

**ECOBIOLOGY AND MANAGEMENT OF CUTWORMS,  
*Agrotis* spp. (LEPIDOPTERA : NOCTUIDAE) ON COTTON**

**R. S. GIRADDI**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY  
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD-580 005**

**APRIL, 1992**

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**ECOBIOLOGY AND MANAGEMENT OF CUTWORMS,  
*Agrotis* spp. (LEPIDOPTERA : NOCTUIDAE) ON COTTON**

Thesis Submitted to the  
University of Agricultural Sciences, Dharwad  
in partial fulfilment of the requirements for the  
Degree of

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in

**AGRICULTURAL ENTOMOLOGY**

By

**R. S. GIRADDI**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY  
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD-580 005**

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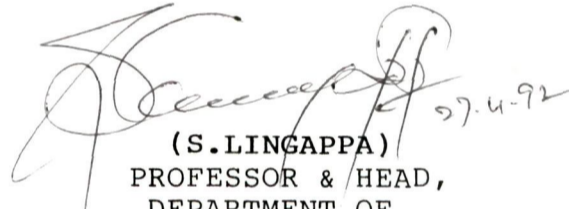
DEPARTMENT OF AGRICULTURAL ENTOMOLOGY  
COLLEGE OF AGRICULTURE,  
UNIVERSITY OF AGRICULTURAL SCIENCES  
DHARWAD-580 005.

C E R T I F I C A T E

This is to certify that the thesis entitled  
" ECOBIOLOGY AND MANAGEMENT OF CUTWORMS, Agrotis spp. (LEPIDOPTERA:  
NOCTUIDAE) ON COTTON " submitted by Mr.R.S.GIRADDI for the degree  
of DOCTOR OF PHILOSOPHY in Agricultural Entomology of the  
University of Agricultural Sciences, Dharwad, is a record of  
research work done by him during the period of his study in this  
university under my guidance and supervision and the thesis has  
not previously formed the basis for the award of any degree,  
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(S.LINGAPPA)  
PROFESSOR & HEAD,  
DEPARTMENT OF  
AGRICULTURAL ENTOMOLOGY,  
U.A.S., DHARWAD

Approved by :

Chairman :

  
(S.LINGAPPA)

Members : 1.

  
(U.G.NALWADI)

2.

  
(G.D.RADDER)

3.

  
(K.A.KULKARNI)

4.

  
(K.JAIRAO)

**Dedicated  
To  
Beloved  
Ex-Vice-Chancellor  
Late. Dr. R. K. Hegde**

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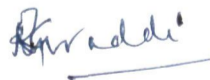
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(R.S.GIRADDI)

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**CHAPTER - I**

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**INTRODUCTION**

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## I. INTRODUCTION

Introduction of varieties and hybrids belonging to hirsutum species into cultivation in the 1970's resulted in drastic improvement in the yield levels of cotton crop. But, at the same time, these agronomically elite cultivars were found to be susceptible to a variety of insect-pests. The pest spectrum of cotton crop is quite complex and as many as 1326 species of insect-pests have been listed on cotton in the world (Hargreaves, 1948). However, in India, about 130 species of insects are known to inflict damage to cotton crop (Sohi, 1964). Till the recent past, the leaf hopper and mites during the vegetative phase and the spotted and pink bollworm in the reproductive phase were the major entomological constraints in cotton production. But in the last decade, use of high yielding varieties and hybrids, monocropping, cultivation under irrigated conditions, extensive and indiscriminate usage of chemical fertilizers and pesticides etc., have changed the insect-pest scenario and the control of these pests in cotton has become a challenging task.

In Karnataka, three species of bollworms during the reproductive phase, thrips and leafhopper in the seedling phase and aphids, mites and whiteflies during vegetative

phase besides a few other sporadic pests are the key pests on cotton. However, economic status of pests of cotton vary in time and space. Cutworm is one such pest which has assumed importance in north-western part of Karnataka. Though the cutworms have been recorded as a pest of cotton for quite sometime, the scenario of this pest has changed of late with the introduction of improved varieties and Indo-American hybrids in to commercial cultivation.

The cutworm larvae which are known to hide in the soil to a depth of three to ten centimeter during day time, become active at dusk, cut the stems of young cotton plants at or slightly below the ground level and feed on the cut seedlings. The typical nature of damage is characterised by scissor like cut to the stem at the ground level, pulling the cut seedlings into the soil and feeding on it (Plate 1). They prefer stem portion more for feeding than the leaves. They do not feed from a single plant, but attack several seedlings taking a share from each and thus they damage more seedlings than they consume. The infested fields show gaps (Plate 2) and in severity re-sowing becomes necessary. Cutworms infest 1 to 30 days old seedlings, but upto 20 days, the crop suffers heavily.

Fletcher (1913a) reported an epidemic of cutworms that destroyed all standing crops covering an area of ten to twelve thousand acres in Bihar. Similarly, an epidemic of

Plate 1. Nature of damage caused by cutworm

Plate 2. Severely infested cotton field  
showing gaps due to cutworm damage



cutworm, Agrotis segetum (Dennis & Schiffermuller) in 1912 that destroyed 13,632 acres of crops in Tula Province of erstwhile USSR has been reported by Sopotzko (1913), while, Zethner (1978) noticed a heavy infestation by A.segetum on five important agricultural crops in Denmark which resulted in losses of 20 to 100 million Dkr.

