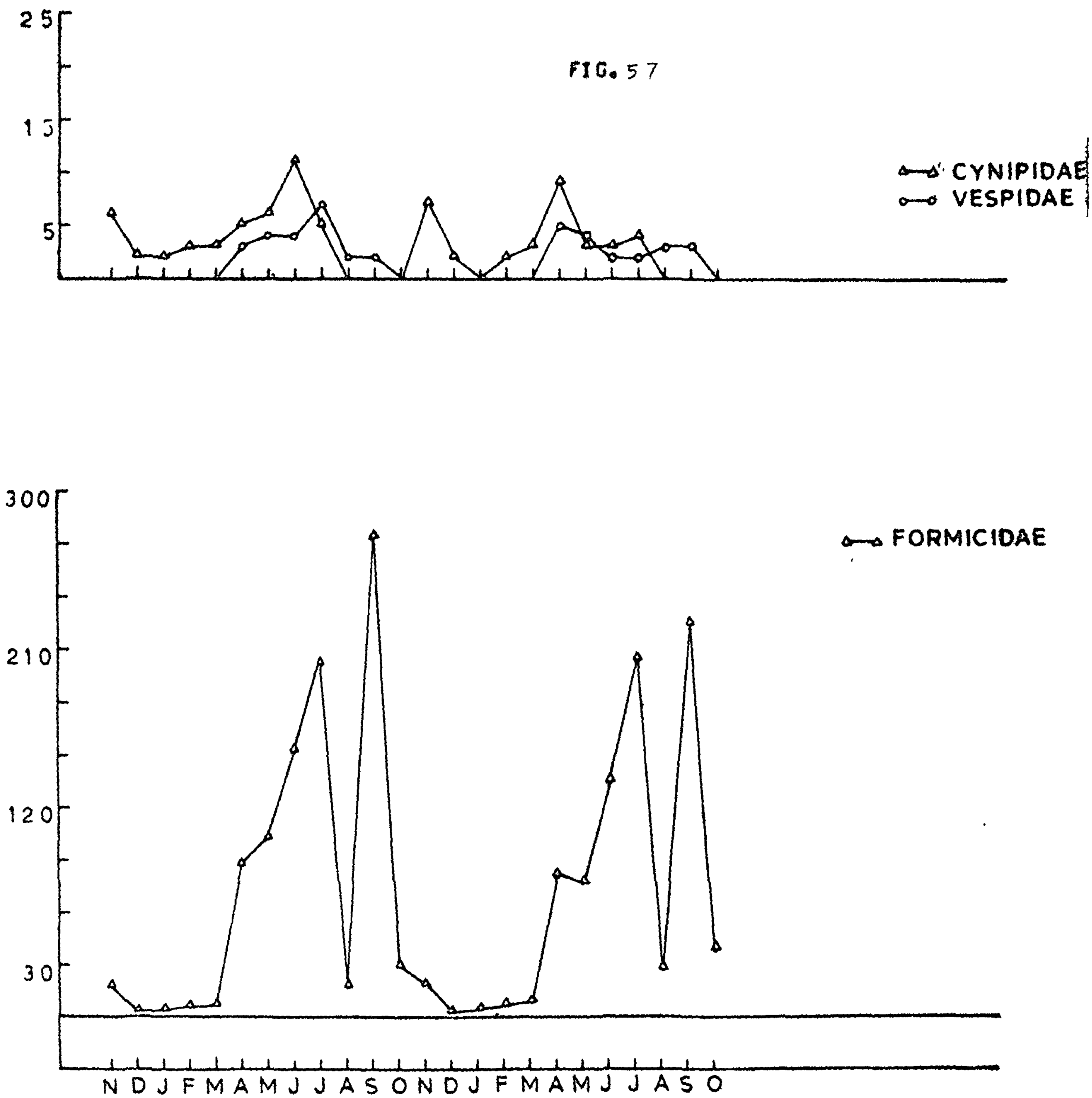


FIG. 57
25
15
5
CYNIPIDAE
VESPIDAE
300
210
120
30
FORMICIDAE
N D J F M A M J J A S O N D J F M A M J J A S O

the first year were as follows : Formicidae 914 (93.36%), Cynipidae 43 (4.39%) and Vespidae 22 (2.24%). During the second year the total catch of each family and its percentage to the total annual Hymenoptera catch were as follows : Formicidae 828 (94.09%), Cynipidae 33 (3.75%) and Vespidae 19 (2.15%).

The relative abundance of different families during the entire study period were as follows :

1. Formicidae -- This was the most dominant family during the experimental period among the Hymenoptera.

During the first year the monthwise total catch and its percentage to the total annual catch of the family were as follows : November 17 (1.86%), December 3 (0.33%), January 4 (0.44%), February 7 (0.77%), March 7 (0.77%), April 88 (9.63%), May 112 (12.25%), June 152 (16.63%), July 203 (22.21%), August 18 (1.97%), September 274 (29.98%) and October 29 (3.17%). The monthwise total catch and its percentage to the total annual catch of the family during the second year were as follows : November 20 (2.42%), December 4 (0.48%), January 5 (0.60%), February 7 (0.85%), March 8 (0.97%), April 81 (9.78%), May 77 (9.30%), June 134 (16.18%), July

203 (24.52%), August 26 (3.14%), September 224 (27.05%) and October 39 (4.71%).

The relative abundance of Formicidae was minimum in December with 3 (0.33%) and maximum in September with 274 (29.98%) during the first year. During the second year the relative abundance was minimum in December with 4 (0.48%) and maximum in September with 224 (27.05%). There were two peaks of catch in July 203 (22.21%) and September 274 (29.98%) during the first year. During the second year also, the two peaks of catch were in July 203 (24.52%) and September 224 (27.05%).

2. Cynipidae -- The monthwise total catch of Cynipidae and its percentage to the total annual catch during the first year were as follows : November 6 (13.95%), December 2 (4.65%), January 2 (4.65%), February 3 (6.98%), March 3 (6.98%), April 5 (11.63%), May 6 (13.95%), June 11 (25.58%), July 5 (11.63%), August 0 (0.00%), September 0 (0.00%) abd October 0 (0.00%). During the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 7 (21.21%), December 2 (6.06%), January 0 (0.00%), February 2 (6.06%), March 3 (9.09%), April 9 (27.27%), May 3 (9.09%), June 3 (9.09%), July 4 (12.12%), August 0 (0.00%), September 0 (0.00%) and October 0 (0.00%).

The relative abundance of Cynipidae was minimum in December and January with 2(4.65%) in each month and maximum in June with 11 (25.58%) during the first year. During the second year the relative abundance was minimum in December with 4 (0.48%) and maximum in September with 224 (27.05%). There were two peaks of catch during the first year in June 11 (25.58%) and November 6 (13.95%). During the second year the two peaks were in July 203 (24.52%) and September 224 (27.05%).

3. *Vespidae* -- The monthwise total catch of Vespidae and its percentage to the total annual catch during the first year were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 3 (13.64%), May 4 (18.18%), June 4 (18.18%), July 7 (31.82%), August 2 (9.09%), September 2 (9.09%) and October 0 (0.00%). During the second year the monthwise total catch of the family and its percentage to the total annual catch were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 5 (10.53%), May 4 (21.05%), June 2 (10.53%), July 2 (10.53%), August 3 (15.79%), September 3 (15.79%) and October 0(0.00%).

The relative abundance of Vespidae was minimum in August and September with 2 (9.09%) in each month and maximum in July with 7 (31.82%) during the first year. During the second year the relative abundance was minimum in June and July with 2 (10.53%) in each month and maximum in April 5 (26.32%). There was a single peak of catch in July 7 (31.82%) in the first year. In the second year there were two peaks of catch in April 5 (26.32%) and September 3 (15.79%).

HEMIPTERA :

Hemiptera comprised of 1028 numbers of individuals and 11.17% of the total annual insect catch of the first year and of 850 numbers of individuals and 12.76% of the total annual insect catch of the second year. The monthly fluctuation of the order in light-trap collection for the entire study period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2. and 5.5.

During the first year monthwise total collection of Hemiptera and its percentage to the total annual collection were as follows : November 302 (29.38%), December 15 (1.46%), January 5 (0.49%), February 5 (0.49%), March 6 (0.58%), April 63 (6.03%), May 92 (8.95%), June 51 (4.96%), July 68 (6.61%), August 27 (2.63%), September 40 (3.89%) and October 355 (34.53%). During the second year monthwise total collection and its percentage to the total annual collection were as follows : November 272 (32.00%), December 14 (1.65%), January 4 (0.47%), February 6 (0.71%), March 19 (2.24%), April 50 (5.88%), May 90 (10.59%), June 44 (5.18%), July 64 (7.53%), August 24 (2.82%), September 26 (3.06%) and October 237 (27.88%).

The relative abundance of Hemiptera was minimum in January and February with 5 (0.49%) in each month and Maximum in October with 355 (34.53%) during the first year. During the second year the relative abundance was minimum in January with 4 (0.47%) and maximum in November with 272 (32.00%). There were three peaks of catch in May 92 (8.95%), July 68 (6.61%) and October 355 (34.53%) during the first year. During the second year the three peaks of catch were in November 272 (32.00%), May 90(10.59%) and July 64 (7.53%).

The relationship of the monthly total Hemiptera catch and certain environmental factors have been shown in Tables 4.4 and 4.5 for the two years. During thec first year the monthly average minimum and maximum temperature, minimum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels while the monthly average maximum relative humidity showed significant positive relationship at 0.05% level. During the second year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

The collected samples of Hemiptera consist of five families, namely, Jassidae, Coreidae, Lygaeidae, Miridae and Pentatomidae. The monthwise catch fluctuation of each family for the entire experimental period has been shown in Figure 5.8.

Total catch of each family and its percentage to the total annaul Hemiptera catch during the first year were as follows : Jassidae 911 (88.61%), Coreidae 48 (4.66%), Lygaeidae 37 (3.59%), Miridae 29 (2.82%), and Pentatomidae 3 (0.29%). During the second year the total catch of each family and its percentage to the total annual Hemiptera catch were as follows :Jassidae 769 (90.47%), Coreidae 42 (4.94%), Lygaeidae 26 (3.05%), Miridae 11 (1.29%) and Pentatomidae 2 (0.23%).

1. Jassidae -- This family dominated the total Hemiptera collection during the entire experimental period.

During the first year monthwise total catch of the family and its percentage to the total

Figure 5.8 : Monthwise total collection of Miridae, Pentatomidae, Jassidae, Coreidae and Lygaeidae in Light-trap from November, 1979 to October, 1981.

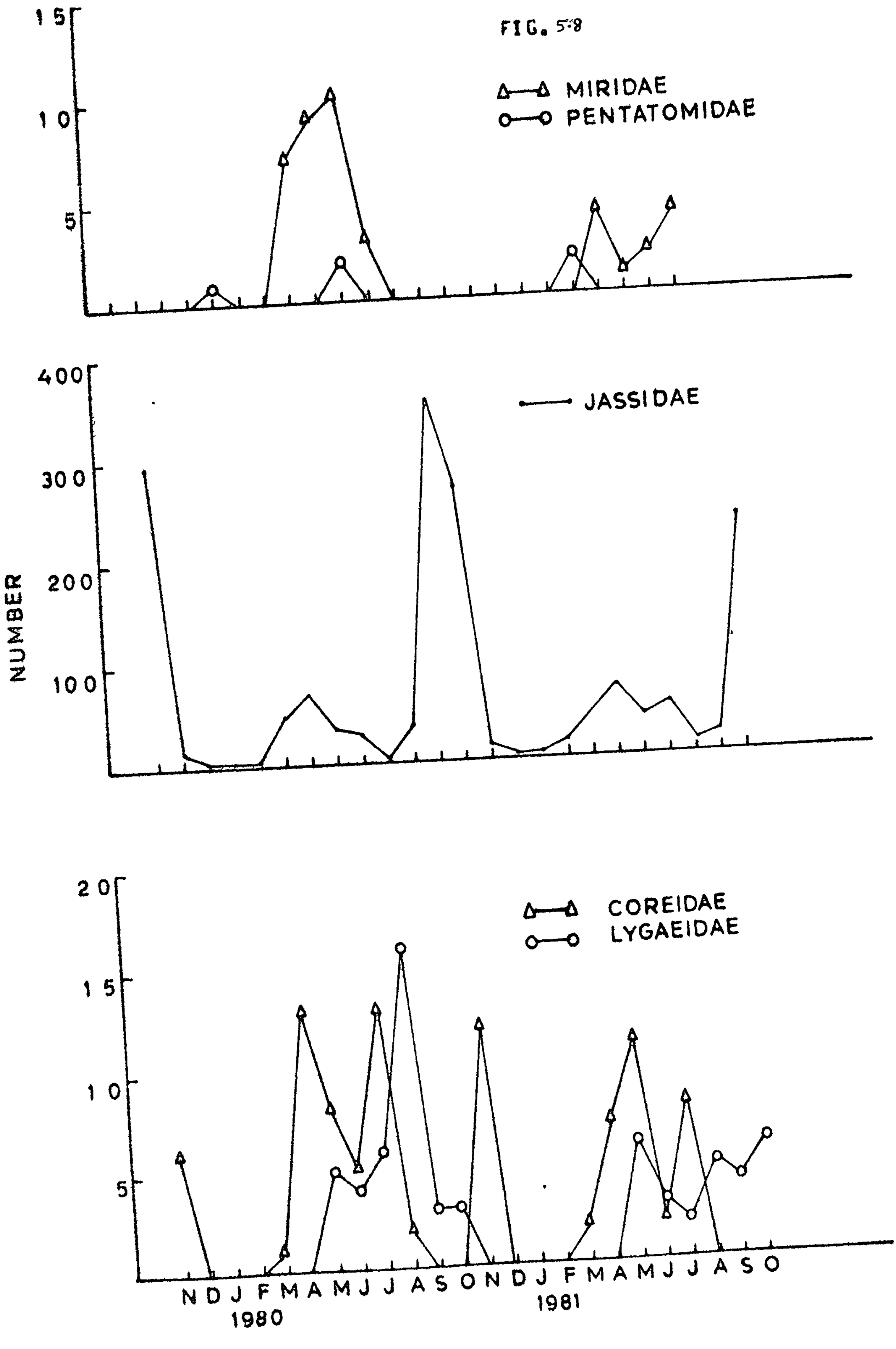


FIG. 5·8
MIRIDAE
PENTATOMIDAE
JASSIDAE
COREIDAE
LYGAEIDAE
NUMBER
15
10
5
400
300
200
100
20
15
10
5
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1981

annual catch were as follows : November 296 32.49%), December 14 (1.54%), January 6 (0.66%), February 4 (0.44%), March 5 (0.55%), April 49 (5.38%), May 72 (7.90%), June 33 (3.62%), July 39 (4.28%), August 4 (0.44%), September 37(4.06%) and October 352 (38.64%). During the second year monthwise total catch and its percentage to the total annual Jassidae catch were as follows : November 260 (33.81%), December 14 (1.82%), January 4 (0.52%), February 6 (0.78%), March 17 (2.21%), April 43 (5.59%), May 69 (8.97%), June 38 (4.94%), July 52 (6.76%), August 13 (1.69%), September 22 (2.86%) and October 231 (30.04%).

The relative abundance of Jassidae was minimum in February and August with 4 (0.44%) in each month and maximum in October with 352 (38.64%) during the first year. During the second year the relative abundance was minimum in January with 4 (0.52%) and maximum in November with 260 (33.81%). There were three peaks of catch in May 72 (7.90%), July 39 (4.28%) and October 352 (38.64%) during the first year. During the second year the three peaks of catch were also in May 69 (8.97%), July 52(6.76%) and November 260 (33.81%).

2. Coreidae -- The monthwise total catch and its percentage to the total annual catch of the

family during the first year were as follows : November 6 (12.50%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 1 (2.08%), April 13 (27.08%), May 8 (16.67%), June 5 (10.42%), July 13 (27.08%), August 2 (4.17%), September 0 (0.00%) and October 0 (0.00%). During the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 12 (28.57%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 2 (4.76%), April 7 (16.67%), May 11 (26.19%), June 2 (4.76%), July 8 (19.05%), August 0 (0.00%), September 0 (0.00%) and October 0 (0.00%).

The relative abundance of Coreidae was minimum in March with 1 (2.08%) and maximum in April and July with 13 (27.08%) in each month during the first year. During the second year the relative abundance was minimum in March with 2 (4.76%) and maximum in November with 12 (28.57%). There were three peaks of catch in November 6 (12.50%), April 13 (27.08%) and July 13 (27.08%) during the first year. During the second year the three peaks were in May 11 (26.19%), July 8 (19.05%) and November 12 (28.57%).

3. Lygaeidae -- The monthwise total catch and its percentage to the total annual catch of this

family during the first year were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 0 (0.00%), May 5 (13.51%), June 4 (10.81%), July 6 (16.22%), August 16 (43.24%), September 3 (8.11%) and October 3 (8.11%). During the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 0 (0.00%), May 6 (23.08%), June 3 (11.54%), July 2 (7.69%), August 5 (19.23%), September 4 (15.38%) and October 6 (23.08%).

The relative abundance of Lygaeidae was minimum in July with 2 (7.69%) and maximum in May amd October with 6 (23.08%) in each month during the first year. During the second year the relative abundance was minimum in July with 2 (7.69%) and maximum catch was in May and October with 6 (23.08%) in each month. There were two peaks of catch in May 5 (13.51%) and August 16 (43.24%) during the first year. During the second year there were three peaks of catch in May 6 (23.08%), August 5 (19.23%) and October 6 (23.08%).

4. Miridae --The monthwise total catch and its percentage to the total annual catch of the

family during the first year were as follows : May 7 (24.14%), June 9 (31.03%), July 10 (34.48%), August 3 (10.34%) and were not found in the samples of the rest of the months. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : May 4 (36.36%), June 1 (9.09%), July 2 (18.18%) and August 4 (36.36%) and were not found in the samples of the rest of the months.

5. Pentatomidae -- During the first year the monthwise total catch and its percentage to the total annual catch were as follows : February 1(33.33%), August 2 (66.67%) and were not found in the samples of the rest of the months. During the second year the family was represented by a single catch in August and were absent in the rest of the months.

COLEOPTERA :

This order comprised of 1537 numbers of individuals and 16.68% of the total annual insect collection in the first year and 919 numbers of individuals and 13.33% of the total annual insect collection in the second year. The monthly fluctuation of Coleoptera for the entire study period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.5.

During the first year the monthwise total collection of Coleoptera and its percentage to the the total annual collection of the order were as follows : November 161 (10.47%), December 20 (1.30%), January 10 (0.65%), February 3 (0.20%), March 19 (1.24%), April 130 (8.46%), May 162 (10.54%), June 121 (7.87%), July 142 (9.24%), August 30 (1.95%), September 20 (1.30%) and October 719 (46.78%). During the second year month-wise total collection and its percentage to the total annual collection were as follows : November 65(7.07%), December 2 (0.22%), January 9 (0.98%), February 8 (0.87%), March 10 (1.09%), April 108 (11.75%), May 150 (16.32%), June 129 (14.04%), July 164 (17.85%), August 48 (5.22%), September 26 (2.83%) and October 200 (21.76%).

The relative abundance of Coleootera was minimum in February with 3 (0.20%) and maximum in October with 719 (46.78%) during the first year. During the second year the relative abundance was minimum in December with 2 (0.22%) and maximum in October with 200 (21.76%). There were three peaks of catch in May 162 (10.54%), July 142 (9.24%) and October 719 (46.78%) in the first year. In the second year there were five peaks of catch in January 9 (0.98%), March 10 (1.09%), May 150 (16.32%), July 164 (17.85%) and October 200 (21.76%).

The relationship of the monthly total Coleoptera collection and certain environmental factors have been shown in Tables 3.1 amd 3.2 for the entire experimental period. During the first year monthly average minimum and maximum temperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant positive relationship at 0.01% and 0.05% levels. During the second year the monthly average minimum temperature and maximum relative humidity showed significant positive relationship at 0.05% level but maximum temperature, minimum relative humidity and monthly total rainfall did not show any significant positive relationship at 0.01% and 0.05% levels.

The Coleoptera collected in the light-trap comprised of twelve families, namely, Nitidulidae, Curculionidae, Chrysomellidae, Elateridae, Byrrhidae, Carabidae, Coccinellidae, Gerridae, Cerambicidae, Lymaxylidae, Tenebrionidae and Staphylinidae. The monthwise catch fluctuation of different families for the entire experimental period have been presented in Figures 4.9 and 4.10.

Total catch of each of the family and its percentage to the total annual Coleoptera catch during the first year were as follows : Nitidulidae 508 (33.05%), Curculionidae 363 (26.61%), Chrysomellidae 286 (18.60%), Elateridae

Figure 5.9 : Monthwise total collection of Nitidulidae, Carabidae, Gerridae, Curculionidae and Chrysomelidae in Light-trap from November, 1979 to October, 1981.

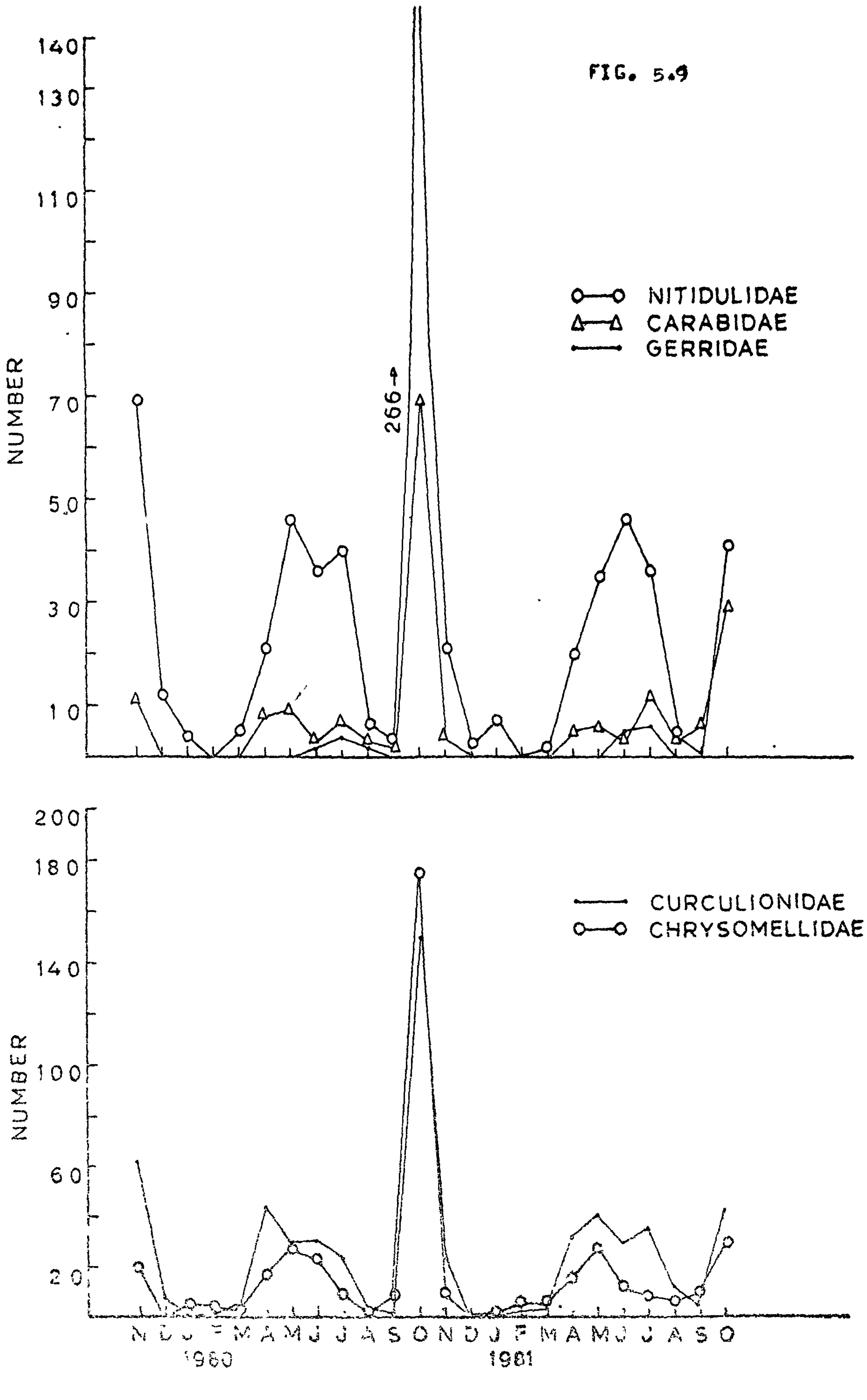
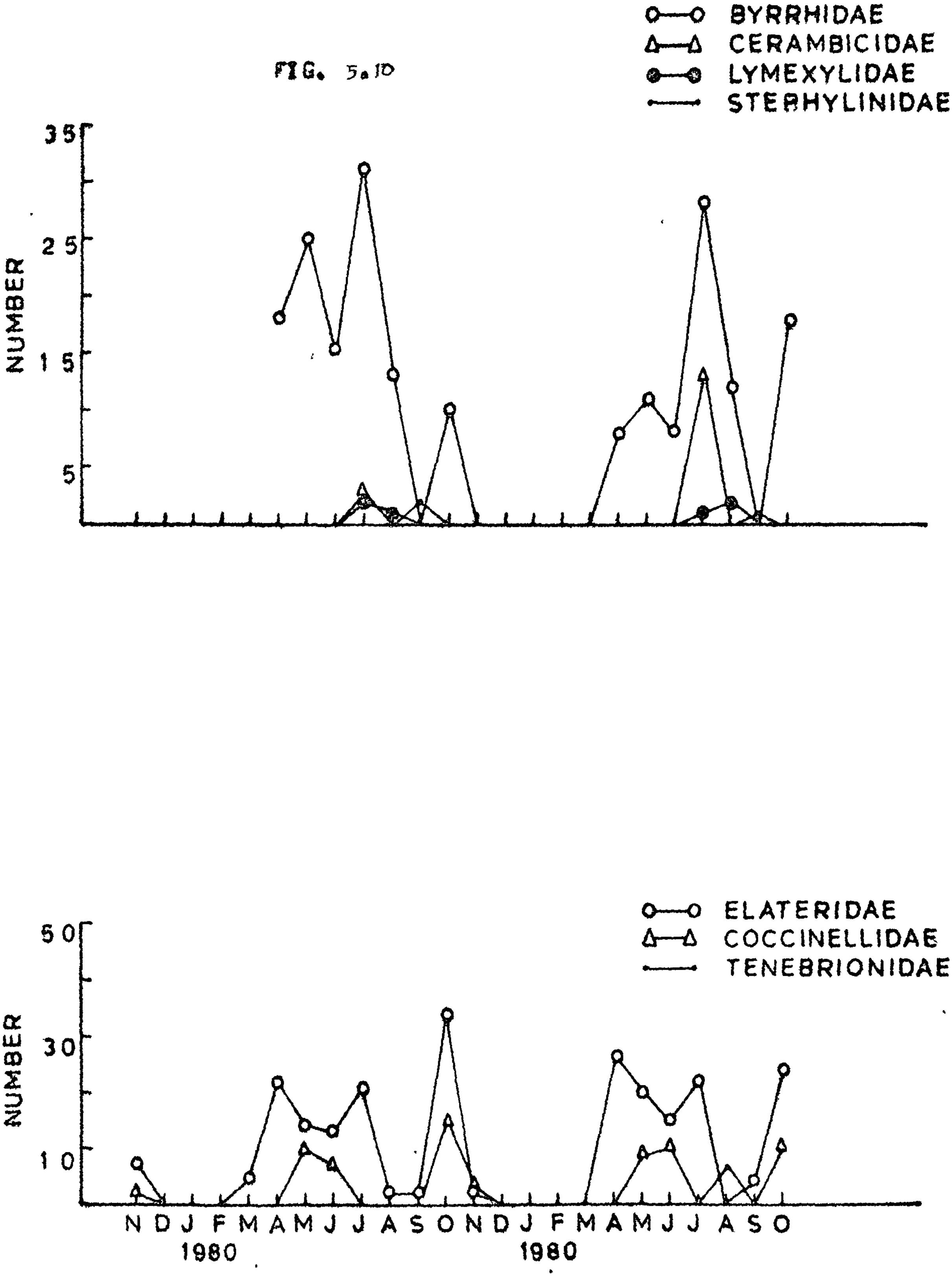


FIG. 5.9
NITIDULIDAE
CARABIDAE
GERRIDAE
266
NUMBER
CURCULIONIDAE
CHRYSOMELLIDAE
NUMBER
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1981

Figure 5.10 : Monthwise total collection of Byrrhidae, Cerambicidae, Lymaxylidae, Stephylinidae, Elateridae, Coccinellidae and Tenebrionidae in Light-trap from November, 1979 to October, 1981.

FIG. 5.10


BYRRHIDAE
CERAMBICIDAE
LYMEXYLIDAE
STERHYLINIDAE
NUMBER
35
25
15
5
ELATERIDAE
COCCINELLIDAE
TENEBRIONIDAE
NUMBER
50
30
10
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1980

118 (7.67%), Byrrhidae 111 (7.22%), Carabidae 101 (6.57%), Coccinellidae 34 (2.21%), Gerridae 8 (0.52%), Cerambicidae 3 (0.19%), Lymexylidae 3 (0.19%) and Staphylinidae 2 (0.13%). During the second year total catch of each family and its percentage to the total annual catch were as follows : Nitidulidae 219 (23.83%), Curculionidae 363 (26.61%), Chrysomellidae 135 (14.68%), Elateridae 114 (12.40%), Byrrhidae 85 (9.24%), Carabidae 69 (7.50%), Coccinellidae 32 (3.48%), Gerridae 11 (1.19%), Cerambicidae 13 (1.41%), Lymexylidae 3 (0.32%) and Staphylinidae 1 (0.10%).