In India, though quite a few number of species of cutworms have been reported damaging different cultivated crops and wild hosts, two species namely, Agrotis ipsilon (Hufnagel) and A.segetum are the dominant ones. These two species of cutworms are cosmopolitan in distribution (Hill, 1975) (Fig.1) and polyphagous (Pruthi, 1969). Among the different crop plants, tobacco, cotton, potato, chillies, cabbage, cauliflower, onion, tomato, bengalgram, greengram, cowpea, groundnut, safflower and sunflower suffer heavily. In Karnataka, in the transitional zone comprising mainly of deep black soils, the cutworms are of serious concern to different crops, specially cotton (Thimmaiah et al., 1972; Devaiah, 1973 and Thippeswamy et al., 1981a).

Despite greater economic status, no significant work has been done on cutworms specially in South India. The information so far generated is limited to chemical control, specially on potato (Chaudhary, 1953; Nirula, 1961; Srivastava and Khan, 1962; Abraham et al., 1972; Saxena, 1977;

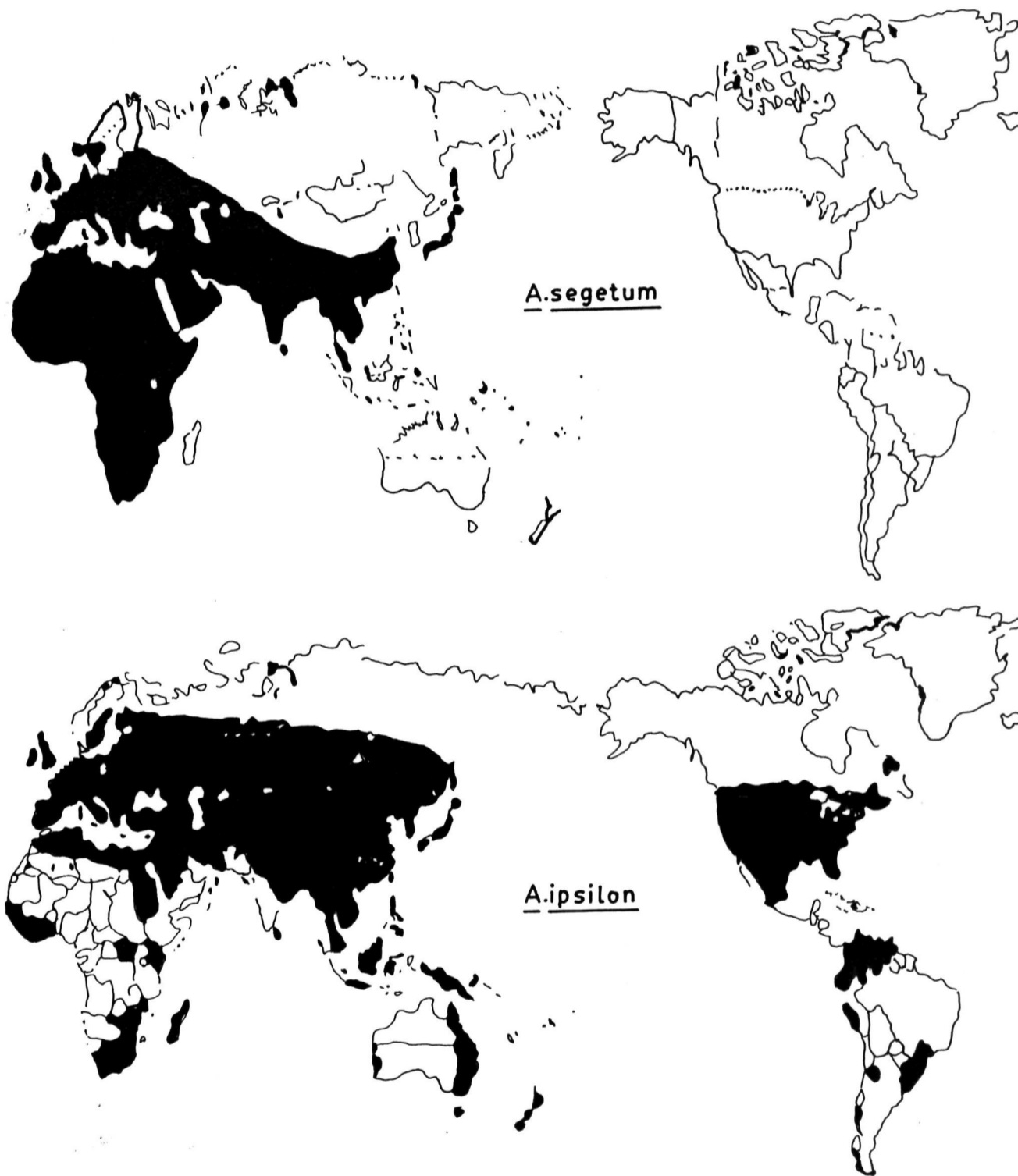


FIG.1 DISTRIBUTION OF A.segetum AND A.ipsilon.  
(The area marked black indicates distribution)

Verma and Chandla, 1977; Das, 1989; Rajendran and Verma, 1989 etc.). No studies have been made in cotton on the ecology, biology and control of cutworm, A.segetum, which is the principal species damaging cotton, excepting the work of Devaiah (1973) on biology on tobacco. In contrast, considerable amount of work has been done on the biology and chemical control of A.ipsilon (Thimmaiah et al., 1972; Babu et al., 1980; Malik and Chaudhary, 1980; Thippeswamy et al., 1981a and 1981b; Vaishampayan and Veda, 1981; Chavan, 1985 etc.).

The seriousness of a pest can only be measured by the quantum of loss inflicted by the destructive creature. Therefore, it becomes imperative to make quantitative estimation of loss inflicted by and damage potentiality of cutworms in cotton. At present, literature on this aspect is totally lacking. Equally important study is understanding of the species complexity of cutworms in cotton ecosystem in particular and on other hosts, in general. Though seasonal abundance studies using light trap have been carried out in other countries to a considerable extent, no reports are available in India excepting the studies of Yadav et al. (1984). In addition, the information on host-plant interaction on the survival and build-up and behaviour of the cutworm is obscure. Therefore, unless these fundamental aspects are thoroughly investigated, any amount of information on chemical control alone, may not help in tackling this pest

satisfactorily. Therefore, investigations were undertaken with the following objectives.

1. To study the species dynamics, biology and natural enemies of cutworms infesting cotton.
2. To monitor the seasonal activity through light trap.
3. To assess the crop loss in cotton under field conditions.
4. To study the host-plant interaction and host suitability.
5. To study the larval behaviour with reference to dispersal and damage potential.
6. To test a growth regulator and chemical toxicants for the suppression of cutworms.

**CHAPTER - II**

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**REVIEW OF LITERATURE**

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## II. REVIEW OF LITERATURE

The cutworms falling under the genus Agrotis belong to the subfamily: Noctuinae, group: Trifinae, family: Noctuidae and order: Lepidoptera (Holloway et al., 1987). In the year, 1816, Ochsenheimer erected the genus Agrotis under the subfamily Agrotinae. Hampson (1903) listed about 1200 species in the family, of which one tenth are from India (Maxwell Lefroy, 1909). The genus Euxoa which is now placed under Agrotis was erected by Hubner.

Noctua ipsilon Rottenburg, N. suffusa Schiffermuller, Bombyx spinula Esp. (Hampson, 1903) and Agrotis ypsilon Rottenburg are the synonyms for the greasy cutworm, Agrotis ipsilon (Hufnagel) while, Noctua segetum Schiffermuller, Agrotis sricula Boisd., Agrotis dimidia Zell, Agrotis marginalis Walker (Hampson, 1903) and Euxoa segetum Schiffermuller are the synonyms for the presently referred species, Agrotis segetum (Dennis and Schiffermuller).

### 2.1 Species dynamics

Fletcher (1917) from India was the pioneer to record six species of cutworms under the genera Agrotis and Euxoa on different host plants. They were Agrotis ipsilon (Rottenburg), A. biconica Koll., A. flammatra Schiffermuller,

A.c-nigrum Linnaeus, Euxoa segetum schiffermuller and E.spinifera Hubner. Jack (1918) recorded A.segetum, A.longidentifera (Hmps.), A.spinifera and A.ipsilon on potato, tobacco, maize etc., in Rhodesia. Among these, A.segetum was the commonest and dominant one, though A.ipsilon sometimes occurred in overwhelming numbers but was sporadic in its occurrence. According to Ustinov (1932), among the cutworms infesting tobacco, 80 per cent were A.segetum, 11 per cent A.ipsilon and nine per cent A.puta Hubner. Agrotis segetum and A.ipsilon were principal species on cotton in USSR (Rekach, 1933).

In Karnataka, Kannan (1925) recorded for the first time the destructive nature of E.segetum larvae to coffee seedlings in the erstwhile Mysore State which was later confirmed by Usman (1953), who observed the pest in Coorg, Chickmagalore, Hassan and Mysore districts on coffee and ragi. Devaiah (1973) reported A.ipsilon and A.spinifera as new records on bhendi, potato and ragi, respectively and E.segetum on tobacco and potato.

Agrotis tokionis (Btlr.) was predominant in all localities in South Korea. The only species occurring on radish and rape constituted 75.2 per cent of the cutworm population on maize, 64.3 per cent on potato and 51 per cent on red pepper. While, A.ipsilon predominated on soybean (Kim and Kim, 1981). On potato during 1976, Singh (1989)

recorded 84.7 per cent of cutworm larvae belonging to A.spinifera, 14.7 per cent to A.segetum and 0.6 per cent to A.ipsilon. Of the five species of cutworms recorded on vegetables in Nilgiris by Chandramohan and Nanjan (1990), black cutworms, A.segetum and A.ipsilon dominated in most blocks.