1. Nitidulidae -- During the first year monthwise total catch and its percentage to the total annual catch were as follows : November 69 (13.58%), December 12 (2.36%), January 4 (0.79%), February 0 (0.00%), March 5 (0.98%), April 21 (4.30%), May 46 (9.06%), June 36 (7.09%), July 40 (7.97%), August 6 (1.18%), September 3 (0.59%) and October 266 (52.36%). During the second year monthwise total catch and its percentage to the total annual catch were as follows : November 21 (9.59%), December 2 (0.91%), January 7 (3.20%), February 0 (0.00%), March 2 (0.91%), April 20 (9.13%), May 35 (15.98%), June 46 (21.00%), July 36 (16.44%), August 4 (1.83%), September 0 (0.00%) and October 46 (21.00%).

The relative abundance of Nitidulidae was minimum in September with 3 (0.59%) and maximum in October with 266 (52.36%) during the first year. During the second year the relative abundance was minimum in December with 2 (0.91%) and maximum in June and October with 46 (21.00%) in each month. There were three peaks of catch in May 46 (9.06%), July 40 (7.87%) and October 266 (52.36%) during the first year. During the second year the three peaks were in January 7 (3.20%), June 46 (21.00%) and October 46 (21.00%).

2. Curculionidae -- The monthwise total catch and its percentage to the total annual catch of Curculionidae in the first year were as follows : November 63 (17.36%), December 8 (2.20%), January 0 (0.00%), February 1 (0.28%), March 6 (1.65%), April 44 (12.12%), May 30 (8.26%), June 31 (8.54%), July 24 (6.61%), August 4 (1.10%), September 2 (0.55%) and October 150 (41.32%). In the second year monthwise total catch and its percentage to the total annual catch were as follows : November 24 (10.43%), December 0 (0.00%), January 0 (0.00%), February 2 (0.87%), March 3 (1.30%), April 32 (13.91%), May 41 (17.83%), June 30 (13.04%), July 37 (16.09%), August 13 (5.60%), September 5 (2.17%) and October 43 (18.70%).

The relative abundance of Curculionidae was minimum in February with (0.28%) and maximum in October with 150 (41.32%) during the first year. During the second year the relative abundance was minimum in February with 2 (0.87%) and maximum in October with 43 (18.70%). There were three peaks of catch in April 44 (12.12%), June 31 (8.54%) and October 150 (41.32%) during the first year. During the second year the three peaks were in May 41 (17.83%), July 37 (16.09%) and October 43 (18.70%).

3. Chrysomellidae -- In the first year the monthwise total catch and its percentage to the total annual catch of Chrysomellidae were as follows: November 20 (6.99%), December 0 (0.00%), January 6 (2.10%), February 2 (8.70%), March 3 (1.05%), April 17 (5.94%), May 28 (9.79%), June 14 (4.90%), July 10 (3.50%), August 2 (0.70%), September 9 (3.15%) and October 175 (61.19%). In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 10 (7.41%), December 2 (1.48%), January 2 (1.48%), February 6 (4.44%), March 5 (3.70%), April 16 (11.85%), May 28 (20.74%), June 12 (8.89%), July 9 (6.67%), August 7 (5.19%), September 10 (7.41%) and October 30 (22.22%).

The relative abundance of this family was minimum in February and August with 2 (0.70%) in each month and maximum in October with 175 (61.19%) during the first year. During the second year the relative abundance was minimum in January with 2 (1.48%) and maximum in October with 30 (22.22%). There were three peaks of catch in January 6 (2.10%), May 28 (9.79%) and October 175 (61.19%) in the first year. In the second year the three peaks were in February 6 (4.44%), May 28 (29.74%) and October 30 (22.22%).

4. Elateridae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 7 (5.83%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 5 (4.23%), April 22 (18.64%), May 14 (11.86%), June 13 (11.02%), July 21 (17.80%), August 0 (0.00%), September 2 (1.69%) and October 34 (28.81%). In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 2 (1.75%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 0 (0.00%), May 27 (23.68%), June 15 (13.16%), July 22 (19.30%), August 0 (0.00%), September 4 (3.51%) and October 24 (21.05%).

The relative abundance of this family was minimum in September 2 (1.69%) and maximum in October 34 (20.81%) during the first year. During the second year the relative abundance was minimum in November 2 (1.75%) and maximum in April 27 (23.68%). There were three peaks of catch in April 22 (18.64%), July 21 (17.80%) and October 34 (28.81%) in the first year. In the second year also the three peaks were in April 27 (23.68%), July 22 (19.30%) and October 24 (21.05%).

5. Byrrhidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 18 (16.22%), May 25 (22.52%), June 15 (13.51%), July 31 (27.93%), August 12 (10.81%), September 0 (0.00%) and October 10 (9.01%). In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 8 (9.41%), May 11 (12.94%), June 8 (9.41%), July 28 (32.94%), August 12 (14.12%), September 0 (0.00%) and October 18 (21.18%).

During the first year minimum catch was in October 10 (9.01%) and maximum catch was in July 31 (27.93%). During the second year minimum catch was in April 8 (9.41%) and maximum catch was in July 28 (32.94%). There were three peaks of catch in May 25

(22.52%), July 31 (27.93%) and October 10 (9.01%) during the first year. During the second year the three peaks were also in May 11 (12.94%), July 28 (32.94%) and October 18 (21.18%).

6. Carabidae -- The monthwise total collection and its percentage to the total annual collection of the family in the first year were as follows : April 8 (7.92%), May 9 (8.91%), June 3 (2.97%), July 7 (6.93%), August 3 (2.97%), September 2 (1.98%), October 69 (68.32%) and were absent in the rest of the months. In the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 5 (7.25%), April 5 (7.25%), May 6 (8.70%), June 3 (4.35%), July 13 (18.84%), August 3 (4.35%), September 6 (8.70%), October 29 (42.03%) and were absent in the rest of the months.

During the first year minimum catch was in September 2 (1.98%) and maximum catch was in October 69 (68.32%) and there were three peaks of catch in May 9 (8.91%), July 7 (6.93%) and October 69 (68.32%). During the second year minimum catch was in June 3 (4.35%) and maximum catch was in October 29 (42.03%) and the three peaks of catch were in May 6 (8.70%), July 12 (18.84%) and October 29(42.03%).

7. Coccinellidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 2 (5.88%), May 10 (29.41%), June 7(20.59%), October 15 (44.12%) and were not found in the samples of the rest of the months. In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 3 (9.38%), May 9 (28.13%), June 10 (31.25%), October 10(31.25%) and were absent for the rest of the months.

8. Gerridae -- During the first year the family was caught in June 2 (25.00%), July 4 (50.00%), August 2 (25.00%) and were absent for the rest of the months. During the second year it was caught in June 5 (45.45%), July 6 (54.55%) and were absent for the rest of the months.

9. Cerambicidae -- During the first year this family was represented only in July 3 (100.00%) and were absent for the rest of the months. During the second year also this family was represented only in July 13 (100.00%) and were absent for the rest of the months.

10. Lymaxylidae -- During the first year this family was caught in July 2 (66.67%), August 1 (33.33%) and were absent for the rest of the months.

During the second year it was caught in July 1 (33.33%), August 2 (66.67%) and were absent for the rest of the months.

11. Stephylinidae -- During the first year this family was caught only in September 2 (100.00%) and during the second year also it was caught in September 1 (100.00%) and were absent for the rest of the months of the experiment.

12. Tenebrionidae -- No Tenebrionidae was caught during the first year. During the second year it was caught only in August 7 (100.00%).

DICTYOPTERA :

This order comprised of 65 numbers of individuals and 0.70% of the total annual insect catch of the first year and of 48 numbers of individuals and 0.70% of the total annual insect catch of the second year. The monthly fluctuation of Dictyootera for the entire study period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.11.

The monthwise total collection of the order and its percentage to the total annual collection in the first year were as follows :
November 1 (1.54%), December 0 (0.00%), January 0

(0.00%), February 0 (0.00%), March 0 (0.00%), April 16 (24.62%), May 25 (38.46%), June 5 (7.69%), July 3 (4.62%), August 5 (7.69%), September 7 (10.77%) and October 3 (4.62%). In the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 2(4.17%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 4 (8.33%), April 5 (10.42%), May 8 (16.67%), June 6 (12.50%), July 5 (10.42%), August 6 (12.50%), September 7 (14.58%) and October 5 (10.42%).

The relative abundance of the order was minimum in November with 1 (1.54%) and maximum in May with 25 (38.46%) during the first year. During the second year the relative abundance was minimum in November with 2 (4.17%) and maximum in May with 8 (16.67%). There were two peaks of catch during the first year in May 25 (38.46%) and September 7 (10.77%). During the second year also the two peaks were in May 8 (16.67%) and September 7 (14.58%).

The relationship of the monthly total Dictyoptera collection and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire experimental period. During the first year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant positive relationship at

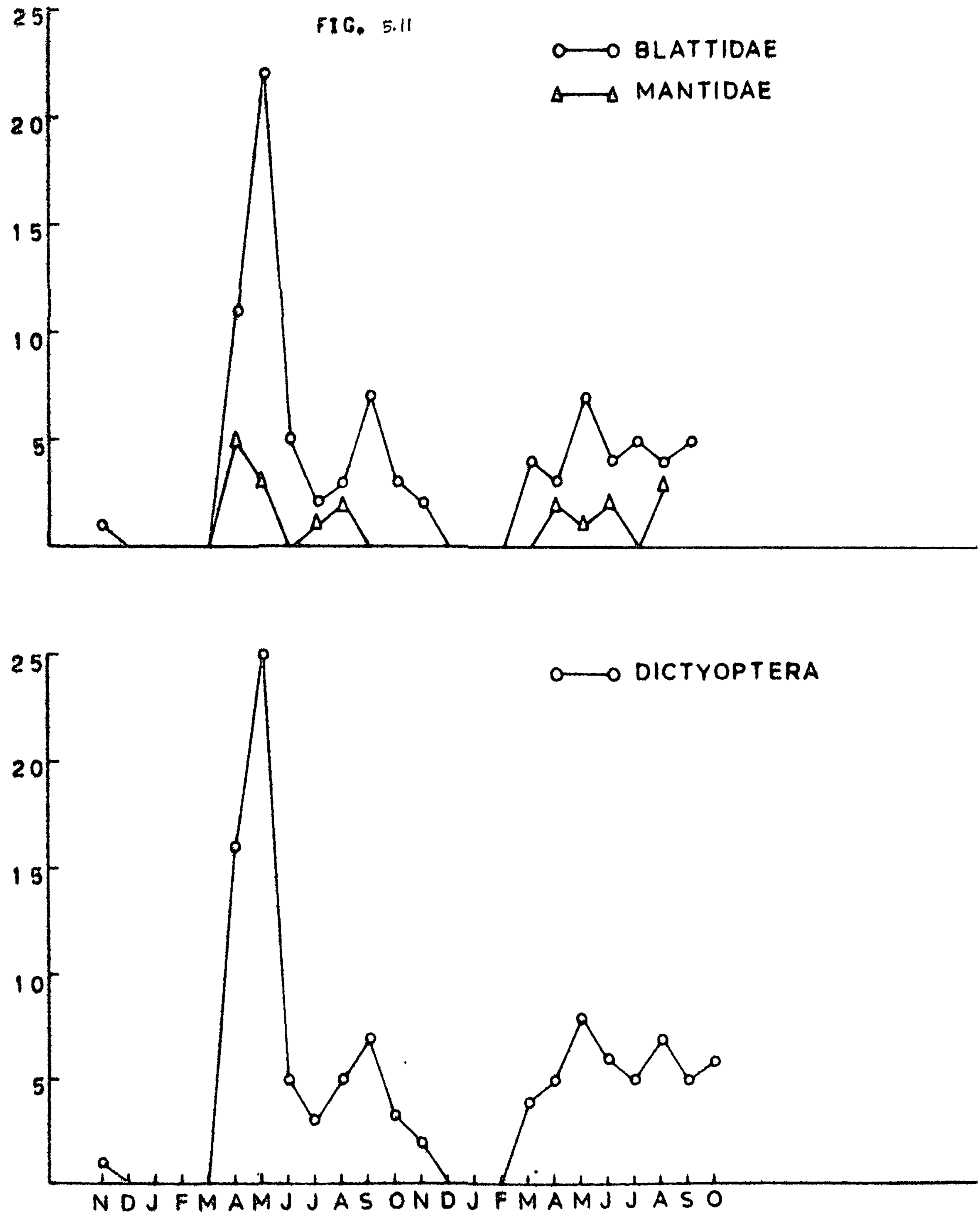
0.01% and 0.05% levels. During the second year the monthly average minimum and maximum temperature, minimum and maximum relative humidity showed significant positive relationship at 0.01% level only while monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

The Dictyoptera collected in the light-trap comprised of two families, namely, Blatidae and Mantidae during the entire experimental period. The monthwise catch fluctuation of the two families has been shown in Figure 9. During the first year total catch of each family and its percentage to the total annual Dictyoptera catch were as follows : Blatidae 55 (64.61%), Mantidae 10 (15.38%) and during the second year it were as follows : Blatidae 40 (83.33%) and Mantidae 8 (16.66%).

1. Blatidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 1 (1.82%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 11 (20.00%), May 22 (40.00%), June 5 (9.09%), July 2 (3.34%), August 4 (7.27%), September 7 (12.73%) and October 3 (5.45%). In the second year the monthwise total catch and its percentage to

Figure 5.11 : Monthwise total collection of Dictyoptera and its families Blattidae and Mantidae in Light-trap from November, 1979 to October, 1981.

FIG. 5.11



BLATTIDAE
MANTIDAE
DICTYOPTERA
25
20
15
10
5
N D J F M A M J J A S O N D J F M A M J J A S O

the total annual catch were as follows : November 2 (5.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 4 (10.00%), April 3 (7.50%), May 7 (17.50%), June 4 (10.00%), July 5(12.50%), August 4 (10.00%), September 5 (12.50%) and October 6 (15.00%).

The relative abundance of the family was minimum in November 1 (1.82%) and maximum in May 22 (40.00%) and there were two peaks of catch in May 22 (40.00%) and September 7 (12.73%) during the first year. During the second year the relative abundance was minimum in November 2 (5.00%) and maximum in May 7 (17.50%) and there were four peaks of catch in March 4 (10.00%), May 7 (17.50%), July 5 (12.50%) and October 6 (15.00%).

2. Mantidae -- The monthwise total catch and its percentage to the total annual catch of the family during the first year were as follows : April 5(50.00%), May 3 (30.00%), July 1 (10.00%), August 1 (10.00%) and were absent for the rest of the months. During the second year the monthwise total catch and its percentage to the total annual catch were as follows : April 2 (25.00%), May 1 (12.50%), June 2 (25.00%), August 3 (37.50%) and were absent for the rest of the months.

The relative abundance of Mantidae was minimum in July and August with 1 (10.00%) and maximum in April with 5 (50.00%) during the first year. During the second year the minimum catch was in May with 1 (12.50%) and maximum in August with 3 (37.50%).

ORTHOPTERA :

Orthoptera comprised of 345 numbers of individuals and 3.74% of the total annual insect collection of the first year and of 316 numbers of individuals and 4.58% of the total annual insect collection of the second year. The monthly fluctuation of Orthoptera for the entire study period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.3.

The monthwise total collection of the order and its percentage to the total annual collection in the first year were as follows : November 11 (3.19%), December 8 (2.32%), January 3 (0.87%), February 7 (2.03%), March 47 (13.62%), April 17 (4.93%), May 27 (7.83%), June 26 (7.54%), July 23 (6.67%), August 10 (2.90%), September 12 (3.48%) and October 154 (44.64%). In the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 8 (2.53%), December 9 (2.85%), January 5 (1.58%), February 6 (1.90%), March 21 (6.65%), April 24 (7.59%), May 34 (10.76%), June 26 (8.23%), July 27 (8.54%), August 7 (2.22%), September 10 (3.16%) and October 139 (43.99%).

The relative abundance of Orthoptera during the first year was minimum in January 3 (0.87%) and maximum in October 154 (44.64%). During the second year the relative abundance was minimum in January 5 (1.58%) and maximum in Octoher 139 (43.99%). During the first year there were three peaks of catch in March 47 (13.62%), May 27 (7.83%) and October 154 (44.64%). During the second year there were four peaks of catch in December 9 (2.85%), May 34 (10.76%), July 27(8.54%) and October 139 (43.99%).

The relationship of the monthly total Orthoptera collection and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire study period. In the first year the monthly average minimum and maximum temperature, minimum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels, while maximum relative humidity showed significant positive relationship at 0.01% level. In the second year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

Four families of Orthoptera, namely, Acrididae, Gryllidae, Tettigonidae and Gryllotalpidae were collected in the light-trap during the experimental period. The monthly fluctuation of different families for the entire experimental period has been shown in Figure 10. The catch fluctuation of different families and their percentage to the total annual Orthoptera catch in the first year were as follows : Acrididae 133 (38.55%), Gryllidae 105 (30.43%), Tettigonidae 100 (28.98%) and Gryllotalpidae 7 (2.02%). In the second year catch fluctuation of the different families and their percentage to the total annual Orthoptera catch were as follows : Acrididae 116 (36.70%), Gryllidae 81 (25.63%), Tettigonidae 112 (35.44%) and Gryllotalpidae 7 (2.21%).

1. Acrididae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 5 (3.76%), December 6 (4.51%), January 2 (1.50%), February 4 (3.01%), March 38 (28.57%), April 9 (6.77%), May 9 (6.77%), June 6 (4.51%),

Figure 5.12 : Monthwise total collection of Acrididae, Gryllidae, Tettigonidae and Gryllotalpidae in Light-trap from November, 1979 to October, 1981.

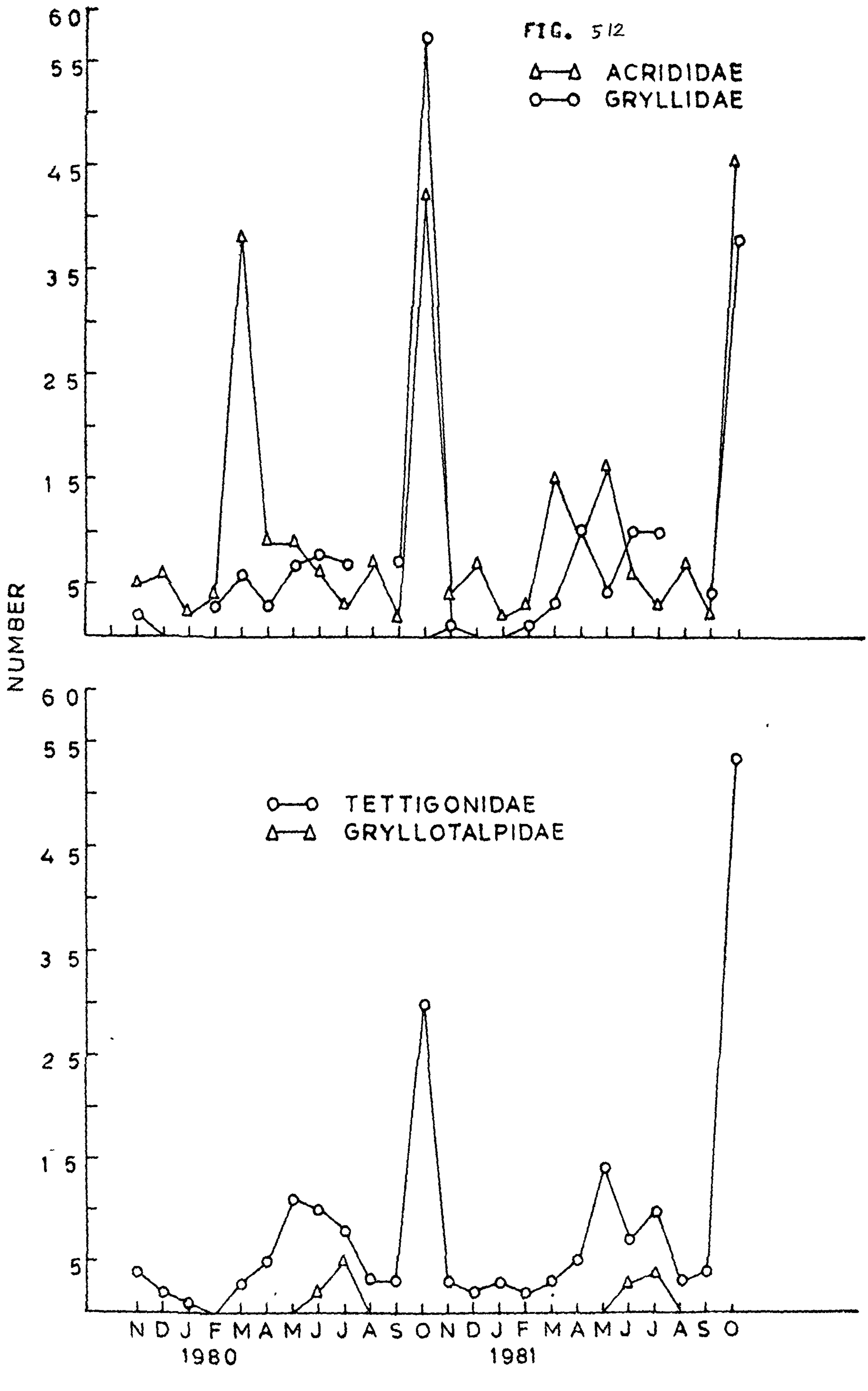


FIG. 512
ACRIDIDAE
GRYLLIDAE
TETTIGONIDAE
GRYLLOTALPIDAE
NUMBER
60
55
45
35
25
15
5
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1981

July 3 (2.26%), August 7 (5.26%), September 2 (1.50%) and October 42 (31.58%). In the second year the monthwise total catch and its percentage to the total annual catch of the family were as follows : November 4 (3.45%), December 7 (6.03%), January 2 (1.72%), February 3 (2.59%), March 15 (12.93%), April 9 (7.76%), May 16 (13.79%), June 6 (5.17%), July 3 (2.59%), August 4 (3.45%), September 2 (1.72%) and October 45 (38.79%).

The relative abundance of the family was minimum in January and September with 2 (1.50%) in each month and maximum in October with 42(31.58%) during the first year. During the second year the relative abundance was minimum in January and September with 2 (1.72%) in each month and maximum in October with 45 (38.79%). There were four peaks of catch in December 6 (4.51%), March 38 (28.57%), August 7 (5.26%) and October 42 (31.58%) during the first year. During the second year there were five peaks of catch in December 7 (6.03%), March 15 (12.93%), May 16 (13.79%), August 4 (3.45%) and October 45 (38.97%).

2. Tettigonidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 4 (4.00%), December 2 (2.00%), January 1 (1.00%),

February 0 (0.00%), March 3 (3.00%), April 5 (5.00%), May 11 (11.00%), June 10 (10.00%), July 8 (8.00%), August 3 (3.00%), September 3 (3.00%) and October 50 (50.00%). In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 3 (2.68%), December 2 (1.79%), January 3 (2.68%), February 2 (1.79%), March 3 (2.68%), April 5 (4.46%), May 14 (12.50%), June 7 (6.25%), July 10 (8.93%), August 3 (2.68%), September 4(3.57%) and October 56 (50.00%).

The relative abundance of the family during the first year was minimum in January with 1 (1.00%) and maximum in October with 50 (50.00%) and there were two peaks of catch in May 11(11.00%) and October 50 (50.00%). In the second year the relative abundance was minimum in December and February with 2 (1.79%) in each month and maximum in October with 56 (50.00%) and there were four peaks of catch in January 3 (2.68%), May 14 (12.50%), July 10 (8.93%) and October 56 (50.00%).

3. Gryllidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : November 2 (1.90%), December 0 (0.00%), January 0 (0.00%), February 3 (2.86%), March 6 (5.71%), April 3 (2.86%), May 7 (6.67%), June 8 (7.62%), July 7

(6.67%), August 0 (0.00%), September 7 (6.67%) and October 62 (59.05%). In the second year the monthwise total catch and its percentage to the total annual catch were as follows : November 1 (1.23%), December 0 (0.00%), January 0 (0.00%), February 1 (1.23%), March 3 (3.70%), April 10 (12.35%), May 4 (4.94%), June 10 (12.35%), July 10 (12.35%), August 0 (0.00%), September 4(4.94%) and October 38 (46.91%).

The relative abundance of the family was minimum in November with 2 (1.90%) and maximum in October with 62 (59.05%) and there were three peaks of catch in March 6 (5.71%), June 8 (7.62%) and October 62 (59.05%) during the first year. During the second year the relative abundance was minimum in November and February with 1 (1.23%) in each month and maximum in October with 38 (46.91%) and there were three peaks of catch in April 10 (12.35%), June and July 10 (12.35%) in each month and October 38 (46.91%).

4. Gryllotalpidae -- The monthwise total catch and its percentage to the total annual catch of the family in the first year were as follows : June 2 (28.57%), July 5 (71.43%) and were absent for the rest of the months. In the second

year the monthwise total catch and its percentage to the total annual catch of the family were as follows : June 3 (42.86%), July 4 (57.14%) and were absent for the rest of the months.

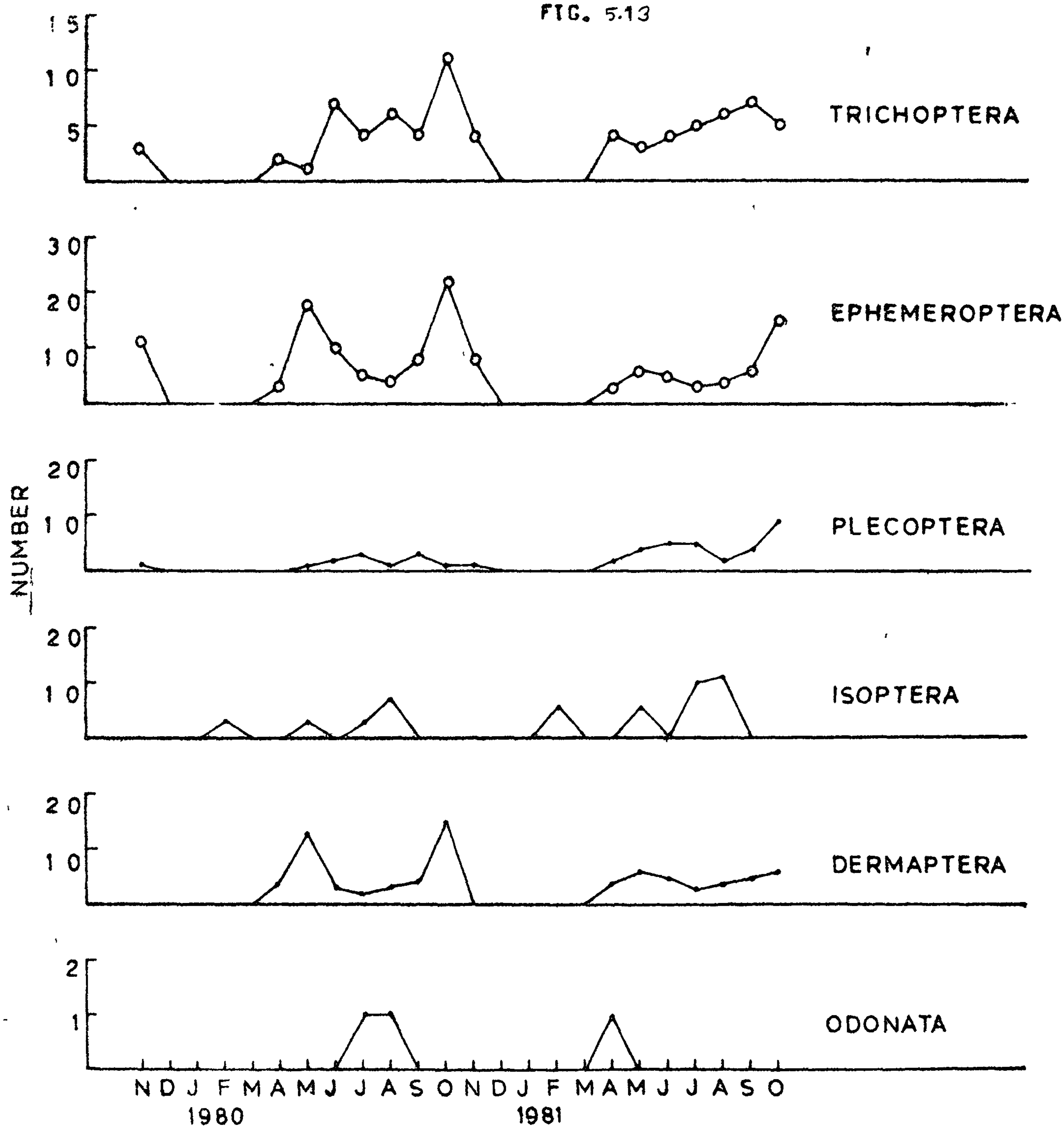
EPHEMEROPTERA :

Ephemeroptera comprised of 81 numbers of individuals and 0.87% of the total annual insect collection of the first year and 50 numbers of individuals and 0.73% of the total annaul insect collection of the second year. The monthly catch fluctuation of the order for the entire study period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.13.

The monthwise total collection of the order and its percentage to the total annual collection in the first year were as follows : November 11(13.58%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 3 (3.70%), May 18 (22.22%), June 10 (12.35%), July 5 (6.17%), August 4 (4.94%), September 8 (9.88%) and October 22 (27.16%). In the second year the monthwise total catch and its percentage to the total annaul catch were as follows : November 8 (16.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 3 (6.00%), May 6 (12.00%), June 5 (10.00%), July 3(6.00%), August 4 (8.00%), September 6 (12.00%) and October 15 (30.00%).

Figure 5.13 : Monthwise total collection of Trichoptera, Ephemeroptera, Plecoptera, Isoptera, Dermaptera and Odonata in Light-trap from November, 1979 to October, 1981.

FIG. 5.13



15
10
5
TRICHOPTERA
30
20
10
EPHEMEROPTERA
20
10
PLECOPTERA
NUMBER
20
10
ISOPTERA
20
10
DERMAPTERA
2
1
ODONATA
N D J F M A M J J A S O N D J F M A M J J A S O
1980
1981

The relative abundance of Ephemeroptera was minimum in April with 3 (3.70%) and maximum in October with 22 (27.16%) during the first year. During the second year the relative abundance was minimum in April and July with 3 (6.00%) in each month and maximum in October with 15 (30.00%). There were two peaks of catch in May 18 (22.22%) and October 22 (27.16%) in the first year. In the second year also the two peaks of catch were in May 6 (12.00%) and October 15 (30.00%).