## 2.2 Host range

The cutworms are the polyphagous insects (Mathur, 1962 and Pruthi, 1969) feeding on grasses, dicot weeds and diversified cultivated species. Among the different species, A.ipsilon and A.segetum are the main cause of damage to many agricultural crops specially, potato, tobacco, cotton, chillies, bengalgram, cruciferous vegetables etc. Agrotis ipsilon has been reported for the first time as a pest of cotton in the seedling stage in USA (Pierce, 1917), in USSR (Rekach, 1933). In India, though the species has been reported to cause considerable damage to cotton by Pramanik and Basu (1971), Dastur et al. (1960) placed it on record about the considerable damage caused by A.segetum to cotton a decade earlier.

Srivastava (1958) in Rajasthan reported cutworms as new pest of potato crop, whereas Srivastava and Pandey (1968) recorded Agrotis sp. as a new pest of onion in India. Agrotis segetum has been listed as a seedling pest on peas

(Sharma et al., 1970), soybean (Kumar et al., 1988), sunflower (Rohilla et al., 1981) and A.segetum and A.ipsilon as major pests on sunflower (Khaemba and Mutinga, 1982).

Agrotis ipsilon was recorded as a pest of tea in Transcaucasian Russia (Hope, 1914), Agrotis spp. on grain sorghum (Passlow, 1973), A.segetum on wheat (Camprag et al. 1980 and Manninger, 1980) and A.ipsilon and A.segetum on sugarbeet in India (Khan and Sharma, 1972). Thippeswamy et al. (1981a) noticed A.ipsilon to feed on sunflower, bengalgram, greengram, ladiesfinger and sorghum besides cotton and chillies at Dharwad in Karnataka. Later, Reddy and Puttaswamy (1985) observed A.ipsilon and A.segetum as most serious pests infesting chillies in nursery, in Karnataka.

Agrotis segetum was recorded as a new pest on rapeseed in North India (Singh and Singh, 1983), A.ipsilon as a new record on orobanche (Chari and Patel, 1972) and on opium (Singh and Tripathi, 1984).

Contrastingly different results from the above were reported from Korea by Lee et al. (1970) who noticed adult A.ipsilon to suck the sap from fruits of grapes and pears.

### 2.3 Biology

The biology of the cutworm species namely, A.segetum and A.ipsilon has been studied by various workers. The

information on biological observations on different host plants is consolidated in Table 1.

### 2.3.1 Oviposition site

#### A.segetum

The gravid female lays eggs among low growing vegetation, on plant stems, stones and lumps of earth (Jack, 1918), in clusters on leaves near the soil or actually on the soil (Theobald 1927); on weeds and crops specially on the stems or on the soil near host plant (Rekach, 1933 and Hill, 1975), singly or in small groups, mostly on the lower surface of leaves or on the basal part of the stem in field and on glass slides, wire mesh and paper strips in cages (Devaiah, 1973) and on the lower surface of the leaves of weeds that curve downward (Kim et al., 1982).

#### A.ipsilon

The eggs are laid mainly on newly ploughed or irrigated soil or on the grounds that were moist or recently dried (Dutt, 1915 and Franssen, 1935); on the leaves near the ground or on the soil in masses of 200 to 250 (Nikolova,1961); on the earth clods, bengalgram stem bases and both sides of leaves (Malik and Chaudhary, 1980); singly on the soil, ventral surface of the cotyledonary leaves and stems of cotton seedlings in field and on soil, walls of the container and

Table 1. Literature on the biology of Agrotis segetum and A. ipsilon

Year of study	Place	Host	Duration(Days) of various stages			Total life cycle Gen/yr.	Adult longevity (days)		Fecundity (Nos.)	Pre-oviposition period (Days)	Oviposition period (Days)	Study environment		Reference	
			Egg	Larva	Pre-pupa		pupa	Male				Female	Temperature (°C)		Relative humidity (%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<b>I. <u>A. segetum</u></b>															
1932	USSR	Tobacco	5	34	5	14-17	58-61	-	-	1284 to 2246	-	-	-	-	Ustinov (1932)
1933	USSR	Cotton	6	26-36	-	13-22	$\frac{56}{3}$	15*	-	722	3	-	-	-	Rekach (1933)
1953	India (Karnataka)	-	-	-	-	-	-	-	-	1500	-	-	-	-	Usman (1953)
1965	Rumania	Maize	-	36-45	-	-	$\frac{2}{-}$	-	-	-	-	-	Under field conditions	-	Ionescu et al. (1965)
1973	India (Karnataka)	Tobacco	4-7	24-34	1-3	10-17	39-61	9-14*	-	1587	-	-	Laboratory at 26-27°C	-	Devaiah (1973)
1975	Europe	-	10-14	-	-	-	$\frac{1}{-}$	-	-	1000	-	-	-	-	Hill (1975)
1981	USSR	Cotton	10	25	-	10	$\frac{45}{3}$	15	-	-	-	-	Summer	-	Ilichev and Galitsina (1981)
1982	S.Korea	Chinese cabbage	-	-	-	-	$\frac{36}{3}$	-	-	-	-	-	27-28°C	80.00	Kim et al. (1982)
<b>II. <u>A. ipsilon</u></b>															
1913	India	-	-	-	-	-	42 & 30	-	-	300	-	-	Autumn	-	Woodhouse and Dutt (1913)
1917	India	-	2	19	-	9	30	-	-	-	-	-	Summer	-	Dutt (1917)
			4-6	47	-	> 30	81-83	10-14*	-	-	-	-	Rainy season	-	
													Winter		