The relationship of the monthly total Ephemeroptera collection and certain environmental factors have been shown in Tables 3.1 and 3.2 for the entire experimental period. Both the year the monthly average minimum and maximum teperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

During the entire experimental period only one family, namely, Baetidae, represented the order

PLECOPTERA :

This order comprised of 12 numbers of individuals and 0.13% of the total annual insect collection of the first year and of 32 numbers of individuals and 0.46% of the total annual insect collection of the second year. The monthly catch fluctuation of the order have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.13 for the entire experimental period.

The monthwise total collection of the order and its percentage to the total annual collection in the first year were as follows : November 1 (8.33%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 0(0.00%), May 1 (8.33%), June 2 (16.67%), July 3 (25.00%), August 1 (8.33%), September 3 (25.00%) and October 1 (8.33%). In the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 1 (3.13%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 2 (6.25%), May 4 (12.50%), June 6 (18.75%), July 4 (12.50%), August 2 (6.25%), September 4 (12.50%) and October 9(28.13%).

The relative abundance of the order was minimum in April, May, October and November with 1 (8.33%) in each month and maximum in July and September with 3 (25.00%) in each month in the first year. In the second year the relative abundance was minimum in November with 1 (3.13%) and maximum in October with 9 (28.13%). During the first year there were two peaks of catch in July 3 (25.00%) and September 3 (25.00%). During the second year the two peaks were in June 6 (18.75%) and October 9 (28.13%).

The relationship of the monthly total Plecoptera collection and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire experimental period. In the first year the monthly average minimum and maximum temperature, minimum relative humidity and the monthly total rainfall showed significant positive relationship at 0.01% level while maximum relative humidity did not show any significant relationship at 0.01% and 0.05% levels. In the second year the monthly average minimum temperature showed significant positive relationship at 0.01%, while maximum temperature and maximum relative humidity showed significant positive relationship at 0.05% level, minimum relative humidity and the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

TRICHOPTERA :

Trichoptera comprised of 38 numbers of individuals and 0.41% of the total annual insect collection of the first year and of 38 numbers of individual and 0.55% of the total annual insect collection of the second year. The monthly catch fluctuation of the order for the entire experimental period have been shown in Tables [illegible].1, [illegible].2 and Figures 5.1, 5.2 and 5.13.

The monthwise total collection of the order and its percentage to the total annual collection in the first year were as follows : November 3 (7.89%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 2 (5.26%), May 1 (2.63%), June 7 (18.42%), July 4 (10.53%), August 6 (15.79%), September 4 (10.53%) and October 11 (28.95%). In the second year the monthwise total collection and its percentage to the total annual collection of the order were as follows : November 4 (10.53%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 4 (10.53%), May 3 (7.89%), June 4 (10.53%), July 5 (13.16%), August 6 (15.79%), September 7 (18.42%) and October 5 (13.16%).

During the first year the relative abundance was minimum in May 1 (2.63%) and maximum in October 11 (28.95%) and there were four peaks of catch in April 2 (5.26%), June 7 (18.42%), August 6 (15.79%), and October 11 (28.95%). During the second year the relative abundance was minimum in May 3 (7.89%) and maximum in September 7 (18.42%) and there were two peaks of catch in April 4 (10.53%) and September 7 (18.42%).

The relationship of the monthly total Trichoptera collection and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire experimental period. During the first year the monthly average minimum and maximum temperature, and minimum relative humidity showed significant positive relationship at 0.05% level while maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels. During the second year the monthly average minimum and maximum temperature showed sigificant positive relationship at 0.01% level while minimum and maximum relative humidity and the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

ISOPTERA :

Isoptera comprised of 16 numbers of individuals and 0.17% of the total annual insect collection of the first year and of 33 numbers of individuals and 0.48% of the total annual insect collection of the second year. The monthly catch fluctuation of the order for the entire experimental period have been shown in Tables 5.1 and 5.2 and Figures 5.1, 5.2 and 5.13.

The monthwise total collection of the order and its percentage to the total annual collection of it in the first year were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 3 (18.18%), March 0 (0.00%), April 0 (0.00%), May 3 (18.18%), June 0 (0.00%), July 4 (25.00%), August 6 (37.50%), September 0 (0.00%) and October 0 (0.00%). In the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 6 (18.18%), March 0 (0.00%), April 0 (0.00%), May 7 (21.21%), June 0 (0.00%), July 9 (27.27%), August 11 (33.33%), September 0 (0.00%) and October 0 (0.00%).

The relative abundance of Isoptera was minimum in February and May with 3 (18.75%) in each month and maximum in August with 6 (37.50%) during the first year. During the second year the relative abundance was minimum in February with 6 (18.18%) and maximum in August with 11 (33.33%).

The relationship of the monthly total Isoptera collection and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire experimental period. During the first year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels. During the second year the monthly average minimum and maximum temperature, minimum relative humidity and monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels while maximum relative humidity showed significant positive relationship at o.0.05% level.

DERMAPTERA :

This order comprised of 44 numbers of individuals and 0.47% of the total annual insect collection of the first year and of 33 numbers of individuals and 0.48% of the total annual insect collection of the second year. The monthly fluctuation of the order have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.13 for the entire experimental period.

The monthwise total collection of the order and its percentage to the total annual collection of it during the first year were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0

(0.00%), April 4 (9.09%), May 13 (29.55%), June 3 (6.82%), July 2 (4.55%), August 3 (6.82%), September 4 (9.09%) and October 15 (34.09%). During the second year the monthwise total collection and its percentage to the total annual collection were as follows : November 0 (0.00%), December 0 (0.00%), January 0 (0.00%), February 0 (0.00%), March 0 (0.00%), April 4 (12.12%), May 6 (18.18%), June 5 (15.15%), July 3 (9.09%), August 4 (12.12%), September 5 (15.15%) and October 6 (18.18%).

The relative abundance of Dermaptera was minimum in July with 2 (4.55%) and maximum in October with 15 (34.09%) and there were two peaks of catch in May 13 (29.55%) and October 15 (34.09%) during the first year. During the second year the relative abundance was minimum in July with 3(9.09%) and maximum in May and October with 6 (18.18%) in each month and there were two peaks of catch in May 6 (18.18%) and October 6 (18.18%).

The relationship of the monthly total Dermaptera collection and certain environmental factors for the entire experimental period have been shown in Tables 4.4 and 4.5. During the first year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels. During the second year the average minimum and maximum temperature and minimum relative humidity showed significant positive relationship at 0.01% level, maximum relative humidity showed significant positive relationship at 0.05% level while the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

During the entire experimental period only one family, namely, Forficulidae, represented the order.

ODONATA :

This order comprised ~~of~~ 2 numbers of individuals and 0.02% of the total annual insect collection of the first year and of 1 number of individual and 0.01% of the total annual insect collection of the second year. The monthly fluctuation of the order for the entire experimental period have been shown in Tables 5.1, 5.2 and Figures 5.1, 5.2 and 5.13.

During the first year the order was collected in July 1 (50.00%) and August 1 (50.00%) and were absent for the rest of the months. During the second year it was collected in August 1(100.00%) and were absent for the rest of the months.

The relationship of the monthly total collection of Odonata and certain environmental factors have been shown in Tables 5.4 and 5.5 for the entire experimental period. During the first year the monthly average minimum and maximum temperature and maximum relative humidity did not show any significant positive relationship at 0.01% and 0.05% levels while the minimum relative humidity and the monthly total rainfall showed significant positive relationship at 0.05% level. During the second year the monthly average minimum and maximum temperature, minimum and maximum relative humidity and the monthly total rainfall did not show any significant relationship at 0.01% and 0.05% levels.

Figure 5.14: Adults of *Cyclosia panthona* Cram. reared in Laboratory.

5.3 : BIOLOGY OF MAJOR INSECT PESTS :

5.31 : *Cyclosia panthona* Cram.

5.311 : Morphology :

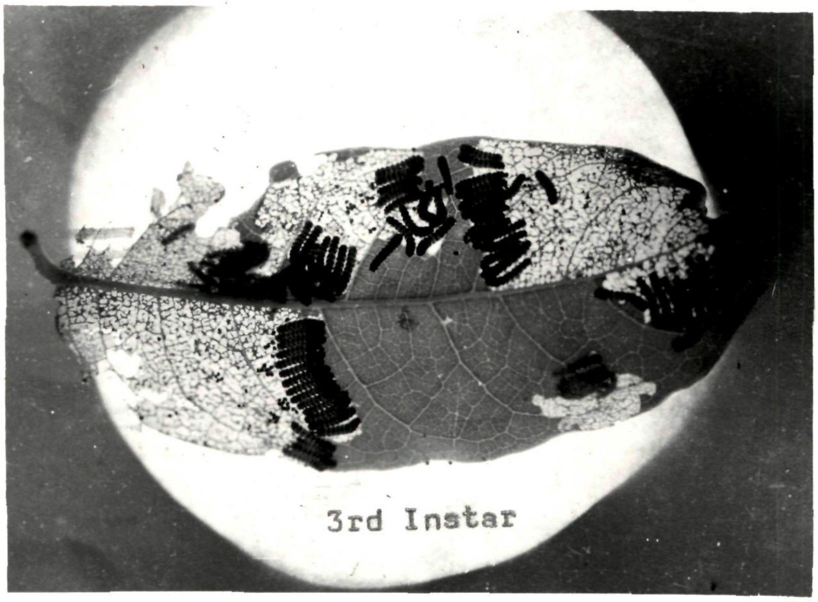
Male -- The adult male insect is about 11.80 mm (range 10.00 - 12.50 mm) in length with wing-span of about 32.80 mm (range 31.00 - 35.00 mm). It is brownish black in colour with dark metallic blue tinge. The abdomen has some white shades on the ventral surface. The fore-wing is with seven and the hind-wing is with four white spots on the distal borders visible on both the surfaces. The antenna is bipectinate and measures about 6 mm in length.

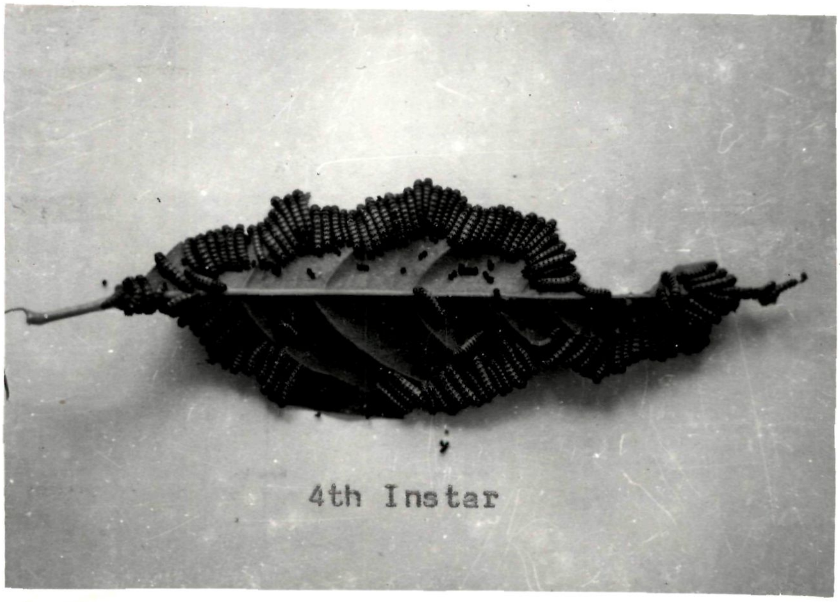
Female -- The adult female is about 13.30 mm (range 12.00 - 14.00 mm) in length with wing-span of about 44.40 mm (range 42.00 - 46.00 mm). It is brownish black in colour. The fore-wing is with ten and the hind-wing is with seven white spots on the distal borders visible on both the surfaces. The bipectinate antenna measures about 7 mm in length (Figure 5.14).

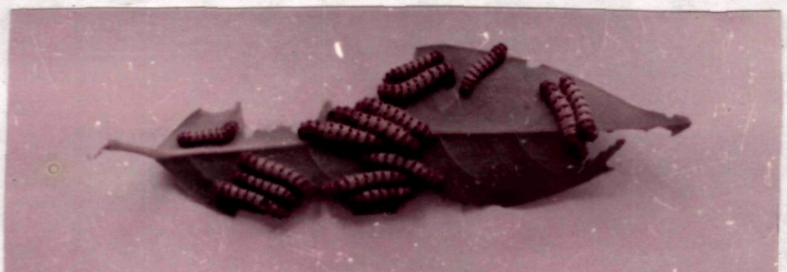
5.312 : Developmental Stages :

The female moth lays eggs in clusters of 161 (range 122 - 251) eggs on the lower surface of the host tree leaf. The hatched out larvae feed on

Figure 5.15 : Cyclosia panthona Cram. larvae feeding on the leaves of Aporosa roxburghii.







5 th Instar

the younger leaves and pass through six instars (Figure 4.15). The 6th instar larvae pupate on fallen leaves or in crevices on the ground. The size of various developmental stages have been shown in Table 5.9 and Figure 5.19 and their duration in Table 4.10 and Figure 5.20.

(A) Eggs :

The eggs are light yellow in colour and oval in shape with smooth chorion. The average length of the egg is 0.78 mm. They turn dark grey before hatching.

(B) Larval Instars :

1st Larval Instar :

Freshly hatched out larvae are light yellow in colour with dark samber coloured head-capsule. It measures about 2.20 mm (range 2.10 - 2.30 mm) in length. The head-capsule is partially covered over with a shield-like extension of the prothoracic segmemt. A few light coloured short bristles are seen arising out from the warts on the dorsal surface of the body. The mean head-capsule width is 0.463 mm (range 0.45 - 0.50 mm) (Figure 5.16).

Table 5.9 : Dimentions of egg, larval instars and head-capsule of larval instars of _Cyclosia panthona_.

(n = 20)

	Length (mm)			Width of Head-capsule (mm)		
Developmental Stages	Mean	Range	S.D.	Mean	Range	S.D.
Egg	0.78	0.76 - 0.79	±0.02	---	----	---
Instar I	2.20	2.10 - 2.30	±0.09	0.46	0.45 - 0.50	±0.02
Instar II	3.10	3.00 - 3.20	±0.01	0.54	0.54 - 0.55	±0.08
Instar III	4.60	4.50 - 5.00	±0.17	0.86	0.85 - 0.88	±0.01
Instar IV	9.60	9.50 -10.00	±0.36	1.21	1.20 - 1.24	±0.01
Instar V	11.70	11.50 -12.00	±0.26	1.57	1.50 - 1.60	±0.05
Instar IV (Male)	14.85	14.50 -15.00	±0.23	2.17	2.10 - 2.20	±0.05
Instar IV (Female)	20.90	20.50 -21.00	±0.19	2.00	1.90 - 2.00	±0.04

Table 5.10: Time taken in different developmental stages of the three generations of *Cyclosia panthona* Cram. in Balphakram Forest.

Generations	Developmental stages in Days										Life-span in Days
	Egg	I	II	III	IV	V	VI	P.Pupa	Pupa	Adult	
Rainy Generation											
(May - July)	11.7	6.8	5.7	4.1	6.2	7.2	9.3	1.2	20.0	7.7	79.9(77 - 85)
Autumn Generation											
(August-October)	12.1	7.7	5.7	4.6	6.6	7.6	9.5	1.3	21.8	8.4	85.3(82 - 88)
Winter Generation											
(November-April)	15.8	13.6	11.5	9.6	8.7	17.3	21.0	1.8	122.1	6.6	228.0(224-231)

I = Instar I V = Instar V P. Pupa = Pre-pupa

II = Instar II VI = Instar VI

III = Instar III

IV = Instar IV

2nd Larval Instar :

This instar is pale greenish in colour with red tinge on the two anterior and the two posterior segments. It measures about 3.10mm (range 3.00 - 3.20 mm) in length. A ring of six reddish warts surrounding a central white spot is seen dorsally on each segment except the posterior most two segments which have four warts on each. Light yellowish white hairy bristles are present on each wart. The mean head-capsule width is 0.54 mm (range 0.53 - 0.55 mm) (Figure 5.16).

3rd Larval Instar :

Larger in size but the morphology and colour pattern of this instar is similar to that of the 2nd instar. It measures about 4.60 mm (range 4.50 - 5.00 mm) in length. The mean head-capsule width is 0.87 mm (range 0.85 - 0.88 mm) (Figure 5.16).

4th Larval Instar :

Still larger in size but the morphology and colour pattern of this instar also is similar to the earlier instars. It measures about 9.60 mm (range 9.50 - 10.00 mm) in length. The mean head-capsule width is about 1.22 mm (range 1.20 - 1.24 mm) (Figure 5.17).

FIG. 5.16

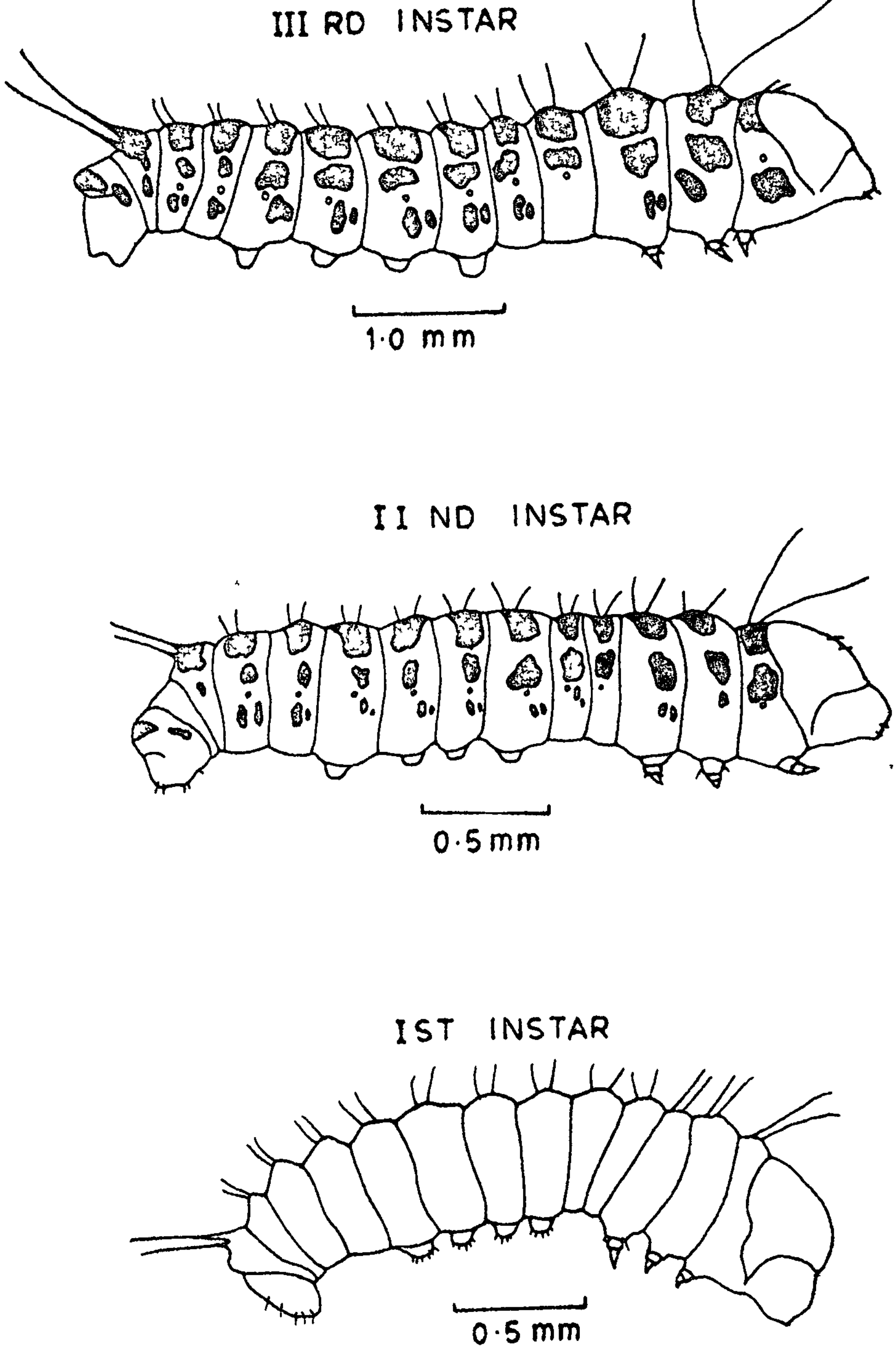


FIG. 5.17

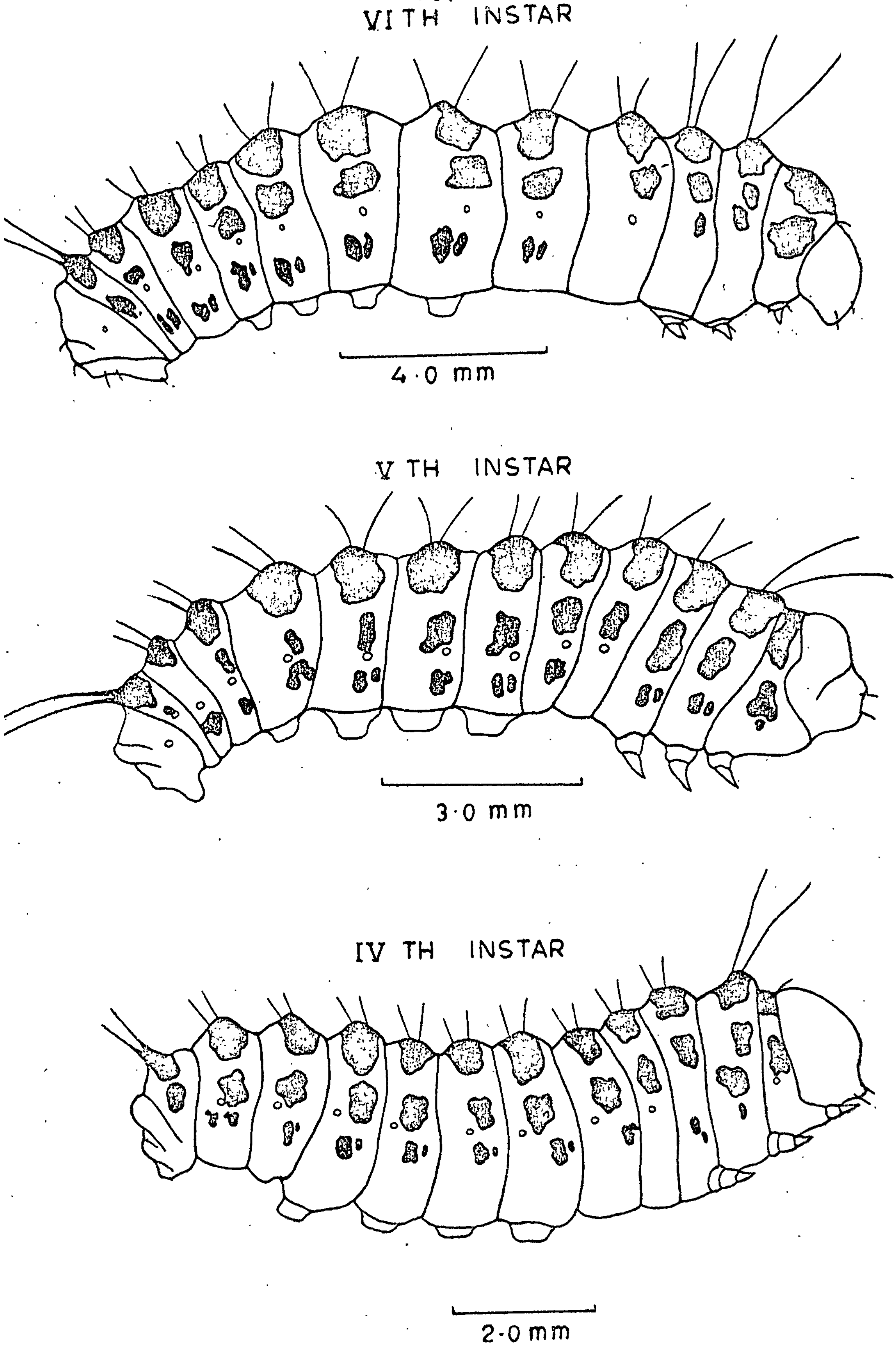


FIG. 5.18

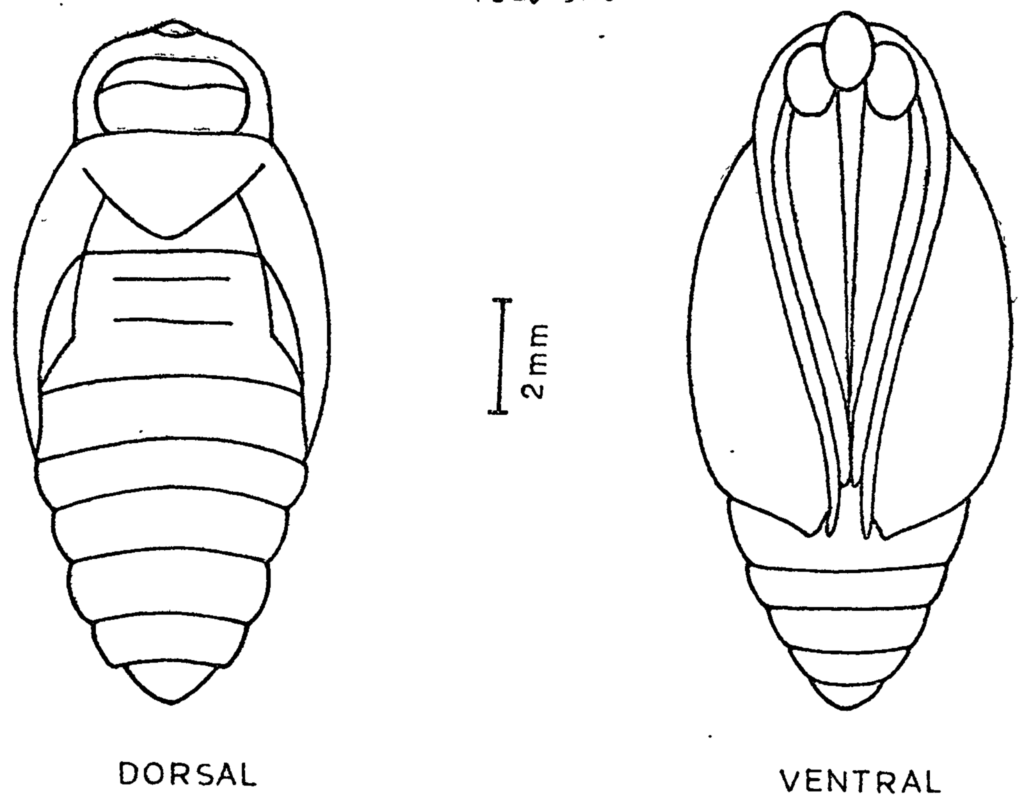
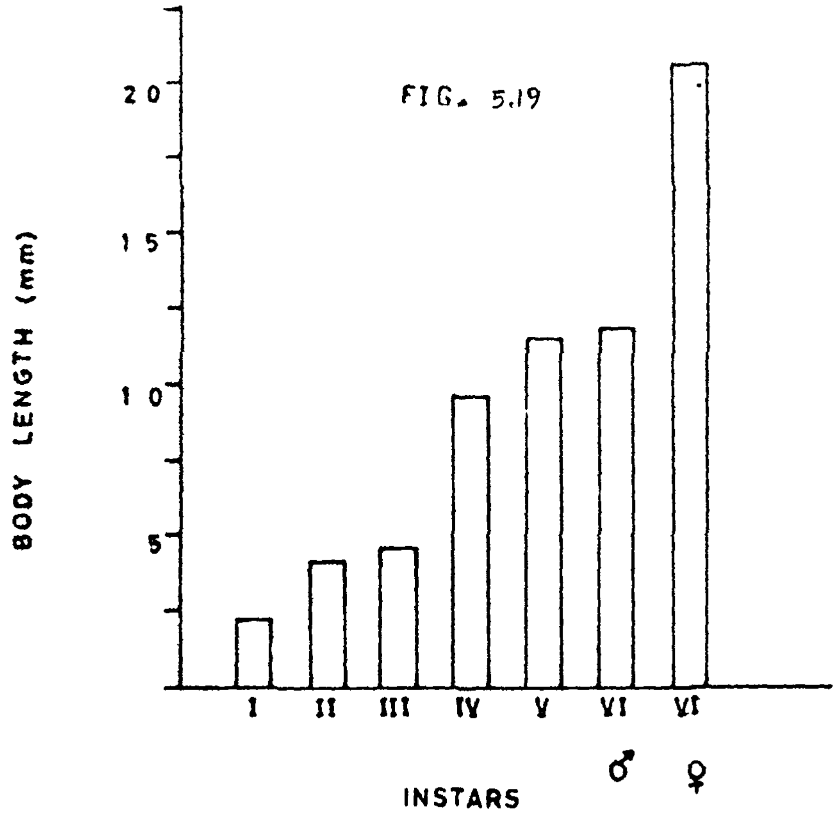