Table 1. Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1932	USSR	Tobacco	4	34	1-5	14-15	-	-	-	835 to 1792	-	-	-	-	Ustinov (1932)
1933	USSR	Cotton	3 $\frac{1}{2}$ -4 $\frac{1}{2}$	30-37	-	15	$\frac{48-56}{3}$	-	-	-	-	-	Summer	-	Rekach (1933)
1961	Bulgaria	-	-	-	-	-	66-81 to 45-50 3	-	-	2300	-	-	16.5-18.5 to 21.7-24.9	-	Nikolova (1961)
1964	Egypt	Cotton	-	-	3.7	14-15	-	6.9	9.3	346	-	-	18	67	Nasr <u>et al.</u> (1964)
1964	Israel	-	3	21	-	13	$\frac{4}{4}$	-	-	-	-	-	26	-	Rivnay (1964)
1967	Rumania	Maize	1-9	20-45	-	-	-	-	-	-	-	-	16-32	-	Ionescu <u>et al.</u> (1967) <sup>1</sup>
1975	-	-	2-9	28-34	-	10-30	32-41 to 67	-	-	1800	-	-	30-20	-	Hill (1975)
1977	Pakistan	Tobacco	2	24	-	12	$\frac{48}{3}$	5-10*	-	1014	2	5	-	-	Shahid and Khan (1977)
1980	India	Bengal- gram	2.7 to 5.1	18.2 to 39.5	-	10.3 to 25.3	31.4 to 69.8 4	8.5 to 12.5	7.6 to 15.0	1432	-	5.8 to 8.3	-	-	Malik and Chaudhary (1980)
1981	India	Cotton	3.50	33 to 37	2.50	12.50 to 13.50	$\frac{45-53}{1}$	10.57	13.13	943	4.25	6.43	25.8 to 29.5	62 to 84	Thippeswamy <u>et al.</u> (1981a)

Table 1. Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1981	USSR	-	-	-	-	-	$\frac{2}{2}$	-	-	-	-	-	-	-	Pospelov and Pukhaev (1981)
1982	Brazil	Cabbage	4	19.46 to 21.09	1.74	12.08	38-41	9.85	14.40	1263	3.25	8.00	25+3	70+10	Santos and Nakano (1982)
1985	China	-	3 to 9	16 to 31	-	6 to 15	$\frac{45}{4}$	8-10*	14-1162 (264.5)	-	-	-	-	-	Zhao (1985)
1987	Taiwan	-	3 to 4	30 to 37	-	10 to 14	45-55 to $\frac{154}{5}$	5-10*	389-2458	-	-	-	24 to 28 and 12	-	Liu and Yang (1987)
1988	Iraq	Synthetic diet	-	28 to 30	-	-	-	-	345	-	-	-	-	-	Alnaji and Ghafoor (1988)
1988	Argentina	-	3 to 6	20 to 36	-	10 to 17	$\frac{33-59}{3}$	6-10*	-	-	-	-	24+2	75+5	Patruelle (1988)

\* Not referred to either of sex

cloth in the laboratory (Thippeswamy et al., 1981a). Egg laying after dusk on the moist soil or on the plants of less than five cm height has been noticed by Santos and Nakano (1982).

### 2.3.2 Egg

#### A.segetum

According to Devaiah (1973), eggs measuring 0.4 mm in diameter are dome shaped, creamywhite when fresh but developed pink speckles at the top, darkened before hatching while other regions remaining dull white.

#### A.ipsilon

Freshly laid eggs are cream coloured, dome shaped and measure  $0.56 \pm 0.02 \times 0.47 \pm 0.04$  mm and turn to lightpink after one day. After two days, they become light orange and on fourth to fifth day turn to brown and deep brown (Malik and Chaudhary, 1980). Thippeswamy et al. (1981a) observed them to be white, shining, spherical with longitudinal ribs around and with slight elevation at the micropylar region. On the second day, an irregular pinkish patch develops around the egg and a day before hatching the entire egg turns pinkish.

### 2.3.3. Larva

#### A.segetum

South (1907) described the caterpillar as greyish-brown tinged with ochreous, spots on body glossy each with

a tiny hair, lines darker but often indistinct. Devaiah (1973) observed the larva as dark grey tinged with pink with mid-dorsal dark brown stripes. The dorsal, subdorsal and spiracular stripes are usually dark with a grey lateral line. The larva measures 40 to 42 mm in length and reduces to one third at pre-pupal stage. The clay coloured caterpillar measures about 30 to 40 mm long at maturity with faint dark lines along the sides of the body, according to Hill (1975).