FIG. 5.19


BODY LENGTH (mm)
2 0
1 5
1 0
5
I
II
III
IV
V
VI
VI
♂
♀
INSTARS

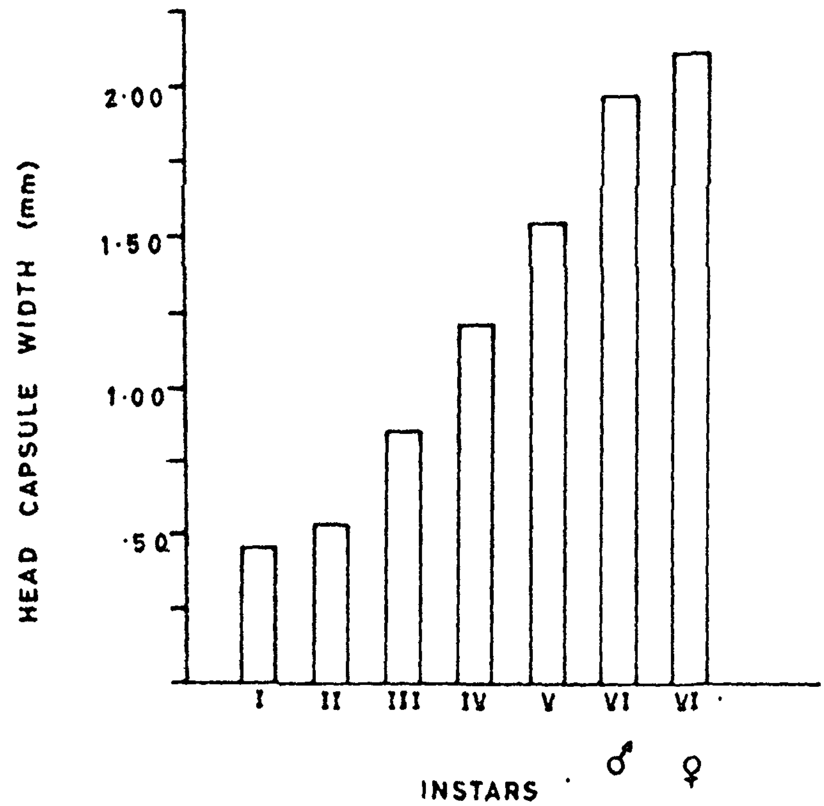
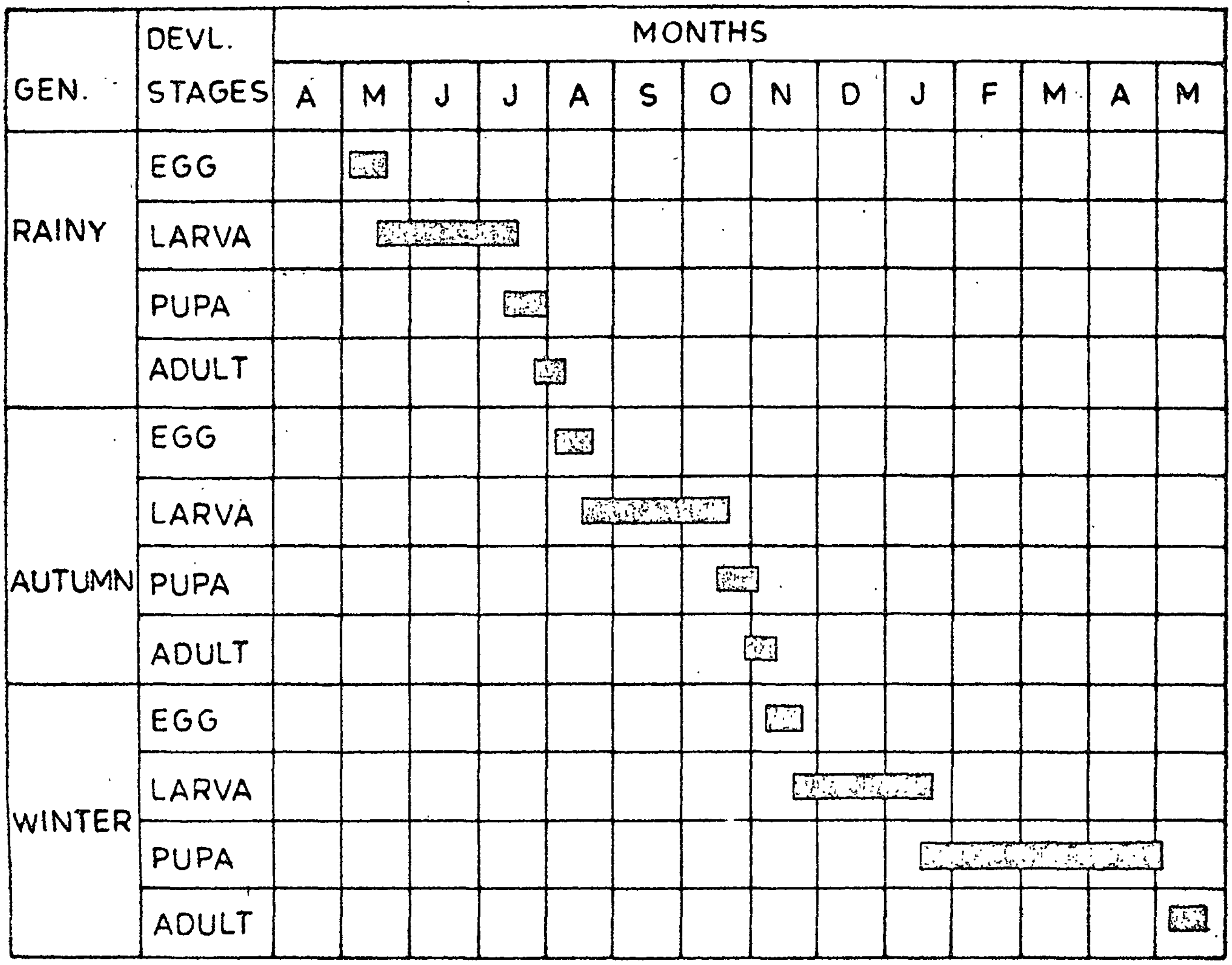

HEAD CAPSULE WIDTH (mm)
2·00
1·50
1·00
·50
I
II
III
IV
V
VI
VI
♂
♀
INSTARS

FIG. 5.20


GEN.
DEVL. STAGES
MONTHS
A
M
J
J
A
S
O
N
D
J
F
M
A
M
RAINY
AUTUMN
WINTER
EGG
LARVA
PUPA
ADULT

5th Larval Instar :

This instar is larger in size without any noticeable change in appearance and colour pattern than the earlier instars. It measures about 11.70 mm (range 11.50 - 12.00 mm) in length. The mean head-capsule width is about 1.57 mm (range 1.50 - 1.60 mm) (Figure 5.17).

6th Larval Instar :

This instar attains maximum size without any change in appearance and colour pattern. The larva to give rise to male moth is smaller and measures about 14.85 mm (range 14.50 - 15.00 mm) and the larva to give rise to female moth is larger and measures about 20.90 mm (range 20.50 - 21.00 mm) in length. The mean head-capsule width is about 2.17 mm (range 2.10 - 2.20 mm) of the male and about 2.00 mm (range 1.90 - 2.00 mm) of the female (Figure 5.17).

(C) Pupal Instar :

The 6th larval instar on attaining full size spins a reddish paper-like cocoon around itself and enters pre-pupal stage. The pre-pupa moults inside the cocoon into pupa. The mean length of the male pupa is about 10.90 mm (range 10.80 - 11.00 mm) and that of the female pupa is about 12.90 mm (range 12.60 - 13.00 mm). At the beginning the pupa is yellow in colour which turns later on into brownish black before the emergence of the moth (Figure 5.18).

5.313 : Population Dynamics :

Cyclosia panthona Cram. is trivoltine and completes three generations in the Balphakram National Wild-life Sanctuary :

(a) Rainy Season (May - July) Generation :

In this generation the moths lay eggs in May, the larval stages occur from May to July, pupation occurs at the end of July and the new moths emerge in July - August. The life cycle is completed in 77 to 85 days.

(b) Autumn Season (August - October) Generation :

In this generation the moths lay eggs in August, the larval stages occur from August to October, pupation occurs at the end of October and the new moths emerge in October - November. The life cycle is completed in 82 to 88 days.

(c) Winter Season (November - April) Generation :

In this generation the moths lay eggs in November, the larval stages occur from

November to January, pupation occurs at the end of January and undergo diapause. Diapause is broken in early May and adult emerges out.

5.314 : Life Table :

Partial life tables of the three generations of *Cyclosia panthona* Cram. have been prepared on the format of Morris and Miller (1954) followed by Mason and Thompson (1971) with the help of density estimates of the eggs and different stages of the larvae and mortality factors operating in the system (Tables 5.11, 5.12 and 5.13). As it was not possible to analyse the density of each larval instar separately the larvae were grouped in two categories, namely, smaller larvae (1st, 2nd and 3rd instars) and larger larvae (4th, 5th and 6th instars). Pupal and adult stages have not been taken into consideration.

In the Rainy Season Generation the mean number of eggs was 161.3 (range 122-251), smaller larvae 124.7 (range 97 - 174) and larger larvae 54.3 (range 35 - 64). In the Autumn Season Generation the mean number of eggs was 175.9 (range 122 - 234), smaller larvae 144.8 (range 118 - 193) and larger larvae 88.8 (range 53 - 105). In the

Table 5.11 : Partial Life-table of the Rainy Generation of *Cyclosia panthona* Cram. during 1981 in the Balphakram Sanctuary.

Months	Age Interval (x)	Number Alive at start of X (1x)	Factors Responsible for dx (dx F)	Number Dying during (dx)	dx as Percentage of 1x (100 qx)
May	Eggs	161.3	Infertility	2.5	1.5
			Rainfall	4.3	2.6
			Wind	21.6	13.3
			Unknown	8.2	5.0
			Sub Total	36.6	22.4
June	Small Larvae	124.7	Rainfall	20.7	16.5
			Wind	32.2	25.8
			Parasite	5.1	4.0
			Unknown	12.4	9.9
			Sub Total	70.4	56.2
July	Large Larvae	54.3	Rainfall	6.6	12.1
			Wind	8.9	16.3
			Parasite	7.5	13.8
			Disease	20.2	37.2
			Unknown	6.3	11.6
			Sub Total	49.5	91.0
	Summary of Mortality :				
			Infertility	2.5	1.5
			Rainfall	31.6	19.5
			Wind	62.7	38.8
			Parasite	12.6	7.8
			Disease	20.2	12.5
			Unknown	26.9	16.6
			Total	156.5	96.7

Table 5.12 : Partial Life-table of the Autumn Generation of *Cyclosia panthona* Cram. during 1981 in the Balphakram Sanctuary.

Months	Age Interval (X)	Number Alive at start of X (1x)	Factors Responsible for dx (dx F)	Number Dying during (dx)	dx as Percentage of 1x (100 qx)
	Eggs	175.9	Infertility	3.1	1.7
			Rainfall	2.2	1.2
August			Unknown	25.8	14.6
			Sub Total	31.1	17.5
	Small Larvae	144.8	Parasite	7.5	5.1
			Disease	25.4	17.5
September			Unknown	23.1	15.9
			Sub Total	56.0	38.5
	Large Larvae	88.8	Parasite	8.2	9.2
			Predator	1.6	1.8
October			Disease	26.7	30.0
			Unknown	10.8	12.1
			Sub Total	47.3	53.1
	Summary of Mortality :				
			Infertility	3.1	1.7
			Rainfall	2.2	1.2
			Parasite	15.7	8.9
			Predator	1.6	1.8
			Disease	52.1	29.6
			Unknown	59.7	33.9
			Total	134.4	77.1

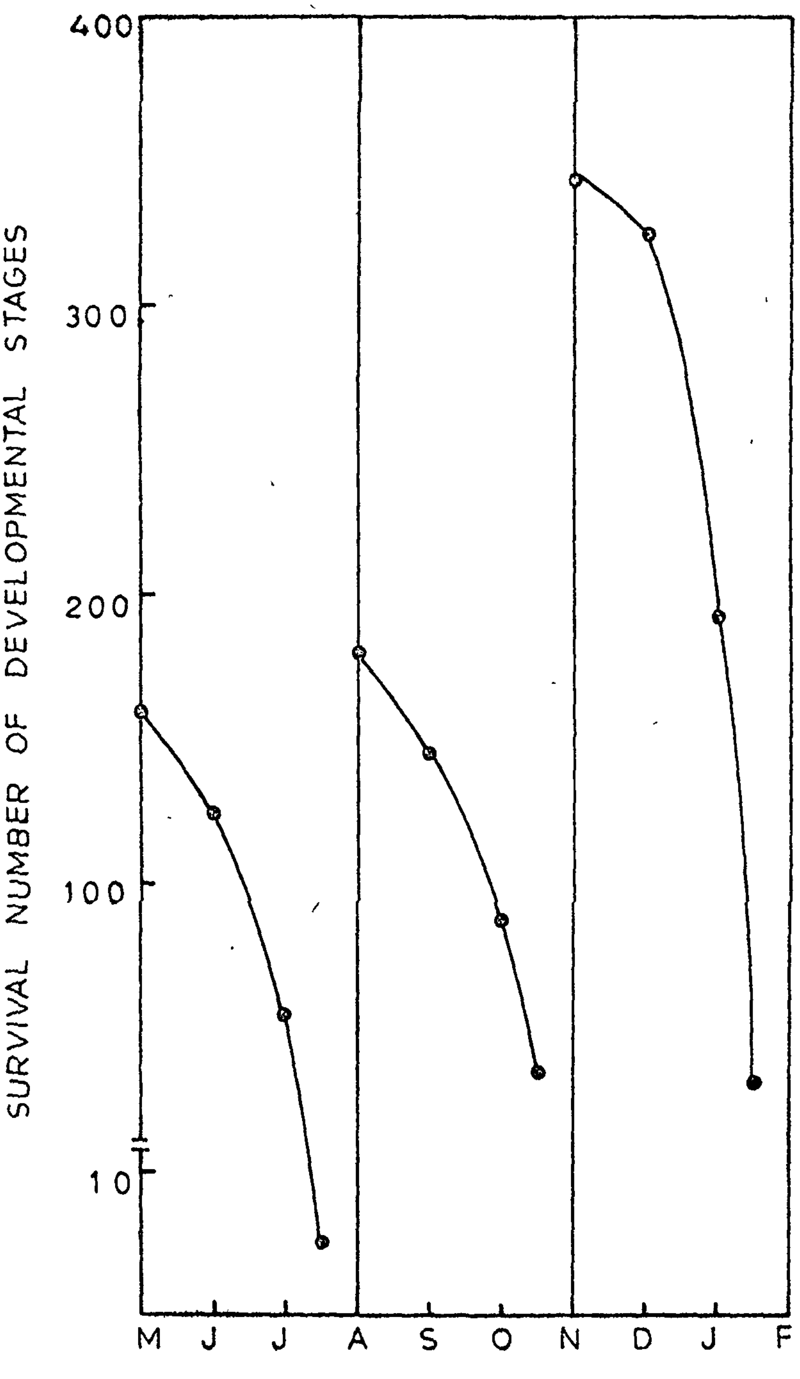
Table 5.13 : Partial Life-table of the Winter Generation of *Cyclosia panthona* Cram. during 1981 and 1982 in the Balphakram Sanctuary.

Months	Age Interval (X)	Number Alive at start of X (1x)	Factors Responsible for dx (dx F)	Number Dying during (dx)	dx as Percentage of 1x (100 qx)
	Eggs	347.1	Infertility	2.9	0.8
November			Unknown	17.4	5.0
			Sub Total	20.3	5.8
	Small Larvae	326.8	Parasite	3.2	0.9
			Predator	1.9	0.5
			Disease	14.6	4.4
			Dispersal	88.7	27.1
December			Unknown	25.4	7.7
			Sub Total	133.8	40.6
	Large Larvae	193.0	Parasite	15.5	8.0
			Predator	4.3	2.2
			Disease	52.8	27.3
			Dispersal	70.6	36.5
January			Unknown	20.1	10.4
			Sub Total	163.3	84.4
	Summary of Mortality :				
			Infertility	2.9	0.8
			Parasite	18.7	5.3
			Predator	6.2	1.7
			Disease	67.4	19.4
			Dispersal	159.3	45.8
			Unknown	62.9	18.1
			Total	317.4	91.1

Winter Season Generation the mean number of the eggs was 347.1 (range 245 - 605), smaller larvae 326.9 (range 216 - 435) and larger larvae 193.0 (range 138 - 289).

The larvae show a gregarious habit throughout their life-span. From 1st to 3rd instar the larvae feed on the lower surface of the leaves of the host tree, Aporosa roxburghii. From 4th instar onwards the larvae consume the whole leaf. Though sluggish in nature they slowly move out in search of food to the other leaves. They also hang down through their silken salivary thread and sometime crawl down through the trunk to the other trees. It was noted during the first two generations of rainy and autumn seasons due to continuous sprouting of fresh leaves of the host trees and low density of the larvae on each twig they live even upto 6th instar on the same twig. There was no remarkable dispersal of the larvae for food in these generations. However, with age and growth in size the mean density of the rainy season generation larvae decline from 124.7 per twig to 54.3 per twig and of the autumn season generation larvae decline from 144.8 per twig to 88.8 per twig and of the winter season generation larvae decline from 326.8 per twig to 193.0 per twig.

FIG. 5.21


400
300
200
100
10
SURVIVAL NUMBER OF DEVELOPMENTAL STAGES
M J J A S O N D J F

Survivorship Curves -- The survivorship curves of the developmental stages of the three generations of *Cyclosia panthona* Cram. have been shown in Figure 5.21. Survivorship curves show the survival of different life stages within the generatien which is depicted by plotting the number of the living stages over time. The degree of slope in the graph shows the mortality rate of different developmental stages in the natural system.

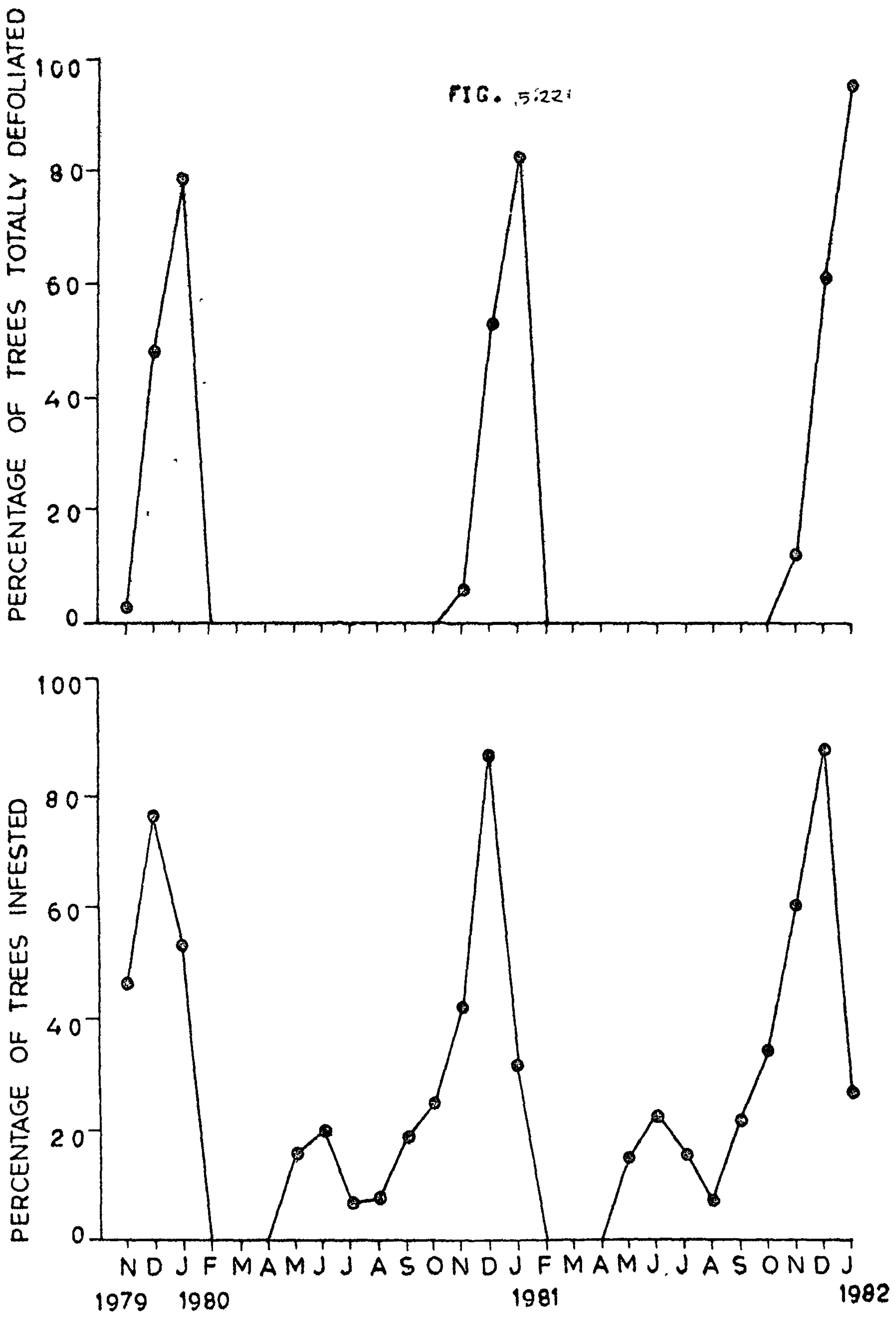
The survival percentage of different stages of *Cyclosia panthona* Cram. in three different generations were as follows :

Generation	Egg	Small Larva	Large Larva	Prepupal Stage
Rainy	77.6%	43.8%	9.0%	3.3%
Autumn	82.5%	61.5%	46.9%	22.9%
Winter	94.2%	59.4%	15.6%	8.9%

Major causes of mortality of the developmental stages in the three generations can be analysed as follows : Rainy Season Generation - rainfall 19.5%, wind 38.8%, parasite 7.8%, disease 12.5% and uncountable reasons 16.6%; Autumn Season Generation - parasite 8.9%, disease 29.6% and unaccountable reasons 18.1%; Winet Season Generation - parasite 5.3%, disease 19.4%, dispersal 45.8% and unaccountable reasons 18.1%. Thus, during rainy season, rain and wind; during autumn

Figure 5.22 : Percentage of infection and total defoliation of *Aporosa roxburghii* by *Cyclosia panthona* Cram. during November, 1979 to January, 1982.

FIG. 5.22


PERCENTAGE OF TREES TOTALLY DEFOLIATED
100
80
60
40
20
0
PERCENTAGE OF TREES INFESTED
100
80
60
40
20
0
N D J F M A M J J A S O N D J F M A M J J A S O N D J
1979 1980 1981 1982

season, disease and unknown factors and during winter season, disease and dispersal cause much loss of the developmental stages in the forest.

5.315 : Host Tree and Infestation :

The larvae of Cyclosia panthona Cram. appear regularly on the tree, Aporosa roxburghii (L) Wall in three seasons, namely, rainy, autumn and winter in a year in the Balphakram National Wild-life Sanctuary. It is only the larval stages which infest the host tree feeding on the leaves. No other stage is found to infest the host tree. Alternate host plant could not be recorded.

Monthwise percentage of infestation and total defoliation of the host trees by the larvae has been shown in Figure 5.22.

From November, 1979 to January, 1982, monthwise percentage of trees infested by the larvae were as follows : November '79 (45%), December '79 (70%), January'80 (52%), February '80 (0%), March '80 (0%), April '80 (0%), May '80 (15%), June '80 (19%), July '80 (11%), August '80 (12%), September '80 (18%), October '80 (29%), November '80 (41%), December '80 (86%), January '81 (31%), February '81 (0%), March '81 (0%), April '81 (0%), May '81 (14%), June '81 (22%), July '81 (15%), August '81 (6%),

Figure 5.23 : *Aporosa roxburghii* tree totally defoliated by the larvae of *Cyclosia panthona*.

September '81 (21%), October '81 (34%), November '81 (60%), December '81 (87%) and January '82 (31%).

During this period monthwise percentage of the totally defoliated trees were as follows : November '79 (2%), December '79 (48%), January '80 (78%), November '80 (6%), December '80 (52%), January '81 (82%), November '81 (12%), December '81 (61%) and January '82 (95%).

Defoliation affected the general health of the trees. In cases of total defoliation the growth of the trees retarded and in some cases the shoots were found dead.(Figure 5.23).

5.32 : <u>Diaphania laticostalis</u> Guene

5.321 : Morphology :

Male -- It is a medium sized moth with milky white body colouration. The wing-span is about 36.00 mm (range 35.60 - 36.50 mm). The costal margin of the fore-wing is dark brown. Both the pairs of wings distally bordered with two thin parallel lines, the proximal one is brown while the distal one is gray in colour. The antennae are filliform and measure about 13.00 mm in length. The proboscis

Figure 5.24 : Adults of Diaphania laticostalis Guene

is long. The eyes are dark samber coloured. The legs are slender and with tibial spurs. (Figure 5.24).

Female -- The female is similar to that of the male in external appearance. It is little larger in size with large abdomen than that of the male. The antennae measure about 14.00 mm in length.

5.322 : Developmental Stages :

(A) Eggs :

The eggs are dull white, round in shape and each measures about 1.00 mm in length. The eggs are laid in cluster of about 47 (range 42 - 74) eggs on the under surface of the leaves of the host tree, *Holarrhena antidysentrica* (Lin.) Wall. They have smooth chorion. Hatching takes place within about 18 days.

(B) Larval Instars :

1st Larval Instar :

The hatched out larvae are pale white with dark samber coloured head-capsule. It measures about 1.8 mm (range 1.7 - 1.8 mm) and attains about 3.8 mm (range 3.5 - 4.0 mm) in length at the end of the instar. There are a few short, white hairs arising out from the warts of the body, legs and prolegs. The pale oval warts are distributed around each abdominal segment, except the posterior most one. There is a transparent shield-like extension from the dorsal surface of the pro-thorasic segment covering partially the head-capsule. The head-capsule measures about 0.47 mm (range 0.46 - 0.50 mm) in width by the end of the instar. Duration in this instar is about 9 days (Figure 525).

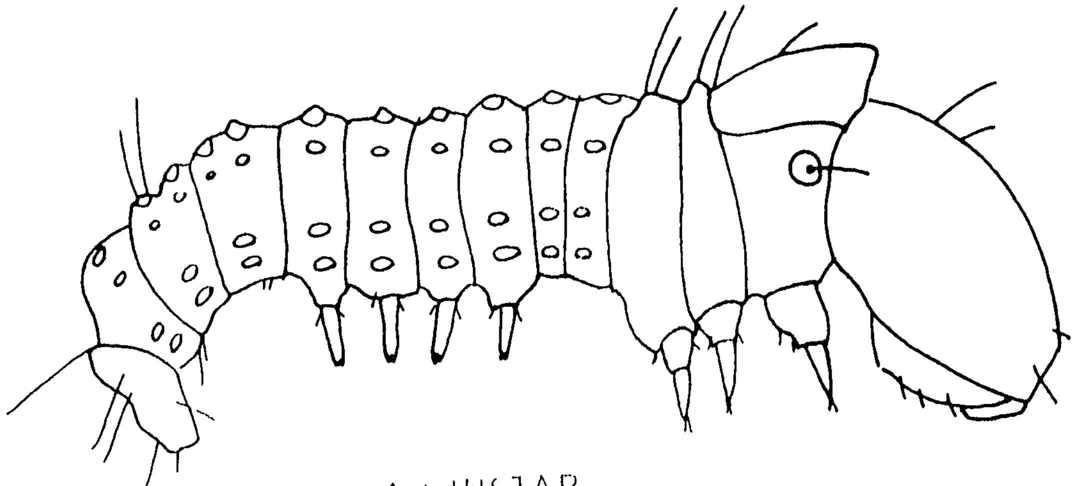
2nd Larval Instar :

Larvae in this instar are more or less similar to the 1st instar. However, in this instar there are appearance of warts on the thorasic segments also. The pro-thorasic shield becomes light dark. The maximum length attained in this instar is about 5.8 mm (range 5.2 - 5.8 mm). Duration in this instar is about 7 days.

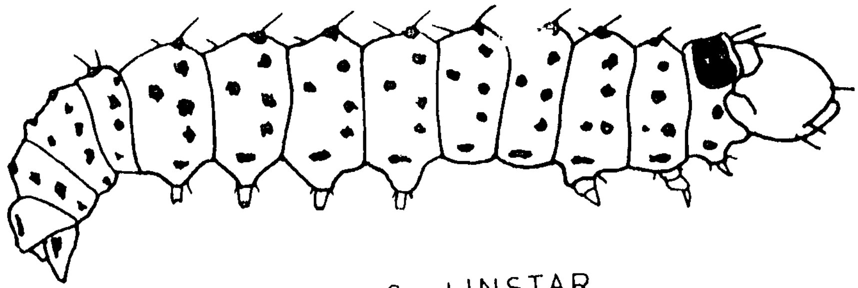
3rd Larval Instar :

In this instar the larvae turn samber coloured and the warts become dark. The head-capsule turns orange red. The legs and the prolegs also become dark. The pro-thorasic shield becomes dark orange with a small dark coloured wart. Each of the meso and metathorax has seven warts laterally in two groups of three and four. In the anterior most two abdominal segments fourteen warts, in each, makes a

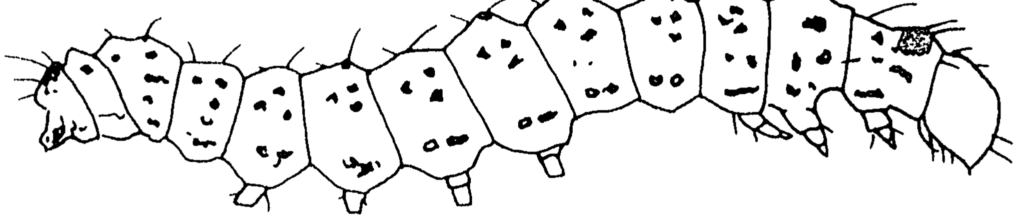
FIG 5.25



1st INSTAR



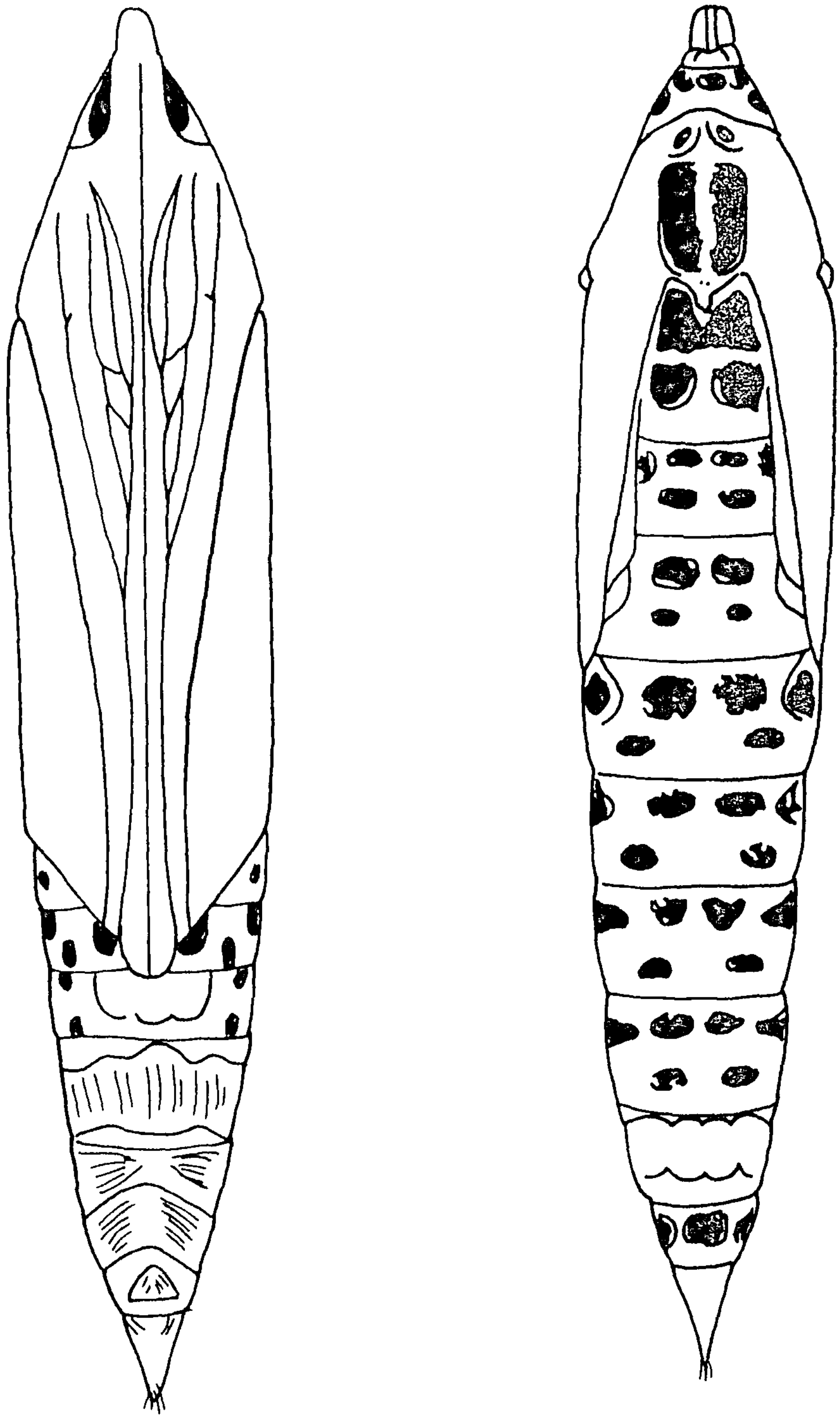
2nd INSTAR



5th INSTAR

Figure 5.26: 3rd Instar larvae of *Diaphania laticostalis* on the leaves of host tree *Holarrhena antidysentrica*.

FIG 5·27



VENTRAL DORSAL

ring circling around the segment. The next four abdominal segments have got ten warts, each, distributed dorsolaterally. The next 7th and 8th abdominal segments have fourteen warts in each, in a ring circling the segments. The 9th segment has nine warts in a ring. The 10th segment is with a big dark spot dorsally. There is one oval white spot laterally on each side from 1st to 7th abdominal segment. From each spot arises out one small and short white hair. There are some still short hairs coming out from the head-capsule, prolegs and leg segments. Maximum length attained in this instar is about 9.70 mm (range 9.5 - 10.0 mm). The mean head-capsule width is about 0.87 mm (range 0.83 - 0.89 mm) by the end of the instar. Duration in this instar is about 8 days. (Figure 5.26).

4th Larval Instar :

This instar is similar to the 3rd instar in external appearance. It attains the maximum length of about 12.7 mm (range 12.5 - 13.0 mm). The mean head-capsule width is about 1.22 mm (range 1.20 - 1.24 mm) by the end of the instar. Duration in this instar is about 10 days.

5th Larval Instar :

This instar is similar to the 3rd

and 4th instars in external appearance. The larva that would become male moth attains maximum of about 29.7 mm (range 29.0 - 30.0 mm) and the larva that would become female moth attains maximum of about 31.2 mm (range 31.5 - 32.0 mm) in length. The maximum mean head-capsule width of the male larva is about 1.75 mm (range 1.71 - 1.76 mm) and of the female larva is about 1.87 mm (range 1.84 - 1.88mm). Duration in this instar is about 8 days (Figure525).

(C) Pupal Instar :

Pre-pupa :

The full grown larva stops feeding , weave a net of its silken thread all around its body inside a leaf-roll of the host tree. The larva shortens its body length and becomes lanceolate and remain silent for pupation.

Pupa :

The pre-pupa moults and turns into a pupa. The anterior part of the new pupa is orange yellow which turns dark samber within about 24 hrs. The pupal duration is about 14 days. The adult moth emerges out by cutting a hole at the anterior part of the cocoon (Figure527).

5.323 : Population Dynamics :

The female moths prefer fresh succulent leaves of the host tree, *Holarrhena antidysentrica* (Lin.) Wall for oviposition. The first evidence of larval attack is ascertained by the curling leaf-roll on the host tree. Single leaf or more than one leaf rolled together with white silken thread by the laevae to make a leaf-roll for their shelter and feeding. The early stage larvae feed on the upper surface of the host leaf. As the chlorophyll content is over the larvae move outward in groups, make a new leaf-roll and start feeding. From the 4th instar onwards the larvae feed on the whole leaf content leaving only the parts of the mid-rib. From the 4th instar onwards the gregarious larvae regroup into smaller groups in different leaves of the same shoot or in different shoots of the same tree.

Diaphania laticostalis Guene is found at least in three overlapping generations in a year in between mid August to early April. From August onwards the attack increases till it reaches a peak in February after which it decreases slowly by April. Pupation takes place in the leaf-roll on the host tree. Adults emerge out in early August. Adult moths are nocturnal and are attracted to light-trap.

Figure 5·28 : Cocoons of parasitic *Apanteles* sp. over dead larva of *Diaphania laticostalis.*

Cannibalism was observed among the *D. laticostalis* larvae in the field as well as in rearing. Mostly the weak, parasite infected and dead larvae were eaten by other healthy larvae. Cannibalism was recorded from 4th instar onwards.

Some larvae in the field were found to be infected by *Apanteles* sp. (Hymenoptera : Braconidae), a larval stage parasite. The mature parasite larvae come out from the host larvae and spin white cocoon around themselves over the dead remain of the host larvae (Figure 5.28).

5.3.2.4 : Host Tree :

The host tree, *Holarrhena antidysentrica* (Lin.) Wall (Family : Apocynaceae) is a common woody tree in Balphakram National Wild-life Sanctuary. Leaves and shoots of the tree is used against amoebic dysentery by the local people. The wood is used for construction of house and as fire-wood (Figure 5.29).

This tree is important in the sense that it reclothes waste land very fast and is one of the first to come up in Jhum fallows and the last to disappear in the denunded areas. It is also reported to act as nurse to more valuable species such as Sal, *Shorea robusta* seedlings in plantation forestry.

Fig. 5.29 : *Helarrhena antidysentrica* tree.

5.4 : MINOR INSECT PESTS :

5.41 : *Delias descombesi*

(Lepidoptera : Pyralidae)

This is a medium sized butterfly commonly found during October to February in flight. Its larval stage feed on the leaves of *Grewia microcos* Lin. a medium sized woody tree common in the Balphakram forest. Larvae are yellow in colour and gregarious in nature. Pupation occurs in groups on the host tree leaves or on some other tree or shrub leaves.

In Balphakram forest the local people use the tree only for fire-wood and for other household purposes. The plant is said to be used for indigestation, eczyma and itch, typhoid fever, dysentery and syphilic ulceration of the mouth (Anonymous, 1956).

5.42 : *Melanitis ismene*

(Lepidoptera : Satyridae)

This is a medium sized butterfly found in shaddy places during November to February. It is commonly known as Rice butterfly. The larvae feed on the leaves of the paddy in the shiefting cultivation field during April to May.

5.43 : *Dicladispa armigera*

(Coleoptera : Chrysomelidae)

It is commonly known as Rice Hispa. Adults are foumd to attack rice and maize and reduce production. Found in shiefting cultivation field during March to May.

5.44 : *Aulacophora foevicollis*

(Coleoptera : Chrysomelidae)

This is orange red coloured beetle found to attack vegetables of Cucurbitaceae family in shifting cultivation field during March to April. Its another host plant recorded is *Cleorodendron* sp.

5.45 : *Epillachna* sp.

(Coleoptera : Coccinellidae)

This lady-bird beetle attacks Brinjal and Cucurbitaceae vegetables in shifting cultivation field as nymph as well as adult during March to May. Its another host plant recorded is *Michanea* sp., a weed in plantation forestry.

5.46 : *Mylebris phalerata*

(Coleoptera : Meloidae)

This blister beetle attacks the thatching grass as young as well as adult during May to July.

5.47 : *Chrysochroa chinensis*

(Coleoptera : Buprestidae)

Metallic green coloured Coleoptera found to make tunnels in the fallen wood in the forest during June to August.

5.48 : *Oxyia velox*

(Orthoptera : Acrididae)

This insect is found throughout the year in the forest on different trees and plants. Young and adult attack the rice field in shifting cultivation during March to May.

5.49 : *Leptocorixa varicornis*

(Hemiptera : Coreidae)

This insect is found to attack rice field as young as well as adult in shifting cultivation during April to May. Alternate host plants recorded were *Michanea* sp. and *Dipterocarpus* sp.

5.5 : RELATIVE TOXICITY

5.51 : Relative Toxicity Test on *Cyclosia panthona* :

5.511 : Relative Toxicity Test with Specific Insecticide :

Nuvacron 40 EC :

In this insecticidal treatment in 0.0025% concentration larval mortality of *Cyclosia panthona* was 0% at 1, 3 and 6 hrs, 2% at 12 hrs, 24% at 24 and 48 hrs. In 0.005% concentration mortality was 0% at 1, 3 and 6 hrs, 10% at 12 hrs, 28% at 24 and 48 hrs. In 0.01% concentration mortality was 0% at 1, 3 and 6 hrs, 12% at 12 hrs, 38% at 24 hrs and 40% at 48 hrs. In 0.02% concentration mortality was 0% at 1, 3 and 6 hrs, 26% at 12 hrs, 54% at 24 and 48 hrs. In 0.04% concentration mortality was 0% at 1, 3 and 6 hrs, 22% at 12 hrs, 60% at 24 hrs and 66% at 48 hrs (Table 5.14 and Figure 5.30).

There was no mortality in the control.

Cythion 50EC :

In this insecticidal treatment at 0.0025% concentration larval mortality was 0% at 1 and 3 hrs, 10% at 6 hrs, 14% at 12 hrs, 34% at 24 and 48 hrs. In 0.005% concentration mortality was 0% at 1 and 3 hrs, 18% at 6 hrs, 28% at 12 hrs,

Table 5.14: Mortality percentage of *Cyclosia panthona* Cram. larvae treated with Dry-film of Nuvacron 40EC, Cythion 50EC, Ekalaux 25EC and Thiodan 35EC.

Concentration Percentage	1hr	3hrs	6hrs	12hrs	24hrs	48hrs
			Nuvacron 40EC			
0.0025	0	0	0	2	24	24
0.005	0	0	0	10	28	28
0.01	0	0	0	12	38	40
0.02	0	0	0	26	54	58
0.04	0	0	0	22	66	66
Control	0	0	0	0	0	0
			Cythion 50EC			
0.0025	0	0	10	14	34	34
0.005	0	0	18	28	48	48
0.01	0	6	22	36	52	54
0.02	0	6	30	56	80	80
0.04	0	12	36	68	80	84
Control	0	0	0	0	0	0
			Ekalaux 25EC			
0.0025	0	6	10	40	48	48
0.005	0	16	52	78	90	90
0.01	0	24	74	90	96	96
0.02	0	26	84	100	100	100
0.04	0	18	90	100	100	100
Control	0	0	0	0	0	0
			Thiodan 35EC			
0.0025	0	8	16	50	54	58
0.005	0	56	88	88	92	92
0.01	0	52	76	100	100	100
0.02	0	56	82	100	100	100
0.04	0	68	94	100	100	100
Control	0	0	0	0	0	0

Figure 5·30: Mortality percentage of *Cyclosia panthona* Cram. larvae with Nuvacron 40EC treatment.

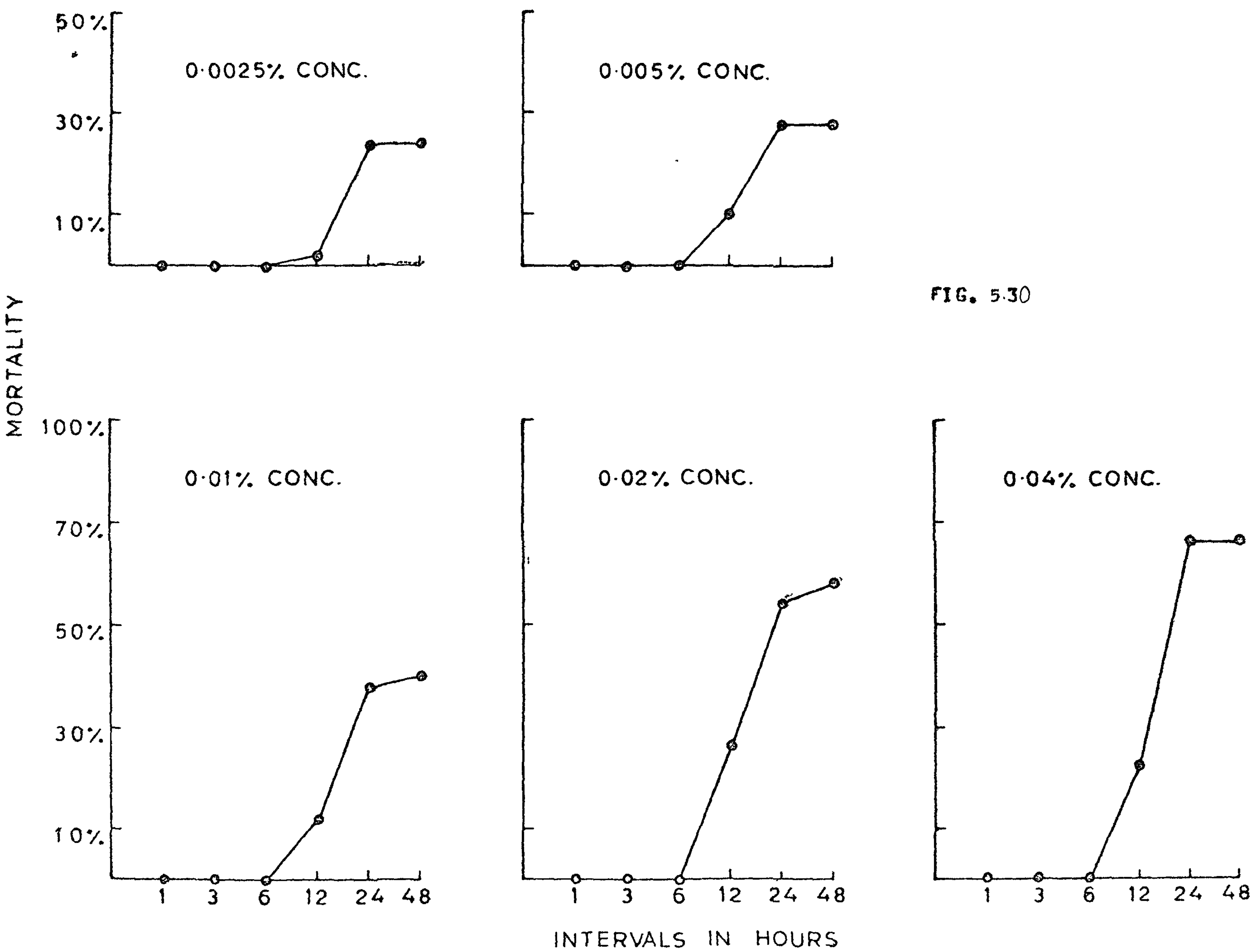
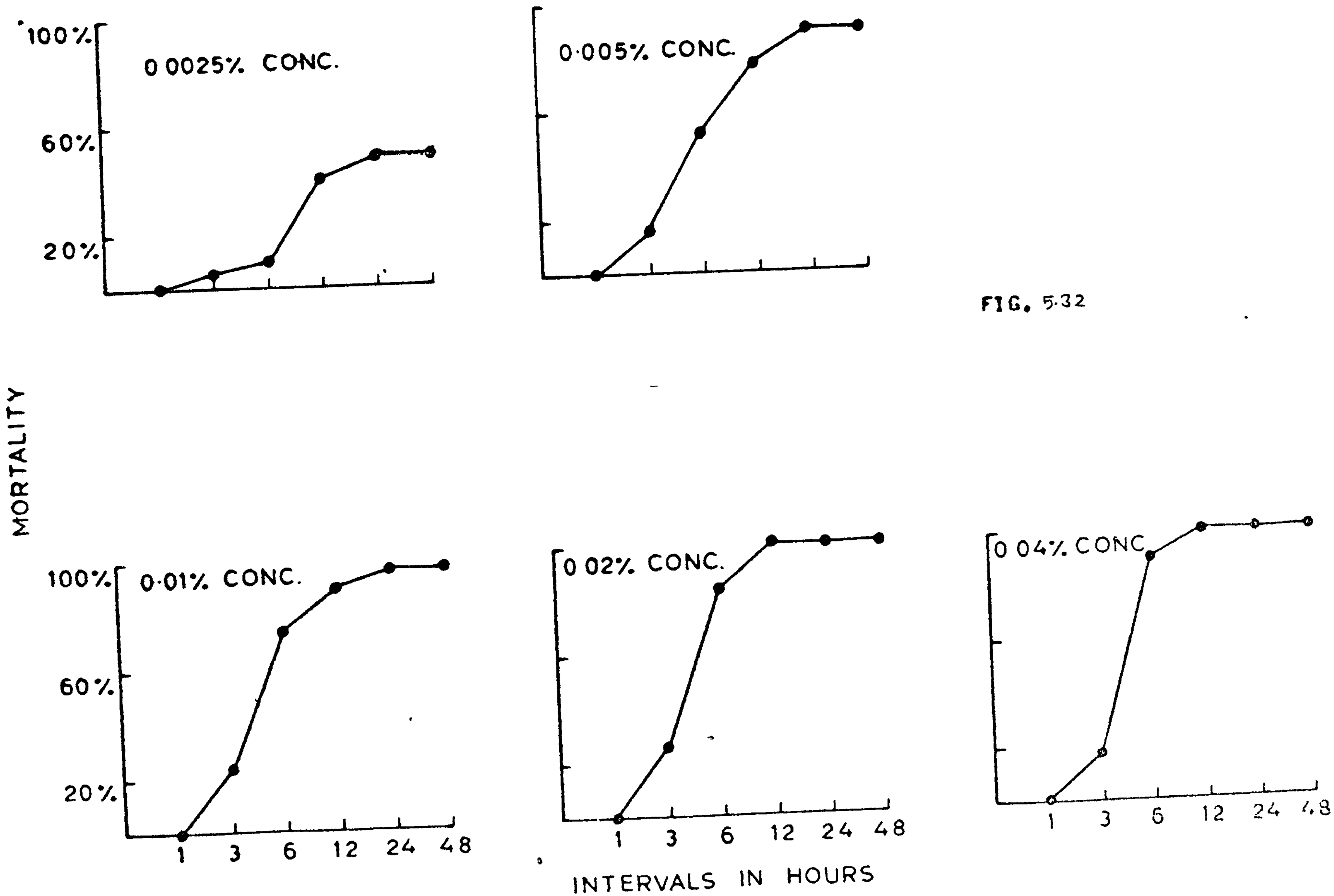

MORTALITY
50%
30%
10%
0·0025% CONC.
0·005% CONC.
100%
70%
50%
30%
10%
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
INTERVALS IN HOURS

FIG. 5.30

Figure 5.31 : Mortality percentage of *Cyclosia panthona* Cram. larvae with Cythion 50EC treatment.

Figure 5.32 : Mortality percentage of *Cyclosia panthona* Cram. larvae with Ekalaux 25EC treatment.



MORTALITY
100%
60%
20%
0 0025% CONC.
0·005% CONC.
0·01% CONC.
0 02% CONC.
0 04% CONC
1
3
6
12
24
48
INTERVALS IN HOURS

FIG. 5·32

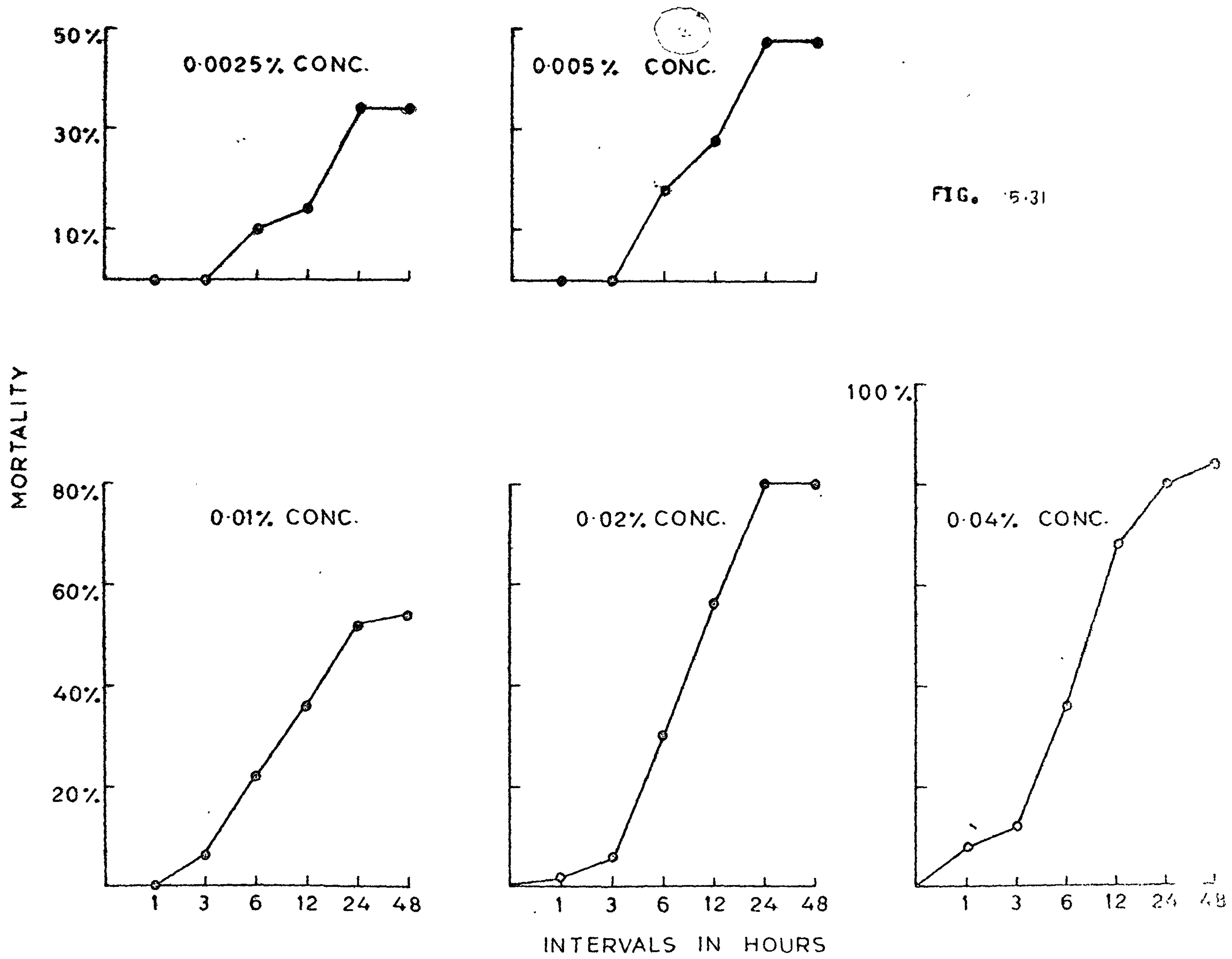
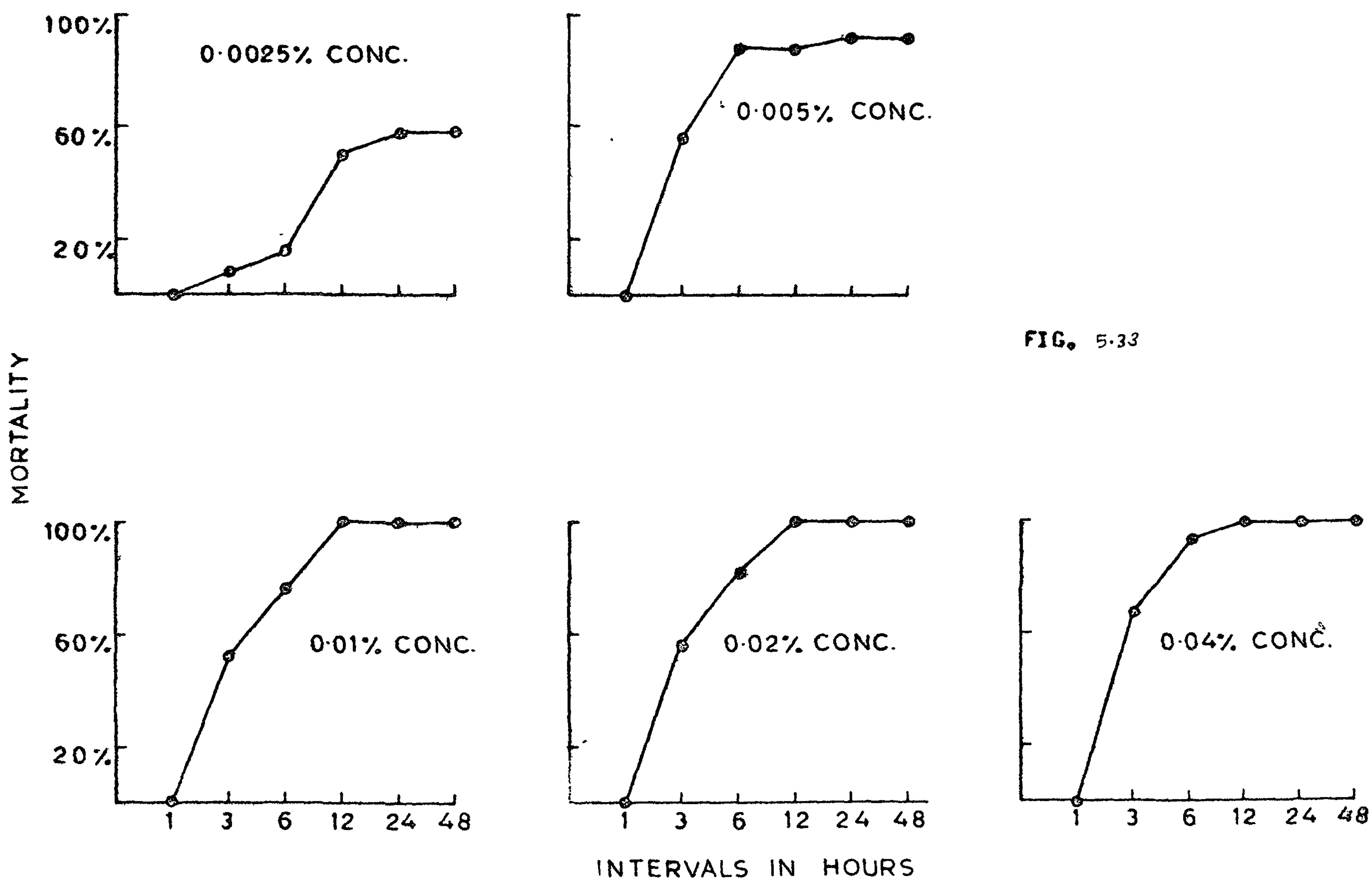

MORTALITY
50%
30%
10%
0·0025% CONC.
0·005% CONC.
80%
60%
40%
20%
100%
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
INTERVALS IN HOURS

FIG. 5·31

Figure 5.33 : Mortality percentage of *Cyclosia panthona* Cram. larvae with Thiodan 35EC treatment.



MORTALITY
100%
60%
20%
0·0025% CONC.
0·005% CONC.
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
INTERVALS IN HOURS

FIG. 5·33

48% at 24 and 48 hrs. In 0.01% concentration mortality was 0% at 1 hr, 6% at 3 hrs, 22% at 6 hrs, 36% at 12 hrs, 52% at 24 hrs and 54% at 48 hrs. In 0.02% concentration mortality was 0% at 1 hr, 6% at 3 hrs, 30% at 6 hrs, 56% at 12 hrs, 80% at 24 and 48 hrs. In 0.04% concentration mortality was 0% at 1 hr, 12% at 3 hrs, 36% at 6 hrs, 68% at 12 hrs, 80% at 24 hrs and 84% at 48 hrs (Table 5.14 and Figure 5.31).

There was no mortality in the control.

Ekalaux 25EC :

In this insecticidal treatment at 0.0025% concentration larval mortality was 0% at 1 hr, 6% at 3 hrs, 10% at 6 hrs, 40% at 12 hrs, 48% at 24 and 48 hrs. In 0.005% concentration mortality was 0% at 1 hr, 16% at 3 hrs, 52% at 6 hrs, 78% at 12 hrs, 90% at 24 and 48 hrs. In 0.01% concentration mortality was 0% at 1 hr, 24% at 3 hrs, 74% at 6 hrs, 90% at 12 hrs, 96% at 24 and 48 hrs. In 0.02% concentration mortality was 0% at 1 hr, 26% at 3 hrs, 84% at 6 hrs, 100% at 12, 24 and 48 hrs. In 0.04% concentration mortality was 0% at 1 hr, 18% at 3 hrs, 90% at 6 hrs, 100% at 12, 24 and 48 hrs. (Table 5.14 and Figure 5.32).

There was no mortality in the control.