A.ipsilon

The caterpillar is purplish or bronzy-brown above and somewhat greener on the sides with black spots and the greyish lines edged with dark colour. Head is black with two white spots (South, 1907). Neonate larvae are slightly yellowish with shining black head (Maxwell Lefroy and Ghosh, 1907), greyish in general body colour with black head (Malik and Chaudhary, 1980). According to Thippeswamy et al. (1981a), they are dull whitish to light greyish with dark head and pro-thoracic shield. Setae arising from brownish elevations are spread all over the body.

Full grown larvae are brownish from above with a broad pale grey band along the mid line and with grey green sides with lateral blackish stripes. The head capsule is brownish black with two white spots and the general appearance of the caterpillar is blackish and measures 25 to 35 mm long (Hill, 1975). They are dark brown with greasy body and

measure 27.1 x 4.45 mm with a prominent head capsule (Malik and Chaudhary, 1980). Thippeswamy et al. (1981a) observed the sixth instar as greyish black, shining larvae with prominent elevated black spots which bear a seta. The dorso-median line is greyish on either side of which runs a light brownish stripe. The caterpillar measures 19.5 mm in length.

#### 2.3.4 Pupa

##### A.segetum

Devaiah (1973) observed that the pupation takes place in soil at 25 to 30 cm deep in an earthen cell. It measures about 17 x 7 mm and is dark brown. Pupae are stout, cremaster bifurcated and projected outwards. While, Hill (1975) described the pupa as smooth, shining brown with two spines at the rear, measuring 20-22 mm long.

The genital opening in male is on IX segment with elevated tubercles on either side of the opening, while in the female it is between VIII and IX segments, edging more on the former than the latter segment without elevated tubercles (Kumar and Verma, 1980).

##### A.ipsilon

Pupation is in earthen cell. Pupae are 20 mm long and reddish brown with a spine at caudal end (Narayanan, 1954; Sen, 1956 and Hill, 1975). Colour change from yellow through light brown to red and presence of two spines at the abdominal

end of 18-19 mm long pupae is apparent (Malik and Chaudhary, 1980) while, change from white with light greyish tinge through light brown to dark brown is on the record (Thippeswamy et al., 1981a). According to the latter authors, male and female pupae measure 16.8 and 17.7 mm in length and 5.2 and 5.8 mm in width at thoracic region, respectively.

A slit like genital aperture is located on a raised oval sclerite with a linear depression in the middle of the IX abdominal segment in male and in between VIII and IX segments in female, while the anal opening is situated on the X segment in both sexes (Malik and Chaudhary, 1980).

#### 2.3.5 Adult

##### A.segetum

Thompson (1894) while describing the adult moth indicated that the forewings possess the orbicular and reniform markings with dark centres and edges and small claviform black marking. All these being much obscured in the dark specimens. Hindwing irridescent white with dark marginal line and sometimes with dark suffusion on the margin. South (1907) reported that the ground colour in male range from pale whitish or brownish ochreous with strong markings to blackish brown with obscured markings. The colour of forewings in female ranges from greyish to blackish.

The forewings possess a kidney shaped black marking with brownish centre, while the hind wings are shiny, white with the margin tinged brownish or darker (Devaiah, 1973 and Hill, 1975) and in addition the former author described the antennae as bipectinate in males and filiform in females.

A.ipsilon

According to Thompson (1894) the moths resemble A.segetum but the forewings being more suffused with brown colour and possess a black streak beyond the reniform marking while, South (1907) indicated that there is little variation in the ground colour of the forewing in both the sexes excepting occasional specimens of males wherein the forewings are rather pale brown.

The adult moths are found with dark greyish or steel black forewings with prominent dark brownish to black reniform and circular markings while, the hind wings are white with a terminal dark fringe (Hill, 1975 and Thippeswamy et al.,1981a) and well pronounced sexual dimorphism in the form of wing colour and antennal characters has been reported by the latter authors wherein the females are darker with setaceous antennae and males with light brownish wings and bipectinate antennae.

### 2.3.6 Natural enemies

A large number of natural enemies have been recorded on both the species of cutworms. These include insects, vertebrates, nematodes and micro-organisms. Literature on parasitoids and predators is presented in tabular form in table 2 and 3.

#### Pathogens

Virus : First record of NPV on A.ipsilon is from Tsai et al. (1978) from China. Later, Santharam and Kumarswamy (1984) reported from Tamil Nadu. The isolate from A.ipsilon caused death of cutworm larvae after five days when administered through host leaf. A.segetum revealed one isolate of NPV and atleast two of granulosis virus but the infection levels never exceeded one per cent in about 10,000 larvae, in Denmark (Ogaard, 1988), while in GDR, 37.8 per cent of the A.segetum larvae died due to the granulosis virus and 10.3 per cent due to NPV (Schilephake, 1989). Chandramohan and Nanjan (1990) opioned NPV and GV as one of the population regulating factors of A.ipsilon and A.segetum infesting vegetable crops in Nilgiris.