Thiodan 35EC :

In this insecticidal treatment at 0.0025% concentration larval mortality was 0% at 1 hr, 8% at 3 hrs, 16% at 6 hrs, 50% at 12 hrs, 54% at 24 hrs and 58% at 48 hrs. In 0.005% concentration mortality was 0% at 1 hr, 56% at 3 hrs, 88% at 6 hrs and 12 hrs, 92% at 24 and 48 hrs. In 0.01% concentration mortality was 0% at 1 hr, 52% at 3 hrs, 76% at 6 hrs, 100% at 12, 24 and 48 hrs. In 0.02% concentration mortality was 0% at 1 hr, 56% at 3 hrs, 82% at 6 hrs, 100% at 12, 24 and 48 hrs. In 0.04% concentration mortality was 0% at 1 hr, 68% at 3 hrs, 94% at 6 hrs, 100% at 12, 24 and 48 hrs (Table 4.14 and Figure 4.33).

There was no mortality in the control.

5.512 : Relative Toxicity Analysis :

Relative toxicity of the four insecticides in five different concentrations and in six different time intervals have been shown in Figures 5.34 and 5.35.

Nuvacron 40EC did not cause mortality in 0.0025%, 0.005%, 0.01%, 0.02% and 0.04% concentrations at 1, 3 and 6 hrs of time intervals. In 0.0025% concentration first mortality (2%) was at 12 hrs and maximum mortality (24%) was recorded at 24 hrs. In 0.005% concentration first mortality (10%) was at 12 hrs and

Figure 5.34 : Relative mortality percentage of *Cyclosia panthona* Cram. larvae with Thiodan 35 EC, Ekalaux 25EC, Cythion 50EC and Nuvacfon 40EC.

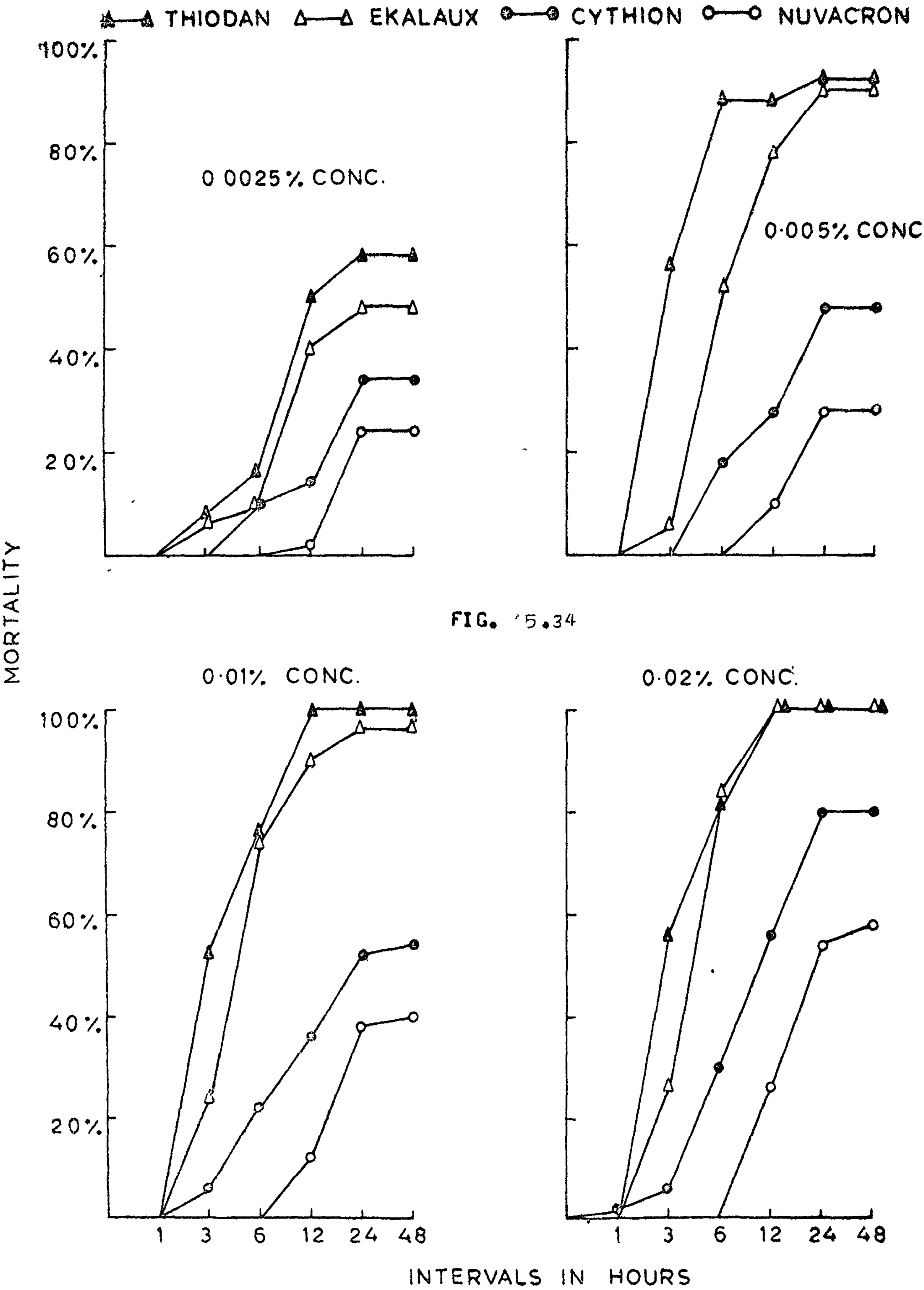
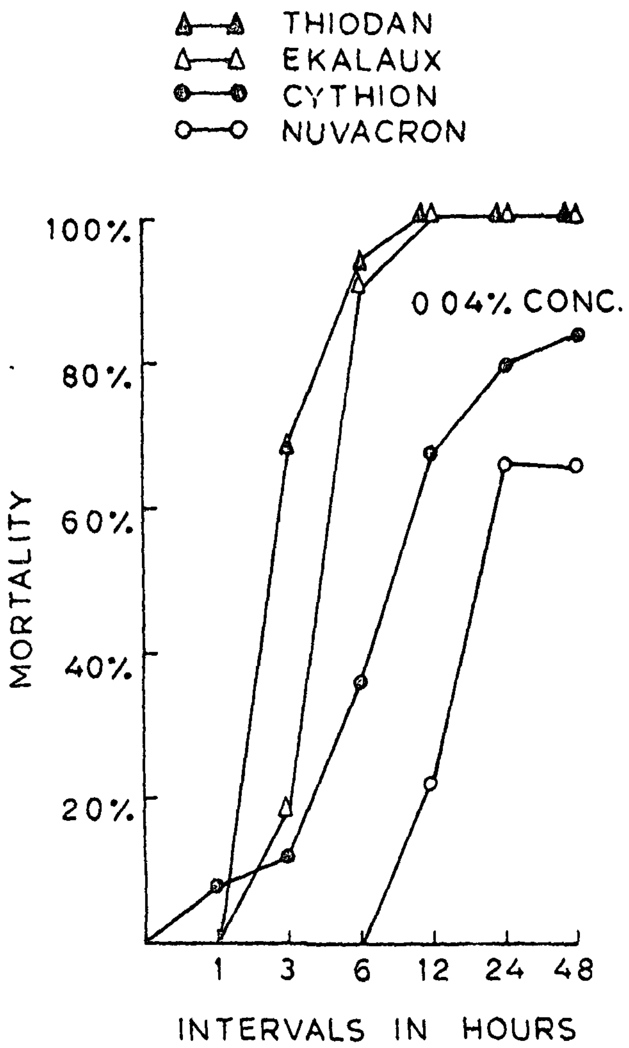

THIODAN
EKALAUX
CYTHION
NUVACRON
0 0025% CONC.
0·005% CONC.
0·01% CONC.
0·02% CONC.
MORTALITY
100%
80%
60%
40%
20%
1
3
6
12
24
48
INTERVALS IN HOURS

FIG. 5.34

Figure 5.35 : Relative mortality percentage of *Cyclosia panthona* Cram. with Thiodan 35EC, Ekalaux 25EC, Cythion 50EC and Nuvacron 40EC.

FIG. 5.35


THIODAN
EKALAUX
CYTHION
NUVACRON
100%
80%
60%
40%
20%
MORTALITY
0 04% CONC.
1
3
6
12
24
48
INTERVALS IN HOURS

maximum mortality (28%) was recorded at 24 hrs. In 0.01% concentration first mortality (12%) was at 12 hrs which progressively increased and maximum mortality (40%) was recorded at 48 hrs. In 0.02% concentration first mortality (26%) was at 12 hrs which progressively increased and maximum mortality (58%) was recorded at 48 hrs. In 0.04% concentration first mortality (22%) was at 12 hrs and maximum mortality (66%) was recorded at 24 hrs.

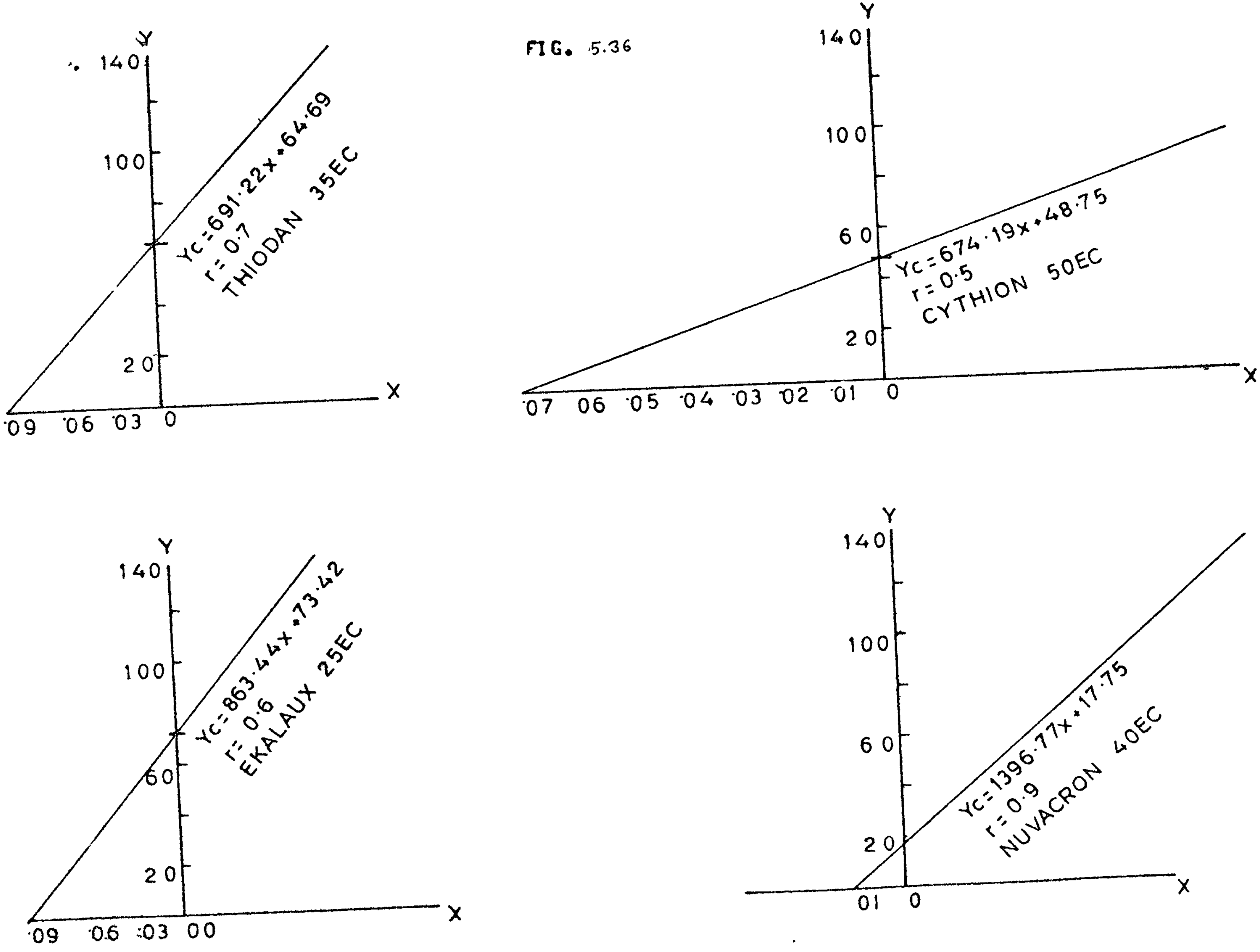
Cythion 50EC did not cause mortality in all the concentrations at 1 hr and in 0.0025% and 0.005% concentrations at 3 hrs. In 0.0025% concentration first mortality (10%) was at 6 hrs and maximum mortality (34%) was recorded at 24 hrs. In 0.005% concentration first mortality (18%) was at 6 hrs and maximum mortality (48%) was recorded at 24 hrs. In 0.01% concentration first mortality (22%) was at 6 hrs which progressively increased and maximum mortality (54%) was recorded at 48 hrs. In 0.02% concentration first mortality (30%) was at 6 hrs and maximum mortality (80%) was at 48 hrs. In 0.04% concentration first mortality (36%) was at 6 hrs which increased progressively and maximum mortality (84%) was recorded at 48 hrs.

Ekalaux 25EC did not cause mortality in all the concentrations at 1 hr of time interval but from 3 hrs onwards there was a progressive increase in mortality in all the concentrations. In 0.0025% concentration first mortality (6%) was at 3 hrs which increased progressively and maximum mortality (48%) was recorded at 24 hrs. In 0.005% concentration first mortality (16%) was at 3 hrs which increased progressively and maximum mortality (90%) was recorded at 24 hrs. In 0.01% concentration first mortality (24%) was at 3 hrs which increased progressively and maximum mortality (96%) was at 24 hrs. In 0.02% concentration first mortality (26%) was at 3 hrs which increased progressively and maximum mortality (100%) was recorded at 12 hrs. In 0.04% concentration first mortality (18%) was recorded at 3 hrs and maximum mortality (100%) was recorded at 12 hrs.

Thiodan 35EC caused progressive mortality from 3 hrs of time interval onwards in all the concentrations. In 0.0025% concentration first mortality (8%) was at 3 hrs and maximum mortality (58%) was recorded at 48 hrs. In 0.005% concentration first mortality (56%) was recorded at 3 hrs which increased upto maximum mortality (92%) at 24 hrs. In 0.01% concentration first mortality (52%) was at 3 hrs which increased upto maximum mortality (100%) at 12 hrs. In 0.02% concentration first mortality (56%) was recorded at 3 hrs and maximum mortality (100%) was recorded at

Figure 5.36 : Regression Equations and Regression Lines of Nuvacron 40EC, Cythion 50EC, Ekalaux 25EC and Thiodan 35EC treatments on *Cyclosia panthona* Cram. larvae.

FIG. 5.36


Y
140
100
20
X
·09 ·06 ·03 0
Yc=691·22x+64·69
r= 0·7
THIODAN 35EC
Y
140
100
60
20
X
·07 06 ·05 ·04 ·03 02 ·01 0
Yc=674·19x+48·75
r=0·5
CYTHION 50EC
Y
140
100
60
20
X
·09 ·06 ·03 00
Yc=863·44x+73·42
r= 0·6
EKALAUX 25EC
Y
140
100
60
20
X
01 0
Yc=1396·77x+17·75
r=0·9
NUVACRON 40EC

12 hrs. In 0.04% concentration first mortality (68%) was recorded at 3 hrs which increased progressively and maximum mortality (100%) was recorded at 12 hrs.

An analysis of the relative toxicity of the four insecticides confirms that Nuvacron 40EC was the least toxic among all. Cythion 50EC was recorded as more toxic than Nuvacron 40EC. Ekalaux 25EC proved highly toxic and more effective than Nuvacron 40EC and Cythion 50EC. Thiodan 35EC proved as the most toxic among the four insecticides tested on the larvae of *Cyclosia panthona*. Regression Equations and Regression Lines of the relative toxicity of the four insecticides has been shown in Figure 28.

Ascending order of the relative toxicity of the four insecticides can be summarised as follows : Nuvacron 40EC, Cythion 50EC, Ekalaux 25EC and Thiodan 35EC.

5.52 : Relative Toxicity Test on *Diaphania laticostalis* :

5.521 : Relative Toxicity Test with Specific Insecticide :

Cythion 50EC:

In this insecticidal treatment there was no mortality of *Diaphania laticostalis* larvae in 0.0025%, 0.005% and 0.01% concentrations at all the time intervals. In 0.02% concentration mortality was 0% at 1, 3, 6 and 12 hrs, 6% at 24 and 48 hrs. In 0.04% concentration mortality was 0% at 1, 3, 6 and 12 hrs, 8% at 24 hrs and 12% at 48 hrs. Mortality percentage in different concentrations and at different time intervals have been shown in Table 5.15 and Figure 5.37.

There was no mortality in the control.

Thiodan 35EC :

In this insecticidal treatment in 0.0025% concentration larval mortality was 0% at 1, 3, 6 and 12 hrs, 4% at 24 hrs and 6% at 48 hrs. In 0.005% concentration mortality was 0% at 1 and 3 hrs, 4% at 6 hrs, 20% at 12 hrs, 34% at 24 and 48 hrs. In 0.01% concentration mortality was 0% at 1 and 3 hrs, 4% at 6 hrs, 26% at 12 hrs, 46% at 24 hrs and 50% at 48 hrs. In 0.02% concentration mortality was 0% at 1 and 3 hrs, 4% at 6 hrs, 30% at 12 hrs, 36% at 24 hrs

Table 5.15: Mortality percentage of *Diaphania laticostalis* Guene larvae treated with Dry-film of Cythion 50EC, Thiodan 35EC, Nuvacron 40EC and Ekalaux 25EC.

Concentration Percentage	1hr	3hrs	6hrs	12hrs	24hrs	48hrs
			Cythion 50EC			
0.0025	0	0	0	0	0	0
0.005	0	0	0	0	0	0
0.01	0	0	0	0	0	0
0.02	0	0	0	0	6	6
0.04	0	0	0	0	8	12
Control	0	0	0	0	0	0
			Thiodan 35EC			
0.0025	0	0	0	0	4	6
0.005	0	0	4	20	34	34
0.01	0	0	4	26	46	50
0.02	0	0	4	30	36	48
0.04	0	2	8	36	60	62
Control	0	0	0	0	0	0
			Nuvacron 40EC			
0.0025	0	6	6	6	18	18
0.005	0	10	24	36	58	58
0.01	2	16	28	46	64	64
0.02	6	24	44	62	74	76
0.04	6	20	46	60	80	80
Control	0	0	0	0	0	0
			Ekalaux 25EC			
0.0025	0	0	2	6	18	18
0.005	0	6	20	50	52	52
0.01	8	24	32	42	56	58
0.02	12	32	44	62	74	74
0.04	14	32	40	68	82	84
Control	0	0	0	0	0	0

Figure 5.37 : Mortality percentage of *Diaphania laticostalis* Guene larvae with Cythion 50EC treatment.

FIG. 5.37

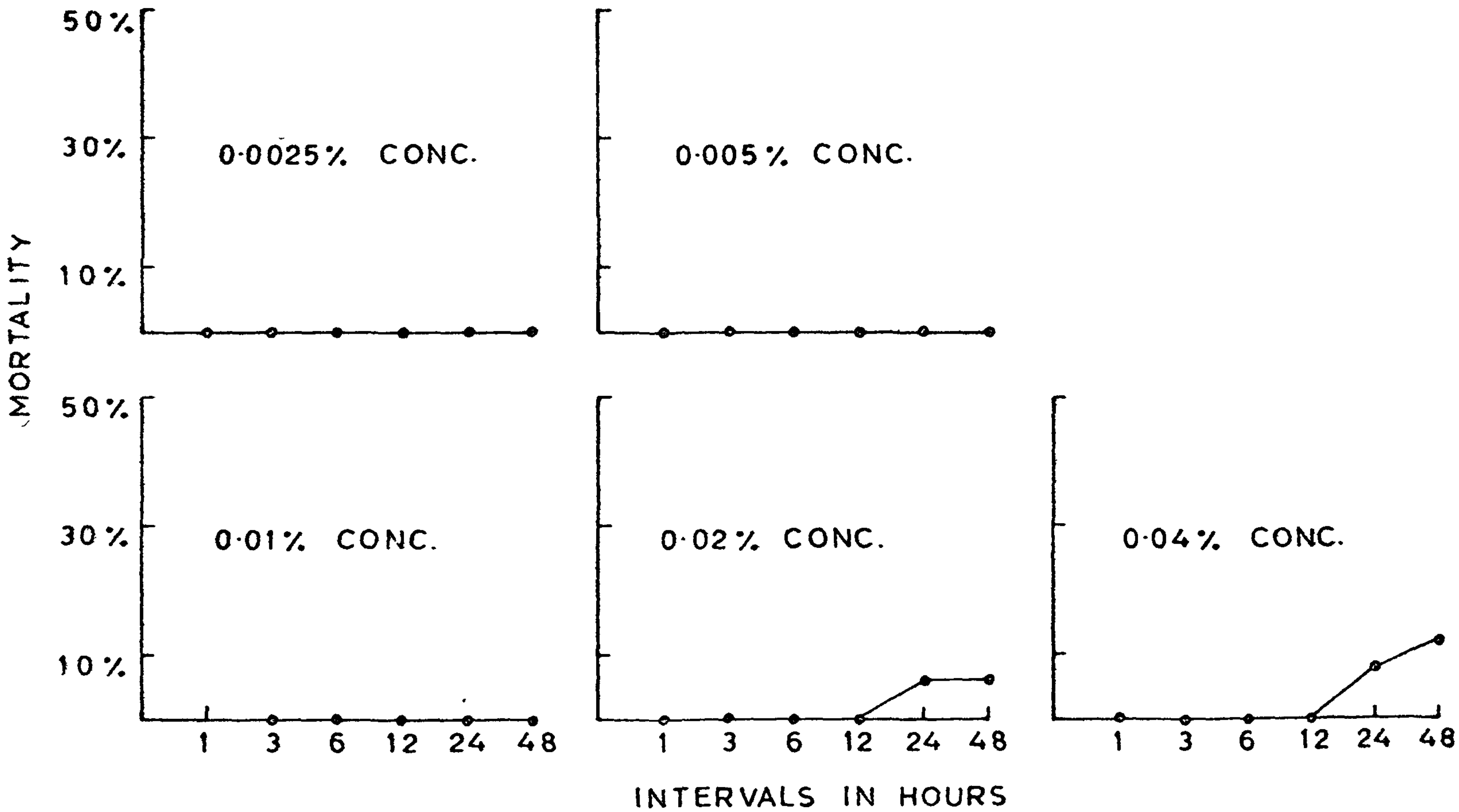

MORTALITY
50%
30%
10%
0·0025% CONC.
0·005% CONC.
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
INTERVALS IN HOURS

Figure5.38 : Mortality percentage of *Diaphania laticostalis* Guene larvae with Thiodan 35EC treatment.

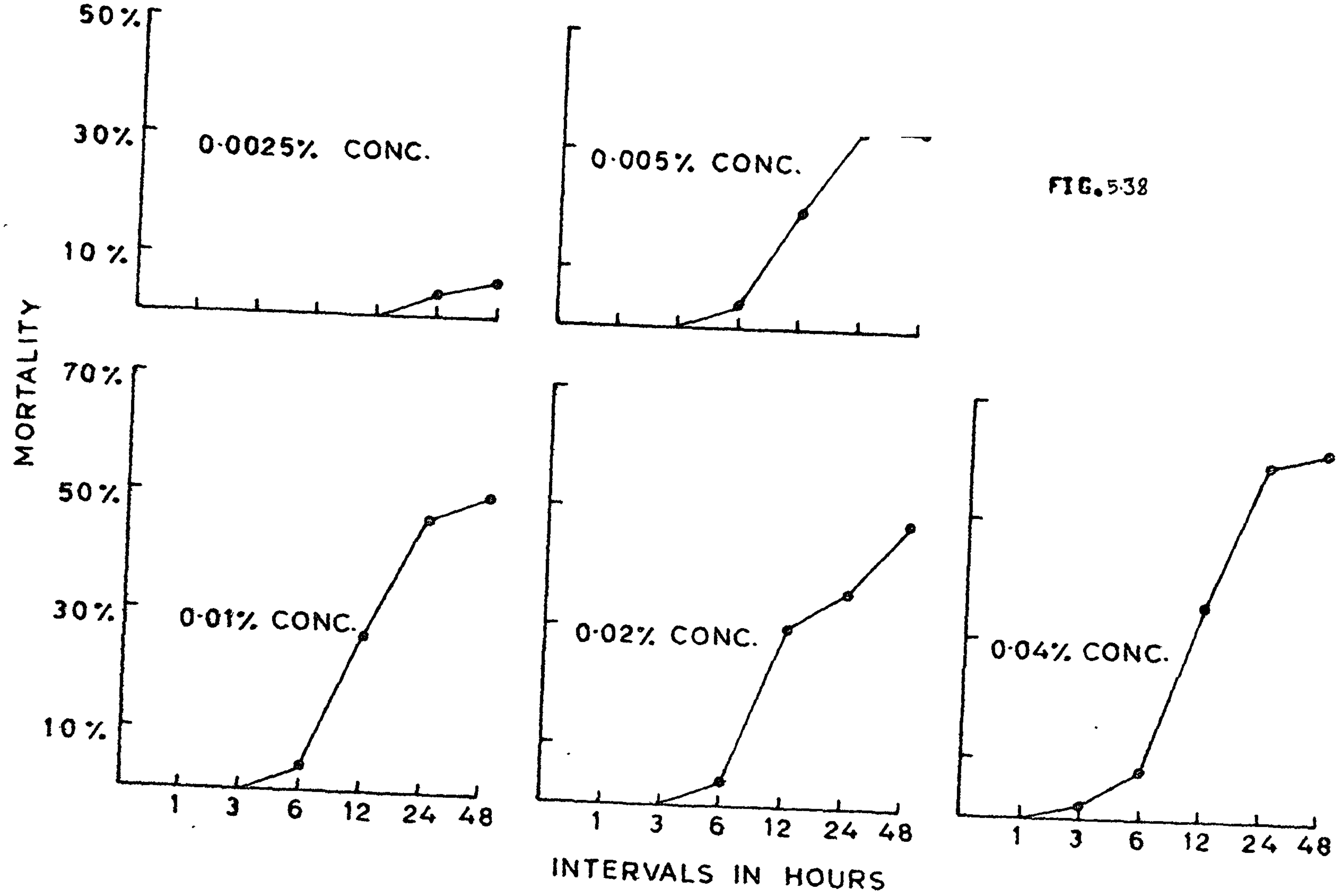
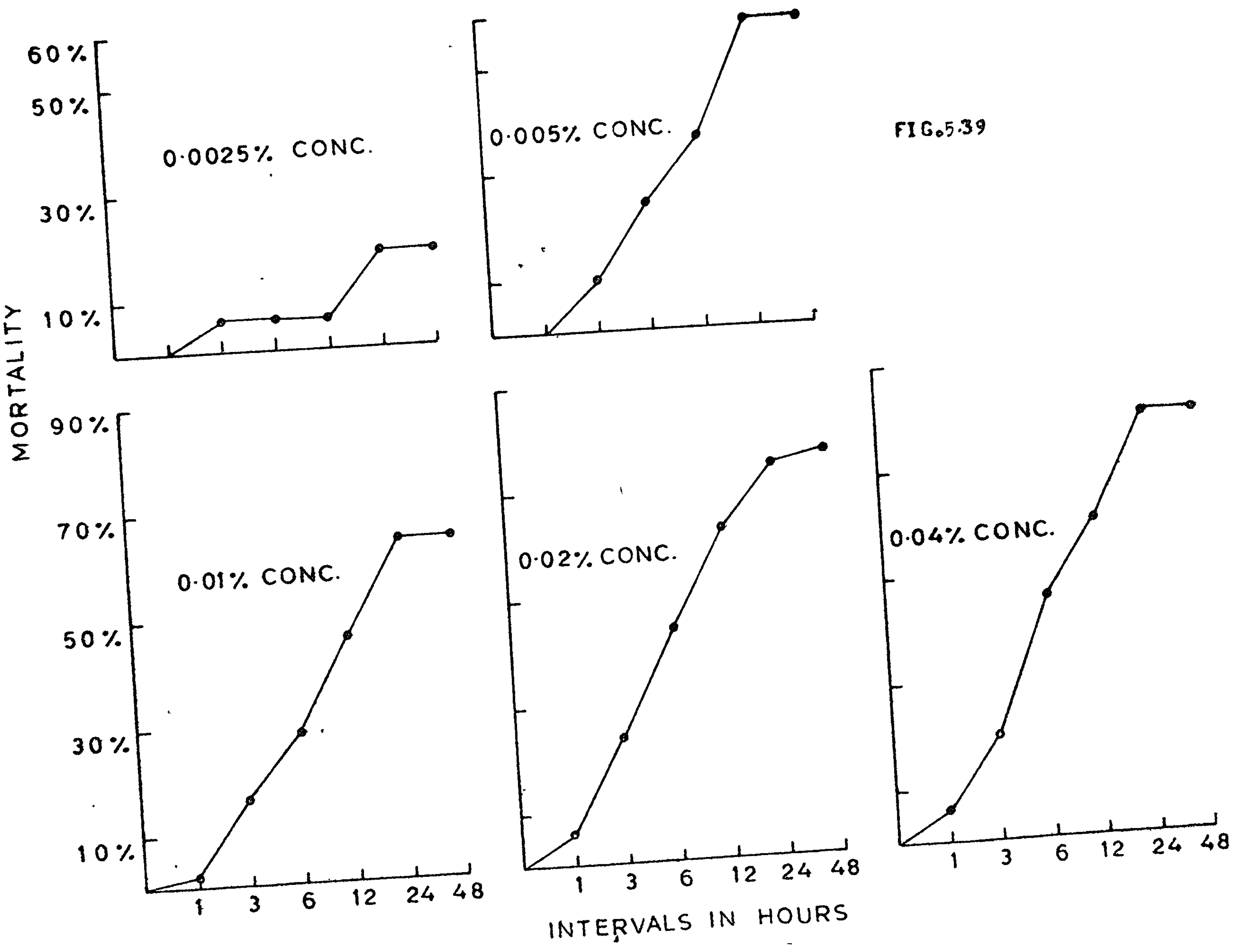

MORTALITY
50%
30%
10%
70%
50%
30%
10%
0·0025% CONC.
0·005% CONC.
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
1 3 6 12 24 48
1 3 6 12 24 48
INTERVALS IN HOURS

FIG. 5·38

Figure 539 : Mortality percentage of *Diaphania laticostalis* Guene larvae with Nuvacron 40EC treatment.