Fungi : Urban (1965) reported the mycosis of A.segetum due to Paecilomyces farinosus (Holm ex Gray), while Lipa (1978) recorded Beauveria bassiana (Bals.) vuill from A.segetum and

Table 2. Literature on natural enemies of cutworms - parasitoids

Sl. No.	Name	Family/Group	Host stage	Eco-system	Status/ extent of parasitization	Place	Source
1	2	3	4	5	6	7	8
I.	<u>A. segetum</u> :						
1.	<u>Henicospilus euxoae</u> (L.)	Ichneumonidae	Larva	-	-	Rhodesia	Wilkinson (1928)
2.	<u>Gonia rufitibia</u> (Macq.)	Tachinidae	Pupa	-	-	Karnataka India	Krishnamurthy and Usman (1954)
3.	<u>Bonnetia compta</u> Fallen	Larvaevoridae	-	-	10.2 to 34.7	China	Yang et al. (1965)
4.	i. <u>Ichneumon sarcitorius</u> L.	Ichneumonidae	Larva	Cotton	10.0	U.S.S.R.	Salamov (1974)
	ii. <u>Ctenichneumon panzeri</u> (Westm.)	"	"	"	"	"	"
	iii. <u>Pimpla instigator</u> (F.)	"	"	Lupin	24.0	"	"
	iv. <u>Enicospilus ramidulus</u> (L.)	"	"	"	"	"	"
	v. <u>E. tournieri</u> (vollen)	"	"	"	"	"	"
5.	i. <u>Macrocentrus collaris</u> (Spin.)	Braconidae	Larva	Cotton	Widespread	"	Ragimov and Rustamova (1977)
	ii. <u>Apanteles cupreus</u> Lyle	"	"	"	-do-	"	"
6.	<u>Trichogramma</u> Sp.	Trichogrammatidae	Egg	-	84.0	"	Grigorenko (1978)

Table 2 Contd.

1	2	3	4	5	6	7	8
7.	i. <u>Apanteles telengai</u> Tobias.	Braconidae	Larva	Cotton	27.0 to 28.0	Tadzhikistan U.S.S.R.	Zhumanov (1978)
	ii. <u>Gonia cilipeda</u> Rond.	Tachinidae	Pupa				
8.	i. <u>Macrocentrus collaris</u>	Braconidae	Larva	Potato	-	Shimla hills, India	Singh (1982)
	ii. <u>Coelichneumon truncatus</u> (Thoms.)	Ichneumonidae	"				
	iii. <u>Periscepsia carbonaria</u> (Panz.)	Tachinidae					
	iv. <u>Turanogonia chinensis</u> (Wied.)	"	Larval/ Pupal				
	v. <u>Enicospilus</u> Sp.	Ichneumonidae	Larva			Rasalpur, Karnataka	
9.	<u>Turanogonia chinensis</u>	Tachinidae	Larva			Haryana, India	Kalra (1984)
II.	<u>A.ipsilon</u>						
10.	<u>Microplitis similis</u> Lyle	Braconidae	Larva			Bihar, Orissa & Bengal, India	Lyle (1921)
11.	i. <u>Apanteles ruficrus</u> Haliday	Braconidae	Larva		1.0 to 34.0	Egypt	Bishara (1932)
	ii. <u>Gonia capitata</u> DeGeer	Tachinidae	Pupa		56.0		
	iii. <u>Microplitis</u> Sp.	Braconidae	Larva	Cotton	-		
	iv. <u>Meteorus laeiventris</u> Wesmael	"	"		-		
	v. <u>Fullimeria xanthostoma</u> (F.)	Ichneumonidae	"		-		

Table 2. Contd.

1	2	3	4	5	6	7	8
12.	<u>Bonnetia compta</u>	Larvaevoridae	-	-	10.2 to 34.7	China	Yang <u>et al.</u> (1965)
13.	<u>Microplitis similis</u>	Braconidae	Larva	-	21.0 to 27.5	India	Mandal and Yadav (1978)
14.	i. <u>Coelichneumon truncatus</u> (Thoms.)	Ichneumonidae	Larva	Potato	-	Jullander, India	Singh (1982)
	ii. <u>Apanteles ruficrus</u>	Braconidae	Larva	-	-	-	-
	iii. <u>Turanogonia chinensis</u>	Tachinidae	Larval/ Pupal	-	-	-	-
15.	i. <u>Apanteles glomeratus</u> Linn.	Braconidae	Larva	-	-	Manipur, India	Rao and Barwal (1983)
	ii. <u>Eutanyacra</u> Sp.	Ichneumonidae	Larval/ pupal	-	-	-	-
	iii. <u>Ichneumon</u> Sp.	"	"	-	-	-	-
	iv. <u>Setanta</u> sp.	"	"	-	-	-	-
	v. <u>Turanogonia</u> sp.	Tachinidae	"	-	-	-	-
16.	<u>Turanogonia chinensis</u>	Tachinidae	Larva	Cotton	-	Dharwad, India	Thippeswamy <u>et al.</u> (1983)
17.i.	<u>Apanteles ruficrus</u>	Braconidae	Larva	Vege- table	22.5	Egypt	El-heneidy and Hassanein (1987)
	ii. <u>Meteorus rubens</u> Nees	"	"	"	"	"	"

Table 2. Contd.