MORTALITY
60%
50%
30%
10%
0·0025% CONC.
0·005% CONC.
90%
70%
50%
30%
10%
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
1 3 6 12 24 48
1 3 6 12 24 48
INTERVALS IN HOURS

FIG.5.39

Figure 5.40: Mortality percentage of *Diaphania laticostalis* Guene larvae with Ekalaux 25EC treatment.

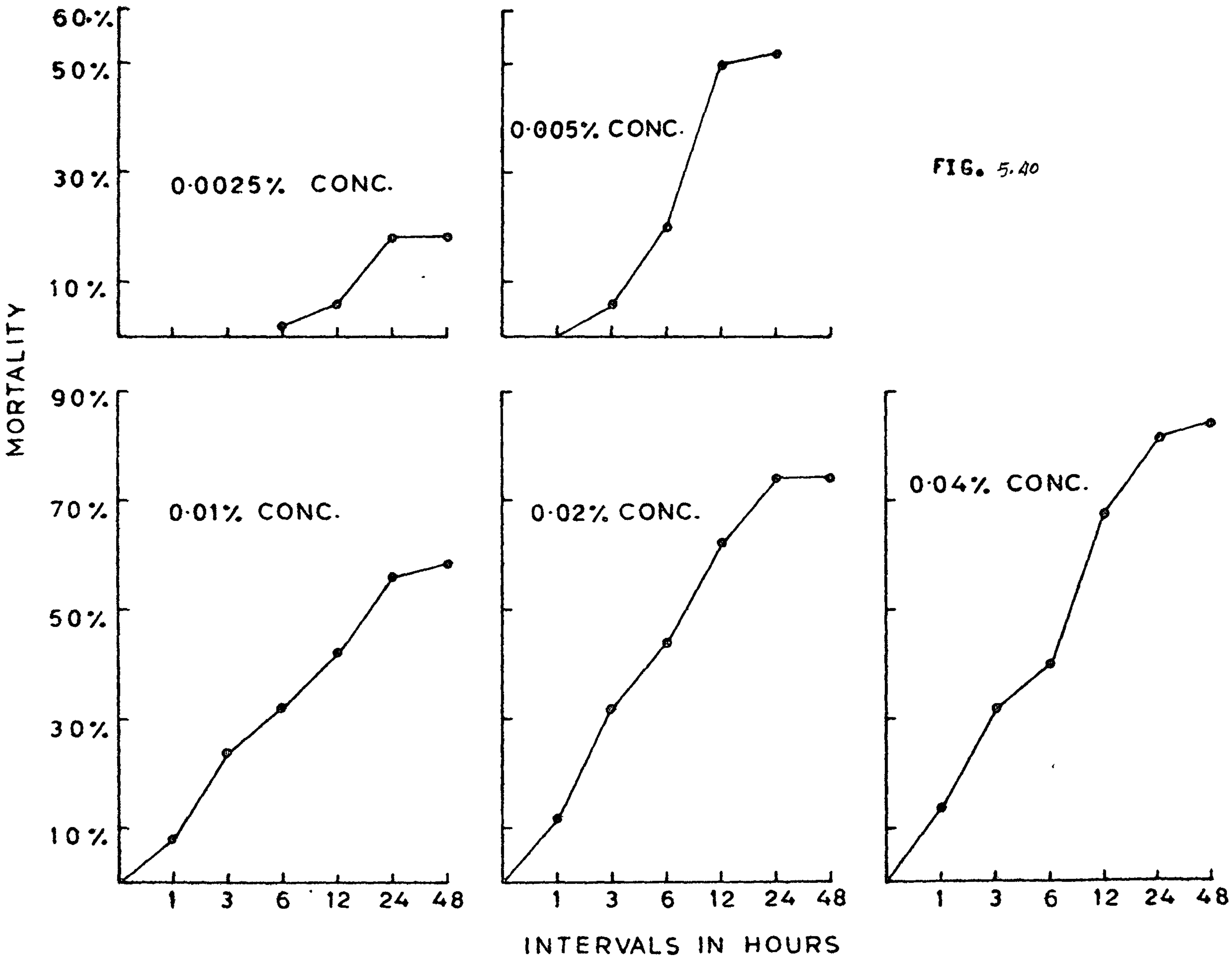

MORTALITY
60%
50%
30%
10%
90%
70%
50%
30%
10%
0·0025% CONC.
0·005% CONC.
0·01% CONC.
0·02% CONC.
0·04% CONC.
1 3 6 12 24 48
INTERVALS IN HOURS

FIG. 5.40

and 48% at 48 hrs. In 0.04% concentration mortality was 0% at 1 hr, 2% at 3 hrs, 8% at 6 hrs, 36% at 12 hrs, 60% at 24 hrs and 62% at 48 hrs (Table 5.15 and Figure 5.38).

There was no mortality in the control.

Nuvacron 40EC :

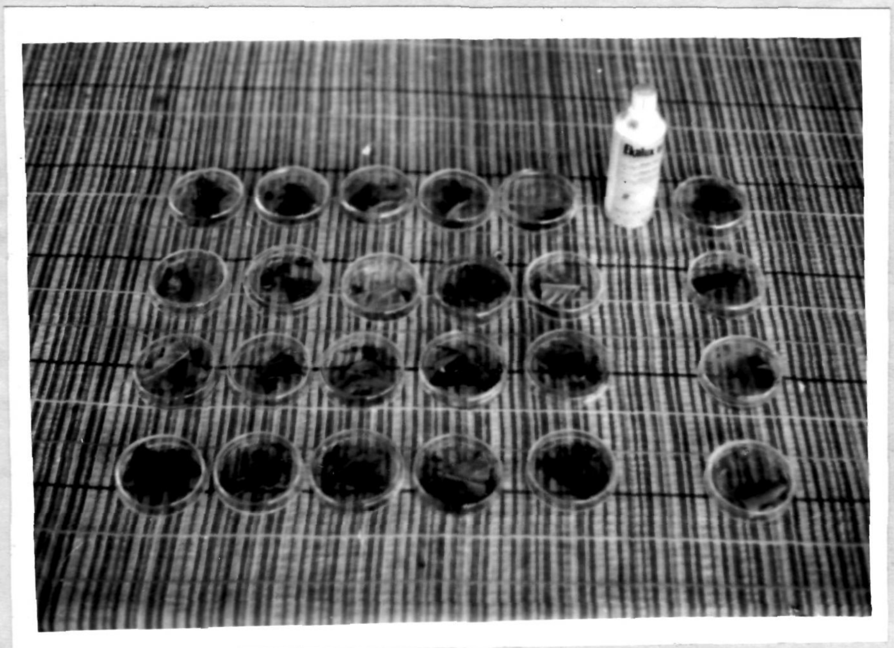
In this insecticidal treatment in 0.0025% concentration mortality was 0% at 1 hr, 6% at 3, 6 and 12 hrs, 18% at 24 and 48 hrs. In 0.005% concentration mortality was 0% at 1 hr, 10% at 3 hrs, 24% at 6 hrs, 36% at 12 hrs, 58% at 24 and 48 hrs. In 0.01% concentration mortality was 2% at 1 hr, 16% at 3 hrs, 28% at 6 hrs, 46% at 12 hrs, 64% at 24 and 48 hrs. In 0.02% concentration mortality was 6% at 1 hr, 24% at 3 hrs, 44% at 6 hrs, 62% at 12 hrs, 74% at 24 hrs and 76% at 48 hrs. In 0.04% concentration mortality was 6% at 1 hr, 20% at 3 hrs, 46% at 6 hrs, 60% at 12 hrs, 80% at 24 hrs and 48 hrs (Table 5.15 and Figure 5.39).

There was no mortality in the control.

Ekalaux 25EC :

In this insecticidal treatment in 0.0025% concentration mortality was 0% at 1 and 3 hrs,

Figure 5.41 : Dry-film Experiment on *Diaphania laticostalis* larvae with Ekalaux 25EC.



2% at 6 hrs, 6% at 12 hrs, 18% at 24 and 48 hrs. In 0.005% concentration mortality was 0% at 1 hr, 6% at 3 hrs, 20% at 6 hrs, 50% at 12 hrs, 52% at 24 and 48 hrs. In 0.01% concentration mortality was 8% at 1 hr, 24% at 3 hrs, 32% at 6 hrs, 42% at 12 hrs, 56% at 24 hrs and 58% at 48 hrs. In 0.02% concentration mortality was 12% at 1 hr, 32% at 3 hrs, 44% at 6 hrs, 62% at 12 hrs, 74% at 24 and 48 hrs. In 0.04% concentration mortality was 14% at 1 hr, 32% at 3 hrs, 40% at 6 hrs, 68% at 12 hrs, 82% at 24 hrs and 84% at 48 hrs (Table 5.15 and Figure 5.40 and 5.41.

There was no mortality in the control.

5.522 : Relative Toxicity Analysis :

The relative toxicity of the four insecticides in five different concentrations and in six different time intervals have been shown in Figure 5.42 and 5.43.

Cythion 50EC did not cause larval mortality in 0.0025%, 0.005% and 0.01% concentrations at all the time intervals. In 0.02% concentration first mortality (6%) was recorded at 24 hrs which did not

Figure 6.42: Relative mortality percentage of *Diaphania laticostalis* Guene larvae with Cythion 50EC, Thiodan 35EC, Nuvacron 40EC and Ekalaux 25EC.

FIG. 5 42

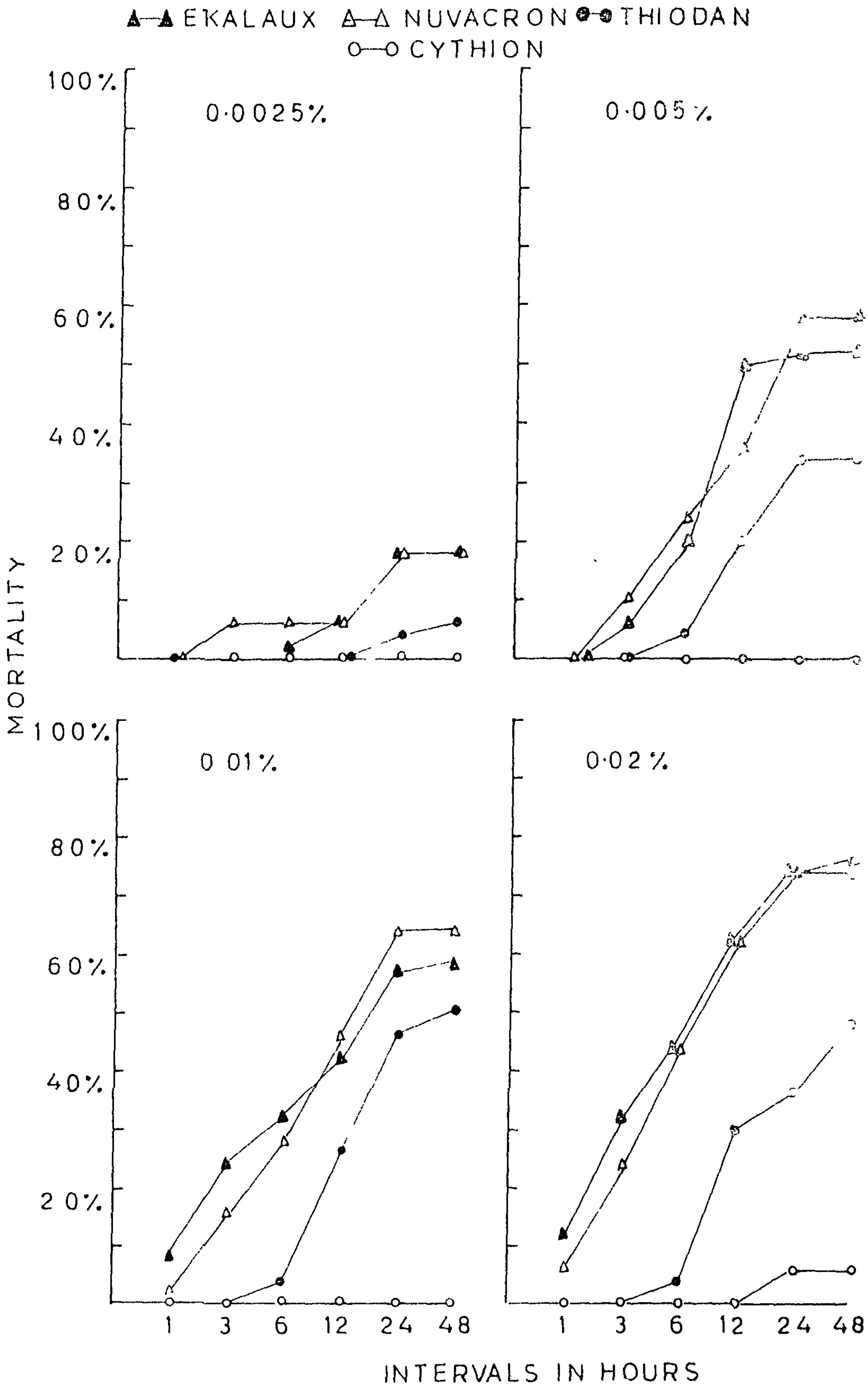
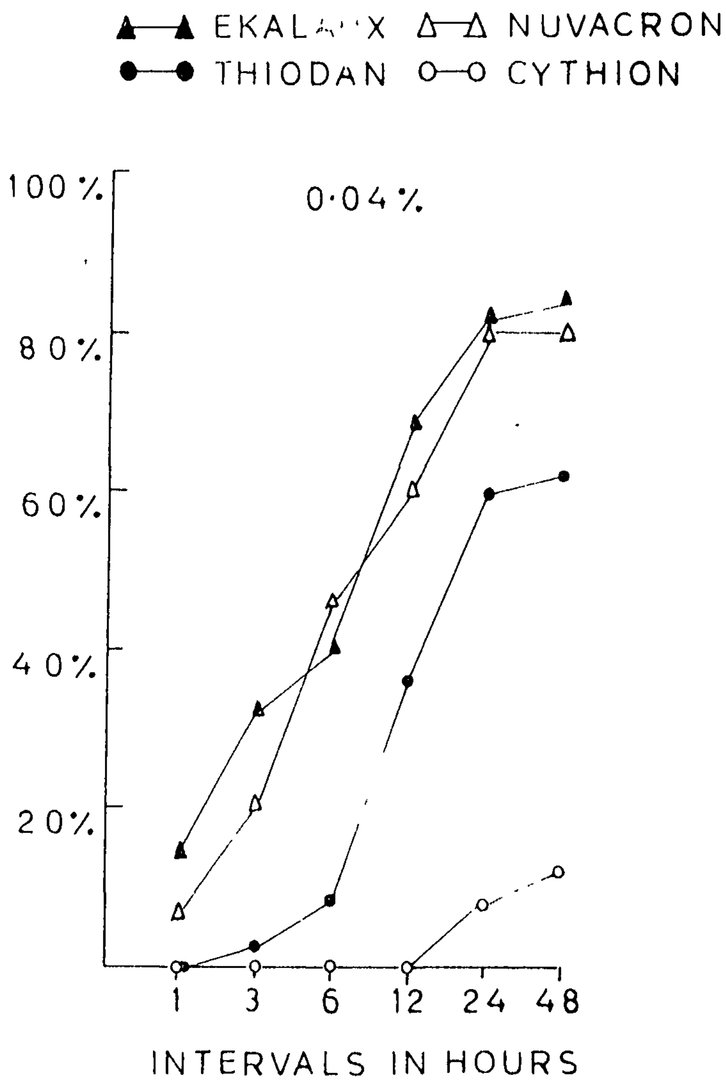

EKALAUX
NUVACRON
THIODAN
CYTHION
MORTALITY
100%
80%
60%
40%
20%
0·0025%
0·005%
0 01%
0·02%
1
3
6
12
24
48
INTERVALS IN HOURS

Figure 5.43: Relative mortality percentage of *Diaphania laticostalis* Guene larvae with Cythion 50EC, Thiodan 35EC, Nuvacron 40EC and Ekalaux 25EC.

FIG. 5.43



EKAL..X
NUVACRON
THIODAN
CYTHION
100 %
80 %
60 %
40 %
20 %
0·04 %
1
3
6
12
24
48
INTERVALS IN HOURS

increase in next time interval. In 0.04% concentration first mortality (8%) was at 24 hrs which increased progressively and maximum mortality (12%) was recorded at 48 hrs.

Thiodan 35EC did not cause mortality in 0.0025% concentration at 1, 3, 6 and 12 hrs, while first mortality (4%) was at 24 hrs and maximum mortality (6%) was recorded at 48 hrs. In 0.005% concentration there was no mortality at 1 and 3 hrs while first mortality (4%) was at 6 hrs and maximum mortality (34%) was recorded at 24 hrs. In 0.01% concentration first mortality (4%) was at 6 hrs which increased progressively and maximum mortality (50%) was recorded at 48 hrs. In 0.02% concentration first mortality (4%) was at 6 hrs and maximum mortality (48%) was recorded at 48 hrs. In 0.04% concentration first mortality (2%) was recorded at 3 hrs which increased progressively and maximum mortality (62%) was recorded at 48 hrs.

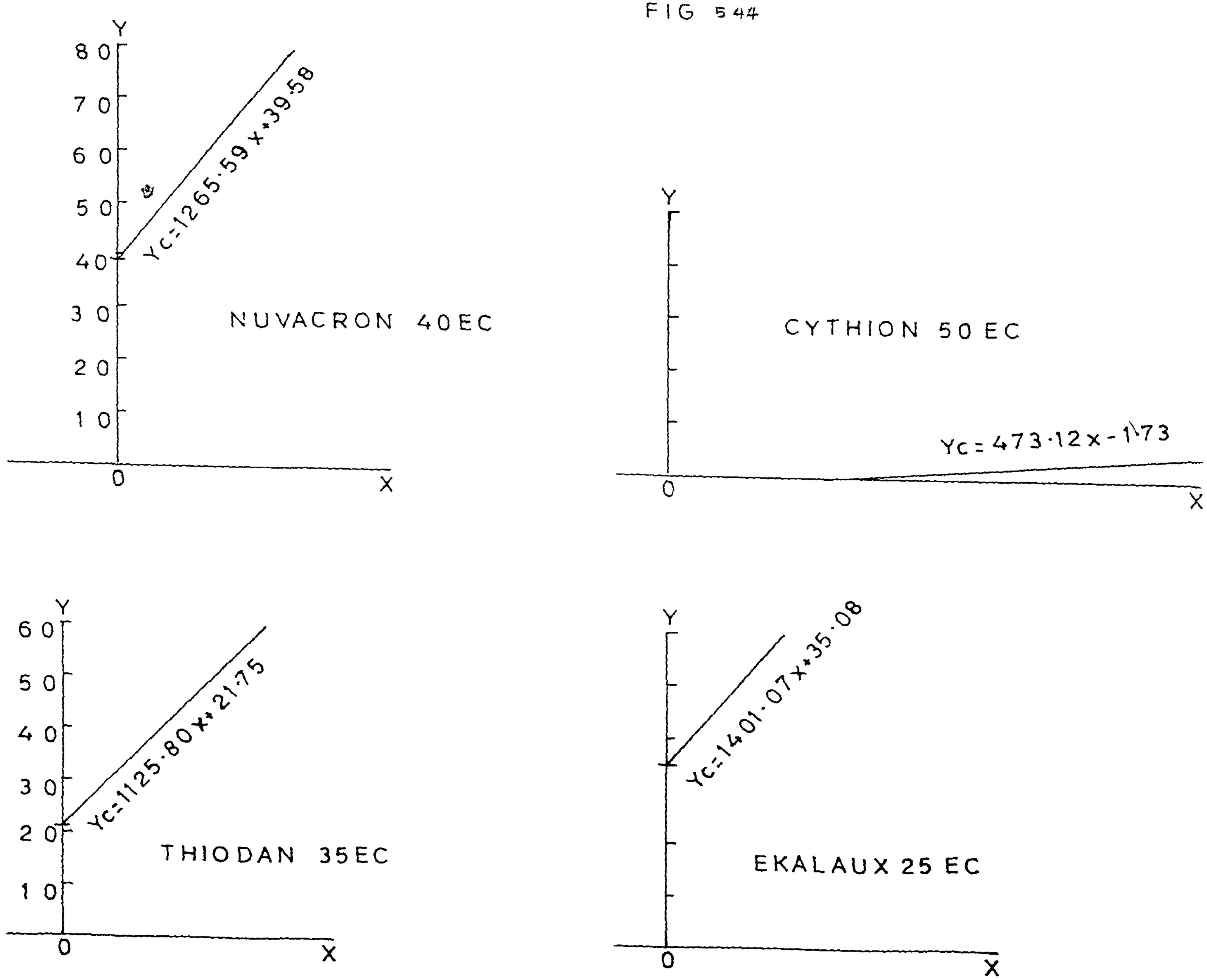
Nuvacron 40EC caused first mortality (6%) at 3 hrs which increased progressively and maximum mortality (18%) was recorded at 24 hrs in 0.0025% concentration. In 0.005% concentration first mortality (10%) was recorded at 3 hrs after which there was a progressive increase and maximum mortality (58%) was at 24 hrs. In 0.01% concentration first mortality (2%)

was recorded at 1 hr after which there was a progressive increase in mortality and maximum mortality (64%) was recorded at 24 hrs. In 0.02% concentration first mortality (6%) was recorded at 1 hr which increased progressively and maximum mortality (76%) was at 48 hrs. In 0.04% concentration first mortality (6%) was recorded at 1 hr after which there was a progressive increase and maximum mortality (80%) was at 24 hrs.

Ekalaux 25EC in 0.0025% concentration caused first mortality (2%) at 6 hrs after which there was a progressive increase and maximum mortality (18%) was recorded at 24 hrs. In 0.005% concentration first mortality (6%) was recorded at 3 hrs which increased progressively and maximum mortality (52%) was recorded at 24 hrs. In 0.01% concentration first mortality (8%) was recorded at 1 hr after which there was a progressive increase and maximum mortality (58%) was recorded at 48 hrs. In 0.02% concentration first mortality (12%) was at 1 hr after which there was a progressive increase in mortality and maximum mortality (74%) was recorded at 24 hrs. In 0.04% concentration first mortality (14%) was at 1 hr after which there was a progressive increase and maximum mortality (84%) was recorded at 48 hrs.

Figure 5.44: Regression Equations and Regression Lines of Nuvacron 40EC, Cythion 50EC, Thiodan 35EC and Ekalaux 25EC treatments on *Diaphania laticostalis* Guene larvae.

FIG 544



Y
80
70
60
50
40
30
20
10
0
X
Yc=1265·59x+39·58
NUVACRON 40EC
Y
0
X
Yc=473·12x-1·73
CYTHION 50 EC
Y
60
50
40
30
20
10
0
X
Yc=1125·80x+21·75
THIODAN 35EC
Y
0
X
Yc=1401·07x+35·08
EKALAUX 25 EC

An analysis of the relative toxicity of the four insecticides confirms that Cythion 50EC was the least toxic among all on *Diphania laticostalis* larvae. Thiodan 35EC was recorded to be quite slow in action but more toxic than Cythion 50EC. Nuvacron 40EC was highly toxic and more effective than Cythion 50EC and Thiodan 35EC. Ekalaux 25EC was recorded as the most toxic among all the tested insecticides. Regression Equations and Regression Lines of the relative toxicity of the insecticides has been shown in Figure 5.44.

Ascending order of the relative toxicity of the four insecticides can be summarised as follows : Cythion 50EC, Thiodan 35EC, Nuvacron 40EC and Ekalaux 25EC.

DISCUSSION

SURVEY AND COLLECTION OF INSECTS :

Faunistic surveys provide a good picture of the varieties of the insects present in the forest. The present survey revealed the occurrence of insects belonging to 14 different orders out of which 134 numbers of species have been identified.

The present list of the identified insects might help forest Entomologists for forestry management practices and may be of taxonomic value of the insect fauna in the Northeastern Hills of India.

LIGHT-TRAP :

In the present investigation 13 different insect orders were collected by light-trap. Earlier, Reddy (1980) reported 14 orders of insects in a similar light-trap collection in a forest system near Shillong. He included Arachnida also as an insect order.

In the present investigation the number of the total insect collection in the first year was much larger than that of the second year.

Similarly, the total number of insects collection in each order in the first year was larger than that of the second year except Trichoptera, which was more or less same in both the years; Plecoptera and Isoptera which were more in numbers in the second year. Such annual variation in the insect numbers have been reported by Deavy, Taylor and Barrett, Jr. (1964), Bakke (1978) and Reddy (1980). Yates and Ebel (1975a) reported similar results where certain groups of insects were totally absent in the succeeding years. Ray-Chaudhury stated that natality was one of the main causes of insect multiplication in any ecosystem. The fall in the catch in the second year of investigation may therefore be due to the elimination of the gravid females by light-trap during the previous year.

The correlation co-efficient between the orderwise collection of insects of the two years were positively significant for most of the insect orders. This shows relationship with the collection for every order between the twp years. However, no relationship could be found in the cases of Coleoptera and Dictyoptera.

MONTHLY FLUCTUATION :

The monthly total insect collection of the first year and the second year exhibited a similar trend in collection (Tables 1.1 and 1.2). During both the years minimum catch was in January and maximum catch was in October. There were two peaks of catch in July and October in both the years. Such regularity may be due to the undisturbed vegetation in the forest as well as similar climatic factors during the two years of study, as rainfall, temperature etc. are vital for increase or decrease of the insect numbers (Cantelo et. al. 1973, Frith 1975). The temperature correlation with the catch of Lepidoptera, Orthoptera, Trichoptera, Plecoptera, Odonata during the first year and of Lepidoptera, Hymenoptera, Coleoptera, Dictyoptera, Trichoptera, Hymenoptera, Plecoptera, Dermaptera during the second year strongly support this view.

HOURLY FLUCTUATION :

The quantitative analysis of the hourly activity of the insects revealed that most of the insects were caught during the first half of the night which covers 84.30% and the second half covers only 15.36% of the total insect catch of the entire study period. During December, 1979 and January, 1980 there were no catch in 3rd quarter (23.00 - 03.00 hrs) and 4th quarter (03.00 - 06.00 hrs) and during February, 1980 there was no catch in 3rd quarter (23.00 - 03.00 hrs) only. For the rest of the months there were always representative catches in every quarter (Table 4.3).

The analysis of the entire study period shows that maximum catch was in the 2nd quarter (46.14%) followed by the 1st quarter (38.02%), the 3rd quarter (10.62%) and 4th quarter (4.73%). Similar type of findings have been reported by Hanna (1969) and Reddy (1980) that the number of insects decreases after the mid-night. In our study the peak activity was found to be 2nd quarter (20.00-23.00 hrs) of the night. Graham, Glick and Martin (1964), Gentry and Davis (1973) also reported that the peak activity of insect groups was near or slightly before mid-night. Reddy (1980) recorded highest catch in the first quarter (18.00 - 21.00hrs) of the night in a forest near Shillong. This early insect activity around Shillong may be due to comparatively cool climate than that of Balphakram forest. In full contrast to the above, greater catch after mid-night have been reported by Glick and Hollingsworth

(1954) in the case of pink Boll-worm moth, Haddow (1961) in the case of Diptera, Standfast (1965) and Gladnery and Turner (1970) in the case of mosquitoes. Apparently this contrast may be due to the site of study and environmental factors. This indicate also different time periods of activity of different insect groups.

ORDERWISE ANALYSIS :

DIPTERA :

The catch number of Diptera showed more or less similar trend in both the annual cycles. The relative abundance was quite low during cold and dry season from November to May. With the onset of rainy season the relative abundance increased from July till October with maximum catch in October (Figure 2). There are two peaks in July and October in each year. Such bimodal pattern reflects that there are at least two phases of emergence of this order in a year. Similar findings were reported by Jamnback and Matheus (1963), Kline and Axtell (1976) and Reddy (1980)

The effect of temperature, humidity and rainfall on the total Diptera catch had no significant correlation at $P < 0.01$ and $P < 0.05$ levels. However, significance of rainfall on Diptera collection was recorded by Williams (1961) and Reddy (1980). Significance of minimum temperature on Diptera was reported by Bradley and Mc Neal (1935) and Porter and Gojmerac (1970).

Of the five families, Chironomidae was the dominant family and comprised of 67.24% and 70.03% of the total annual Diptera catch of the first year and the second year, respectively. Thus, relative abundance of Diptera is largely reflecting the abundance of Chironomidae.

Chironomidae, Cecidomyiidae and Tipulidae had two peaks of catch in July and October in the annual cycle which confirm at least two generations or two phases of emergence of these insects in a year. Syrphidae and Drosophilidae catches were very irregular and insufficient for any conclusion. (Figure 3).

Hourly analysis of Diptera catch in the first year shows that maximum catch (19.82%) was during 18.00 - 19.00 hrs and minimum catch (0.56%) was during 04.00 - 05.00 hrs (Table 4.1).

In the second year maximum catch (22.62%) was in 19.00 - 20.00 hrs and minimum catch (0.70%) was in 04.00 - 05.00 hrs (Table 4.2).

LEPIDOPTERA :

Monthwise catch fluctuations of Lepidoptera were similar in both the years but the second year catch was much less than that of the first year. This is probably due to the catch of gravid females in the preceding year (Ray-Chaudhury 1975, Reddy 1980). The catches were rare during winter months and considerably high during rainy months (Figure 4). Of the nine families, only Geometridae, Pyralidae and Noctuidae were found in every month which comprised of 91.06% of the entire study period Lepidoptera collection. Zygaenidae, Cossidae, Syntomidae, Yponomentidae, Notodontidae and Sphingidae were very rare and did not show any regularity in occurrence.

The monthly average minimum temperature and minimum relative humidity showed positive significance to the monthly total Lepidoptera catch in the first year. In the second year the monthly average minimum and maximum temperature showed significant relationship with the total annual Lepidoptera catch. Rainfall did not show any significant relationship during both the years (Tables 3.1 and 3.2).

Hourly analysis shows that maximum catch of 22.01% and 19.76% in the first and the second year, respectively, were recorded at 20.00 - 21.00 hrs. Minimum catch of 2.26% at 03.00 - 04.00 hrs in the first year and of 0.70% at 04.00 - 05.00 hrs in the second year was recorded. (Tables 4.1 and 4.2).

HYMENOPTERA :

Hymenoptera fluctuation showed similar trend in both the years. They were rare during winter (December - March), attained a high number during rainy season (April - July) and decreased again during autumn (October-November). There were three peaks of high catch in May, July and October in both the years suggest at least three generations or at least three phases of emergence in the annual cycle. Of the three families, namely, Cynipidae, Vespidae and Formicidae only the latter one was found in every month in large numbers whose fluctuation decides the fluctuation of Hymenoptera as a whole.

Temperature and humidity showed significant positive relationship but rainfall did not show any significance with the catch of Hymenoptera in both the years (Tables 3.1 and 3.2). This finding is similar to the findings of Reddy (1980).

Hourly analysis shows that maximum catch (16.75%) was at 20.00 - 21.00 hrs and minimum catch (3.26%) was at 04.00 - 05.00 hrs in the first year. In the second year maximum catch (21.47%) was at 20.00 - 21.00 hrs and minimum catch (1.70%) was at 04.00 - 05.00 hrs.

HEMIPTERA :

Hemiptera catch fluctuation shows a similar trend in both the years. They were very scanty during winter (December - March), fairly common during rainy season (April - September) and abundant during Autumn (October - November). There were three peaks of high catch in both the years which confirms three generations or at least three phases of emergence in a year.

Different environmental factors did not show any significant positive relationship with the monthly total Hemiptera catch. Findings of Yates and Ebel (1975a, b) that rainy weather did not have significant relation with certain moths catches is similar to our finding that rainfall did not have significance with the catch of Hemiptera.

Of the four families only Jassidae had regular occurrence in the annual cycle while Coreidae, Lygaeidae, Miridae and Pentatomidae were not common in many of the months. Thus, the catch fluctuation of Hemiptera is mainly attributed to the fluctuation of Jassidae.

Hourly analysis shows that maximum catches of 20.13% and 23.88% of the total annual catch of the first and the second year, respectively, were at 21.00 - 22.00 hrs. Minimum catches of 0.58% and 0.82% of the total annual catch of the first and the second year, respectively, were at 04.00 - 05.00 hrs.

COLEOPTERA :

The catch fluctuation of Coleoptera showed more or less similar trend in both the years of study. The relative abundance was quite low during cold winter (December - February) which increased rapidly from March onward with the onset of rainy season. There were three peaks of high catch in May, July and October in each year which depicts that there were three generations or at least three phases of emergence of Coleoptera in a year. (Figure 4).

Of the different environmental factors, monthly average minimum temperature and minimum relative humidity showed significant positive relationship at $P < 0.05\%$ level with the monthly Coleoptera catch during the second year.

In total twelve families, namely, Nitidulidae, Curculionidae, Chrysomelidae, Elateridae, Byrrhidae, Carabidae, Coccinellidae, Gerridae, Cerambicidae, Lymaxylidae, Staphylinidae and Tenebrionidae were caught during the study period. Out of these families Nitidulidae, Chrysomelidae and Curculionidae were the most dominant.

<u>Staphylinus</u> sp. is a rare collection in the present investigation belonging to family Staphylinidae. Collection of <u>Scaphium</u> sp. belonging to Lymaxylidae family confirms the report of Mani (1973) that this species is attracted towards light source.

Hourly analysis shows that maximum catches of 23.09% and 29.59% of the total annual catch of the first and the second year, respectively, at 20.00 - 21.00 hrs were recorded. Minimum catches of 0.39% and 0.76% of the total annual catch of the first and the second year, respectively, at 04.00 - 05.00 hrs were recorded.

DICTYOPTERA :

Dictyoptera occurred in very less numbers in the annual cycle and were absent in December, January and February during the entire study period. Of the two families collected, Blattidae was higher in catch than that of the Mantidae. (Figure 9).

Temperature and humidity had significant positive relationship during the second year with that of the monthly Dictyoptera collection. Rainfall did not show any significance to the monthly total Dictyoptera collection.

Hourly analysis shows that there was no catch during 03.00 - 04.00 hrs and 04.00-05.00 hrs in both the years. Maximum catches of 20.00% and 22.91% of the total annual catch of the first and the second year, respectively, at 20.00 - 21.00 hrs were recorded. There was minimum catch of 1.53% at 22.00 - 23.00 hrs and 23.00 - 24.00 hrs each in the first year and in the second year minimum catch of 4.16% was at 01.00 - 02.00 hrs and 02.00 - 03.00 hrs each.

ORTHOPTERA :

Orthoptera catch fluctuation showed more or less similar trend in the two annual cycles. They were fairly scanty during winter (November - February), common in rainy season (March - July) and quite low during early autumn (August - September). (Figure 2).

Of the four families, Acrididae was common in every month, Tettigonidae was also common in every month except in February, 1980, Gryllidae and Gryllotalpidae were irregular in occurrence. The catch fluctuation trends of all the families were similar to the overall fluctuation trend of Orthoptera (Figure 10).

The monthly average maximum relative humidity showed significant positive relationship with the monthly total Orthoptera collection at 0.05% level during the first year. Other environmental factors did not show any significance.

There were maximum catches of 16.52% at 19.00 - 20.00 hrs and 24.36% at 21.00 - 22.00 hrs in the first and the second year, respectively. Minimum catches of 0.28% at 04.00 - 05.00 hrs and 1.58% at 03.00 - 04.00 hrs were in the first and the second year, respectively.

Rest of the orders, namely, Ephemeroptera, Plecoptera, Trichoptera, Isoptera, Dermaptera and Odonata were caught in very few numbers in the light-trap. This may be due to thier pattern of life cycles, habits and other reasons which we shall not discuss in context of the present study.

OVERALL ANALYSIS OF POPULATION DYNAMICS :

To draw up some salient features of the population dynamics of insects attracted to light-trap the following general conclusions of the present study are noteworthy.

BEHAVIOUR OF INSECTS IN RELATION TO LIGHT-TRAP :

(1) That all the insect orders caught during the entire study period show similar trend of seasonal population changes in the annual cycle.

(2) That out of temperature, humidity and rainfall no one was prominant factor for population fluctua-

tion but may all different environmental factors including vegetation, disease, parasite, predator and climatic factors work together for insect population fluctuation in forest ecosystem.

(3) That there is more activity of the insects before mid-night.

(4) That insects occur in large numbers during rainy and autumn seasons.

(5) That Diptera is highly attracted while Coleoptera, Lepidoptera, Hemiptera and Hymenoptera are fairly attracted to light-trap.

(6) Coleoptera is the most diversified order with twelve different families attracted to light-trap.

(7) That light-trap has a controlling effect on insect population.

DOMINANT INSECT FAMILIES :

Light-trap collections were dominated by certain families which were present throughout the monthly catches. Out of 41 identified families only 15 dominant families of different orders were as follows : Chironomidae, Cecidomyiidae, (Diptera); Pyralidae, Noctuidae, Geometridae (Lepidoptera); Formicidae (Hymenoptera); Jassidae (Hemiptera); Nitidulidae, Curculionidae, Chrysomelidae (Coleoptera); Blattidae (Dictyoptera); Acrididae, Gryllidae, Tettigonidae (Orthoptera) and Baetidae (Ephemeroptera). These families occurred in large numbers throughout the study period and were mainly responsible for population dynamics in the forest.

Thus, in light-trap insect diversity was high except in winter. This was due to the constancy of the dominant families in all catches and also during the months when the total insect abundance was high. Such phenomenon was in contrast to the tropical regions in general, where insect abundance and diversity were negatively related (Frith 1975). Our study was carried out in a sub-tropical semi-deciduous mixed forest with limited temperature variations which confirm the findings of Reddy (1980) in a comparatively cool climate of Shillong and of Williams (1964) in temperate region where insect diversity increased with seasonal abundance.

EFFECT OF SEASONAL CHANGES :

The light-trap findings reveal that most of the insects are capable of overwintering. They have an upward thrust in population dynamics after the onset of monsoon rain with the increase of temperature and humidity. Similar findings were reported by Chalfant et. al.(1974) and Reddy (1980). In Balphakram Sanctuary the insect number increases following the onset of rains which is the primary factor for luxuriant vegetative growth, food of phytophagous insects. In tropics rainfall is reported to be the most important factor for population size of insects (Owen 1969). Reddy (1980) also reported on the importance of rainfall in relatively cooler but highly precipitated pine forest insect population near Shillong. He reported that the peak activity of most of the insects occurred immediately after rains and therefore rainfall could be attributed as an operationally significant factor in regulating insect abundance.

USE OF LIGHT-TRAP :

Light-trap can be used as a controlling measure of certain forest insects as is revealed by the spectacular decrease of insect catch in the second year of the light-trap experiment. This kind of study will be useful in predicting insect population dynamics in a forest system if such experiment is done continuously over several years and records are maintained. Such informations are considered to be of primary requisite for wildlife sanctuary and forestry management.

BIOLOGY OF MAJOR INSECT PESTS :

Cyclosia panthona Cram. :

It is a small brownish black moth. The females lay eggs in clusters on the undersurface of the host tree leaf. The freshly hatched out larvae are dark samber in colour with yellow spots and translucent bristles on the body. The larvae pass through six instars before pupation. The larvae develop black-spots on every body segment from 2nd instar onwards. The 6th instar larvae show body size difference - the smaller larvae give rise to male and the larger larvae give rise to female moths. Both larva and pupa are yellow in general appearance. The cocoons are paper-like, oval in shape and brick-red in colour.

The present investigation is a detailed biology with description of developmental stages. Hampson (1976) earlier described the identifying characteristics of its larvae and pupae.

POPULATION DYNAMICS :

The present investigation confirms that *Cyclosia panthona* Cram. is trivoltine and completes three generations in a year in Balphakram forest. The three generations are rainy season (May - July), autumn season (August - October) and winter season (November - April) generations. The time period in life-cycles in different generations are as follows : rainy season 77 days, autumn season 85 days and winter season 228 days. There is a pupal stage diapause in the winter generation in the month of January. Diapause is broken by early May.

LIFE TABLE AND SURVIVORSHIP CURVES :

In the present investigation steep and convex survivorship curves have been found in all the three generations indicating more mortality in the later stages of development. In winter generation the curve is most steep indicating high mortality, in rainy generation the curve is less steep indicating lower mortality and in autumn the curve is in between the winter and rainy generation, indicating a medium mortality rate.

Mason and Thompson (1971) reported concave curves on Douglas fir Tussock moth, Orgyia pseudotsuga depicting relatively constant mortality rate for all the age groups. Similar to our finding Housewart and Kul-man (1976) found convex survivorship curves for yellow headed Spruce saw-fly, Pikonema alaskensis . Such similarity or differences in the survivorship curves in different species in different environment indicates that different mortality factors act in different rates on different species in different environment.

In winter generation the larvae occurred in large numbers. This resulted in food shortage and consequent dispersal of later stage larvae. Diaease and Tachinid parasite also caused larval mortality. In rainy generation rain and wind acted as major mortality factors. In autumn generation disease and parasite were the major mortality factors.

Similar to our finding Mason and Thompson (1971) attributed food shortage and viral disease as major causes of mortality resulting into the collapse of the larval population of the Douglas fir Tussock moth, *Orgyia pseudotsuga*. Similarly, Stairs (1972) recorded nuclear polyhedrosis virus which killed a large number of the 5th instar larvae of *Malacosoma disstria*. Mason (1976) similarly evaluated that larval loss due to dispersion, predation or starvation were highest early in the life cycle of Douglas fir Tussock moth, *O. pseudotsuga*. In high larval density, starvation was recorded as an important mortality factor in forest Tent caterpillar, M. disstria by Hodson (1977). Similar to our rainy generation finding, Goh and Lange (1980) recorded rainfall as one of the major mortality factors on Plume moth, Platyptilia carduidactyla.

Population reduction involves a multitude of natural factors which frequently operate in subtle and compensating ways. Their effects being often difficult to evaluate solely in numbers of insects killed (Mason 1976). Mortality factors act upon the developing stages in different rates. We found in Cyclosia panthona Cram. that mortality factors acted in different rates in different developing stages and in different generations and mortality was higher in later stages of development.

Diaphania laticostalis Guene :

This is a small milky white moth. The females lay eggs in clusters on the under-surface of the host tree leaf. Freshly hatched out larvae are pale yellow with dark samber coloured head capsule. The larvae turn samber coloured from 3rd instar onwards. Pupation takes place in leaf-roll. The pupae are lanceolate in shape.

Cannibalism was observed among the larvae from 4th instea onwards. Weak, parasite infected as well as dead larvae were eaten by other healthy larvae. Our finding is similar to that of Barber (1936) who found with Corn ear worm, *Heliothis obsoleta* that cannibalism is a major regulatory factor at high density population.

Some larvae in the field were found to be infected by the larvae of *Apanteles* sp.(Hymenoptera : Braconidae) which definitely reduce larval population of the host insect. Presence of this larval stage parasite indicate its potentiality to be utilised as an indigenous biological control agent. Different species of *Apanteles* are widely distributed and effective larval stage parasite of Lepidoptera (DeBach, 1964).

POPULATION DYNAMICS :

The first appearance of the larvae on the host tree leaves is found in August in the forest. The larvae are gregarious and live together inside the leaf-roll. Larval attack on the host tree increases from August and it reaches a peak in the month of February after which it decreases and disappear by April.

Pupation takes place in leaf roll of the host tree. Adult moths emerge out in the early part of August. Adults are nocturnal and are attracted to light-trap. Diaphania laticostalis Guene is found at least in three generations in an annual cycle in between August to April.

HOST TREE :

The host tree, Holarrhena antidysentrica (Lin.) Wall is a common woody tree in Balphakram forest. It is a medicinal tree. Its leaves and barks are used against amoebic dysentery by the local inhabitants. The wood is used for making slate frame, mathematical instruments, spools and pirns of silk industry etc. (Anonymous 1959). Other species of Diaphania are reported to feed on the fruit of Cantaloupes, Squashes and Cucumbers (Little 1974). In Balphakram forest no tree other than Holarrhena antidysentrica was found to be fed by Diaphania laticostalis larvae. This is considered to be an important information about the host plants of Pyralidae among the forest trees.

The present investigation covers the biology with detailed description of developmental stages of D. laticostalis and its population dynamics.

MINOR INSECT PESTS :

Nine minor insect pests recorded in the present study were as follows :

1. Delias descombesi (Lepidoptera : Pyralidae). Host plants - Grewia micrococs and Loranthus sp.

2. Melanitis ismene (Lepidoptera : Satyridae). Host plant - Paddy.

3. Dicladispa armigera (Coleoptera : Chrysomelidae). Host plants - Michanea sp. and Paddy.

4. Aulacophora foevicollis (Coleoptera :Chrysomelidae). Host plants - Cleorodendron sp. and Cucurbits.

5. Epilachna sp. (Coleoptera : Coccinellidae). Host plants - Solanum sp., Michanea sp. and Cucurbits.

6. Mylabris phalerata (Coleoptera :Meloidae). Host plant - Thatching grass.

7. Chrysochroa chinensis (Coleoptera : Buprestidae). Host plants - Fallen woods.

8. Oxyia velox (Orthoptera : Acrididae). Host plant - Paddy.

9. Leptocorixa varicornis (Hemiptera : Coreidae). Host plants - Dipterocarpus sp. and Michanea sp.

It is not known whether these insects may attain major pest status in conjenial environment. The short notes on these insects may be of use in the management of the Balphakram Sanctuary.

RELATIVE TOXICITY EXPERIMENTS :

It is a general practice to test the relative toxicity of the candidate insecticides to any target insect pest before using the insecticides for control of the pest insects (See for references, Gupta and Rawlins 1966, Kay 1979, Gupta and Veer 1986).

In the present investigation the relative toxicity of four insecticides, namely, Nuvacron 40EC, Cythion 50EC, Ekalaux 25EC and Thiodan 35EC have been tested on the larvae of *Cyclosia panthona* and *Diaphania laticostalis* both of which are recorded as defoliators of forest trees in Balphakram forest. The insecticides are locally availabe in Agriculture Department at Shillong.

NUVACRON 40EC :

Nuvacron was not at all effective at lower concentrations with the larvae of *Cyclosia panthona*. It caused first mortality at 12 hrs of treatment which is low in percentage and even after 48 hrs the mortality did not exceed 66% at the maximum concentration of 0.04%.

Nuvacron caused first mortality on *Diaphania laticostalis* larvae within 3 hrs at 0.0025% and 0.005% concentrations and within 1 hr at 0.01%, 0.02% and 0.04% concentrations. At higher concentrations there was a progressive increase in mortality with the increase of time interval and concentrations. Maximum mortality of 76% was recorded within 48 hrs at 0.04% concentration.

Nuvacron showed delayed and comparatively limited larval mortality on both the species tested.

Delayed action of Nuvacron with medium effectiveness was earlier reported by Whitlock (1973) while testing the effectiveness of 11 different insecticides on the larvae of *Heliothis armigera*. His finding is close to our findings, as Nuvacron was found to be slow and least effective on *Cyclosia panthona* and slow but effective on *Diaphania laticostalis*.

Singh *et. al.*(1973) found Monocrotophos (Nuvacron) at 0.025% concentration along with Carbaryl 0.1%, DDT + BHC 0.1% as most effective causing 68 - 85% mortality among 14 different insecticides tested to control the Cotton leaf roller, *Sylepta derogota* . Singh and Gupta(1978) further confirmed Monocrotophos as the most effective against Teak skeletonizer, Pyrausta machaeralis along with Chlordimeform, Quinalphos (Ekalaux), Anthio in comparison to Cythion (Cyanamid Malathion), Thiodan (Endosulfan) and Malathion. In present investigation also, Nuvacron has been found to be more effective than Cythion and Thiodan on D. laticostalis.

CYTHION 50EC :

Cythion caused knockdown effect on Cyclosia panthona larvae within 3 hrs at 0.01%, 0.02% and 0.04% concentrations and within 6 hrs at 0.0025% and 0.005% concentrations. There was a progressive increase in mortality with the increase of concentrations and the time intervals after treatment. The maximum mortality of 84% was recorded within 48 hrs at 0.04% concentration. Cythion proved to be more effective than Nuvacron on C. panthona.

Cythion was found to be ineffective on Diaphania laticostalis larvae. There was no mortality at 0.0025%, 0.005% and 0.01% concentrations. The first mortality was recorded within 24 hrs at 0.02% and 0.04% concentrations. The maximum mortality of 12% was recorded within 48 hrs at 0.04% concentration. Cythion proved least effective among the 4 insecticides tested on D. laticostalis.

Singh *et. al.*(1973) while testing 14 different insecticides on the Cotton leaf roller, *Sylepta derogota* found that Cythion was less effective than Monocrotophos (Nuvacron). But in our present testing on *Cyclosia panthona* , Cythion was found to be more effective than Nuvacron. On *Diaphania laticostalis* larvae Cythion was found to be less effective than Thiodan, Nuvacron and Ekalaux.

EKALAUX 25EC :

Ekalaux caused first mortality on *Cyclosia panthona* larvae within 3 hrs of treatment at all the concentrations. There was increase in mortality with the increase of concentrations and time intervals after treatment. Maximum mortality was recorded within 24 hrs at all the concentrations. It was found to be quick in action and more effective than Nuvacron and Cythion causing 100% mortality within 24 hrs at 0.02% and 0.04% concentrations.

On *Diaphania laticostalis* larvae Ekalaux caused first mortality within 1 hr at 0.01%, 0.02% and 0.04% concentrations. There was increase in mortality with the increase in concentrations and the time intervals after treatment. There was maximum mortality of 84% within 48 hrs at 0.04% concentration. Ekalaux proved to be very quick and most effective on *D. laticostalis* among the 4 tested insecticides.

Strong effectiveness of Ekalaux (Quinalphos) has been reported by Singh and Gupta (1978) against the 3rd instar larvae of the Teak skeletonizer, Pyrausta machaeralis . They recorded ascending order of toxicity as DDT (WP), DDT (WDP), Ambithion, Aldrin, Malathion, Dimethoate, Dialdrin, Dichlorovos, Fenitrothion, Carbaryl, Acephate, Anthio, Quinalphos (Ekalaux), Chlordimeform and Monocrotophos (Nuvacron). Their findings are in conformity with our findings that Ekalaux is the second most effective insecticide on Cyclosia panthona and the most effective insecticide on Diaphania laticostalis larvae among Cythion, Thiodan, Nuvacron and Ekalaux.

THIODAN 35EC :

Thiodan also caused first mortality on the larvae of Cyclosia panthona within 3 hrs of treatment at all the concentrations like that of the Ekalaux. However, mortality percentage was higher than that of Ekalaux. There was increase in mortality with the increase of concentrations and time intervals. It caused 100% mortality within 12 hrs of treatment at 0.01%, 0.02% and 0.04% concentrations and proved most toxic on C. panthona among all the insecticides tested. Nevertheless, Thiodan showed only a little edge over Ekalaux in toxicity .

Thiodan caused low mortality on *Diaphania laticostalis* larvae . It caused first knockdown at 0.0025% concentration within 24 hrs, at 0.005%, 0.01% and 0.02% concentrations within 6 hrs and at 0.04% concentration within 3 hrs of treatment. There was increase in mortality with the increase in concentrations and time intervals. It caused maximum of 62% mortality within 48 hrs of treatment at 0.04% concentration. Thiodan was more effective than Cythion but less effective than Nuvacron and Ekalaux on *D. laticostalis*.

High toxicity of Thiodan (Endosulfan) has been reported by Joshi and Sharma (1973) while testing 10 different insecticides for control of the Mustard aphid, *Lipaphis erysimii* and its predators, *Menochilus sexmaculatus* and *Xanthogramma scutellaria*. Their report is similar to the present finding on *Cyclosia panthona*, as Thiodan caused highest mortality among the 4 insecticides tested.

However, in experiments on *Diaphania laticostalis* larvae Thiodan occupied 3rd position in toxicity, Nuvacron being 2nd and Ekalaux 1st. Gupta and Veer (1986) while evaluating the toxicity of 19 contact insecticides against *Glyphodes* (*Diaphania*) *pyloalis* included 3 insecticides tested by us and recorded their relative toxicity in ascending order as Endosulfan (Thiodan), Monocrotophos (Nuvacron) and Quinalphos (Ekalaux). This order of relative toxicity is identical to our finding on *Diaphania laticostalis*. This similarity in response to toxicity seems to be as because their target insect and our target insect belong to same family and same genus.

In the present experiments on the relative toxicity of the 4 insecticides on *Cyclosia panthona* larvae the ascending order of toxicity was as Nuvacron, Cythion, Ekalaux and Thiodan.

The relative toxicity of the 4 insecticides on *Diaphania laticostalis* larvae was as Cythion, Thiodan, Nuvacron and Ekalaux in the ascending order.

From the above discussion it can be inferred that the toxicity of a particular insecticide varies from insect to insect. This variation in toxicity seems to be due to difference in response of the target insects to the insecticides. Related insects respond similarly to a particular insecticide and unrelated insects show variation in their response to insecticides. A particular insecticide may be most toxic to one but may not be so toxic to another insect.

The present investigation on relative toxicity of 4 contact insecticides against two species of forest insect pests, Cyclosia panthona and Diaphania laticostalis may help in selecting out candidate insecticides for controlling the concerned insect pests or other related insect pests in the forest as well as in agricultural field. The result of the present experiment may be used in forest insect pest management in Reserve forests , Wild-life Sanctuaries and other biospheres in the North Eastern Hills and elsewhere.

SUMMARY

The present study incorporates the investigations on the following aspects :

1. SURVEY :

Based on the faunistic survey from September, 1979 to October, 1981 in the Balphakram National Wildlife Sanctuary a list of 134 species of identified insects out of 14 different orders has been provided.

2. POPULATION DYNAMICS OF INSECT FAUNA :

A total of 9211 insects in the first year and 6895 insects in the second year belonging to 13 different orders have been collected by Light-trap.

The monthwise total insect collection in the two years exhibited similar trend of occurrence. The monthwise minimum insect collection was in January and maximum insect collection was in October during both the years. Such regularity in insect collection seems to be due to regularity in climatic factors and undisturbed vegetation.

Most of the insects were collected (84.30%) during the first half (17.00 - 23.00 hrs) of the night and maximum collection (46.14%) was in the second quarter (20.00 - 23.00 hrs) of the night.

In light-trap 13 different insect orders, namely, Diptera, Lepidoptera, Hymenoptera, Hemiptera, Coleoptera, Dictyoptera, Orthoptera, Ephemeroptera, Plecoptera, Trichoptera, Isoptera, Dermaptera and Odonata were collected. In day time survey order Phasmida was collected in addition to the above 13 insect orders.

Collected insects were dominated by certain families which were present in every month of collection. They were - Chironomidae, Cecidomyiidae (Diptera); Pyralidae, Noctuidae, Geometridae (Lepidoptera); Formicidae (Hymenoptera); Jassidae (Hemiptera); Cucculionidae, Chrysomelidae, Nitidulidae (Coleoptera); Blattidae (Dictyoptera); Acrididae, Gryllidae and Tettigonidae (Orthoptera).

Diptera was the most dominant order in respect of highest number of insect collection. Coleoptera was the most diversified order with 12 different families in the collection.

Insect diversity was high every month except during the winter months. The analysis of the population dynamics of the insects indicates overwintering of most of the insects. Upward thrust in population dynamics was noticed with the advent of summer season with the monsoon rain. However, humidity, temperature or rainfall singularly did not have any definite influence in the insect population dynamics in general.

Light-trap may be used as a controlling method of forest insect pests which are attracted to light-trap.

3. INSECT PESTS :

The following two were recorded as major forest insect pests in the Balphakram National Wild-life Sanctuary :

(1) Cyclosia panthona
(Lepidoptera : Zygaenidae)

(2) Diaphania laticostalis
(Lepidoptera : Pyralidae)

Nine other minor insect pests recorded in the Sanctuary were as follows :

(1) Delias descombesi
(Lepidoptera : Pyralidae)

(2) Melanitis ismene
(Lepidoptera : Satyridae)

(3) Dicladispa armigera
(Coleoptera : Chrysomelidae)

(4) Aulacophora foevicollis
(Coleoptera ; Chrysomelidae)

(5) Epilachna sp.
(Coleoptera : Coccinellidae)

(6) Mylabris phalerata
(Coleoptera : Meloidae)

(7) Chrysochroa chinensis
(Coleoptera : Buprestidae)

(8) Oxyia velox
(Orthoptera : Acrididae)

(9) Leptocorixa varicornis
(Hemiptera : Coreidae)

The biology of the two major insect pests has been investigated in detail.

(1) Cyclosia panthona Cram. :

The Cyclosia panthona Cram. (Lepidoptera : Zygaenidae) is a serious defoliator of a common woody tree Aporosa roxburghii of Balphakram forest in its larval stage.

The adults are small brownish black moths. The females lay oval, pale yellow coloured eggs in clusters on the lower surface of the leaves of the host trees. The freshly hatched out larvae are light yellow in colour with translucent bristles and dark samber head-capsules. The larvae develop black spots on every body segment from the 2nd instar onwards. The larvae pass through six instars. Pupation takes place in an oval, brick-red coloured paper-like cocoon on the host tree leaf or on any other substratum.

The Cyclosia panthona is found to be trivoltine in Balphakram forest. The life-cycle is completed in 77 days in rainy season, 85 days in autumn season and 228 days in winter season generations.

Life tables and survivorship curves of the three generations have been provided. In the winter generation the curve is most steep indicating high mortality rate, in the rainy season generation the curve is less steep indicating lower mortality rate and in the autumn season generation the curve is intermediate between winter and rainy season generations indicating a medium mortality rate in between the two generations.

In the winter the larvae occur in large numbers resulting in shortage of food and dispersal of the larvae. Other limiting factors in this generation were disease and parasite. In rainy season rain and wind acted as major mortality factors besides disease and parasite. In autumn disease and parasite were the major mortality factors. Besides the above mentioned factors certain unknown factors might work in its population dynamics. In spite of all these limiting factors *Cyclosia panthona* larvae occur in outbreak level in the winter generation in every year.

(2) *Diaphania laticostalis* Guene :

The *Diaphania laticostalis* Guene (Lepidoptera : Pyralidae) is a leaf roller and defoliator of medicinal and economically important tree, *Holarrhena antidysentrica* of Balphakram forest in its larval stage.

The adults are small milky white moths. Round, pale white eggs are laid in clusters on the undersurface of the leaves of the host trees. The freshly hatched out larvae are pale white in colour. They turn samber coloured from 3rd instar onwards. They pass through five larval instars. Pupation takes place inside the leaf roll.

The *Diaphania laticostalis* larvae occurs in three overlapping generations during August to April in the Balphakram forest.

Large numbers of larvae in the forest are found to be infected by *Apanteles* sp. (Hymenoptera : Braconidae), a larval stage parasite. Record of *Apanteles* sp. in the Balphakram forest as a larval stage parasite of *D. laticostalis* indicates its potentiallity as an indigenous biological agent for control of insect pests.

Cannibalism was observed among the larvae of *D. laticostalis* from 4th instar onwards.

4. RELATIVE TOXICITY :

The relative toxicity of four contact insecticides, namely, Nuvacron 40EC (Monocrotophos), Cythion 50EC (Cyanamid Malathion), Ekalaux 25EC (Quinalphos) and Thiodan 35EC (Endosulfan) has been tested by Dry-film technique of Gupta and Roulins (1966) against the larvae of *Cyclosia panthona* and *Diaphania laticostalis*.

The relative toxicity of the four insecticides on *Cyclosia panthona* larvae was found to be in the following ascending order :

Nuvacron, Cythion, Ekalaux and Thiodan. Thiodan showed highest effectiveness among the four insecticides. Ekalaux was very close to Thiodan in effectiveness. Cythion was medium and Nuvacron was the least toxic.

The relative toxicity of the four insecticides on *Diaphania laticostalis* larvae was found to be in the following ascending order : Cythion, Thiodan, Nuvacron and Ekalaux. Though Ekalaux showed highest effectiveness, there was not much difference with that of Nuvacron in toxicity. In some lower concentrations Nuvacron exceeded Ekalaux in effectiveness. Thiodan was a medium toxicant. Cythion was the least toxic among the four insecticides tested.

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* Original not seen