1	2	3	4	5	6	7	8
III. <u>Agrotis</u> sp. and <u>Agrotis</u> spp.							
18.	<u>Microplitis maculipennis</u> (Szepliget)	Braconidae	Larva	-	-	Bangalore, India	Krishnamurthy and Usman (1954)
19.	<u>Trichogramma agrotidis</u> Perk.	<u>Trichogramma-</u> <u>tidae</u>	Egg	-	-	France	Voegele and Pintureau (1982)
20. i.	<u>Ichneumon</u> sp.	Ichneumonidae	Larva	Potato	-	India	Misra and Agarwal (1988)
ii.	<u>Turanognia chinensis</u>	Tachinidae	"	"	-		
iii.	<u>Periscepsia carbonaria</u>	"	"	"	-		
iv.	<u>Macrocentrus collaris</u>	Braconidae	"	"	-		

Table 3. Literature on natural enemies of cutworms - Predators

Sl. No.	Name	Family/Group	Stage of predator	Preys on	Place	Source
I	<u>A. segetum</u>					
1.	<u>Paederus</u> sp.	Staphylinidae	Adult	Eggs and larvae	India	Verma <u>et al.</u> (1969)
2.	<u>Microlestis discoidalis</u> Fairm.	Carabidae	Larva and adult	Larva	India	Mathur <u>et al.</u> (1971)
3.	<u>Broscus punctatus</u> Dej.	Carabidae	Larva and adult	Larva	USSR	Madatyán <u>et al.</u> (1987)
4.	<u>Acridotheris</u> sp.	Mynah bird	-	Larva	India	Chandramohan and Nanjan (1990)
II	<u>A. ipsilon</u>					
5.	<u>Broscus punctatus</u>	Carabidae	Larva and adult	Larva	India	Fletcher (1917)
6. i.	<u>Dorylus labiatus</u> Shuckard.	Formicidae	Adult	Larva	India	Mehto and Singh (1985)
ii.	<u>Calotes versicolor</u>	Garden lizard	-	"		
7.	<u>Chrysoperla cornea</u> (Stephens)	Chrysopidae	-	Eggs and neonate larva	-	Obrzycki <u>et al.</u> (1989)
8.	<u>Acridotheris</u> sp.	Mynah bird	-	Larva	India	Chandramohan and Nanjan (1990)
III.	<u>Agrotis</u> spp.					
9. i.	<u>Broscus punctatus</u>	Carabidae	Larva and adult	Larva	India	Misra and Agarwal (1988)
ii.	<u>Liogryllus bimaculatus</u> (L.)	Gryllidae	Adult	"		

A.ipsilon and Entomophthora sp. from A.segetum larvae. During 1982, Metarhizium anisopliae (Metch.) was recorded from the larvae of A.segetum in Shimla hills, India (Singh, 1982). In Poland, 5.7 per cent of the larval mortality of A.segetum and A.exclamationis Linnaeus was found to be due to entomogenous fungi viz., B.bassiana, P.farinosus, Verticillium lecanii (Zimm.), Entomophthora sp. and E.gammae (Weiser) (Napiorkowska and Machowiczstefaniak, 1986).

Nematode: Puttler et al. (1973) noticed Hexameris arvalis Poinar as parasitic on A.ipsilon at Illinois in the uncultivated habitats. Record of Neoaplectana sp. on the grown up larvae of A.segetum and A.ipsilon in Shimla and Jullundar is new one (Singh, 1977).

Protozoa : Srivastava and Ramakrishnan (1977) and Mehto and Singh (1985) recorded Nosema sp. in field collected larvae of A.ipsilon.

#### 2.4 Seasonal abundance of the cutworms by light trap studies

Hassanein (1956) observed that four generations of A.ipsilon developed between late September and mid July and the number of moths trapped was greatest in April and 52.5 per cent of moths were females. Besides confirming the above findings Hassanein et al. (1972) added that the peak trap catch was noticed in late September.

Selman and Barton (1972) indicated that moths of A.ipsilon were relatively active to omnidirection U.V.light trap from April to November. Two to three generations of A.ipsilon in a year were observed (Hanna, 1973 and McClanahan and Elliott, 1977). According to the former author, the flight activity was related to maximum temperature in autumn and winter and to minimum temperature in spring, while relative humidity had little effect on the flight activity with low wind velocities encouraging the flights, but the peak activity was correlated with temperature sums as observed by the latter author. Four overlapping generations during the period from April to October in A.ipsilon in Egypt (Ghanim et al., 1979) and in A.segetum in China (Hu, 1982) were noticed with peak numbers in June in A.ipsilon and early May, mid July, mid September and late October in A.segetum.

Blair (1982) reported that the cutworms, A.segetum and A.ipsilon, occurred throughout the year with seasonal fluctuations. The former had four generations, while the latter species completed five generations per annum. Three generations of A.segetum with peak flights in mid June, mid August and late September was the contrasting observation made by Kim et al. (1982) in South Korea. According to Yadav et al. (1984) first peak attraction of A.ipsilon was during IV week of March in 1977 and I week of March in 1978. The second peak was recorded in both the years during

II week of April, while third peak appeared only in 1978. On the basis of three peaks during February, April II week and May II week, Gul and Chaudhary (1986) suggested that A.ipsilon completes three generations in Pakistan.

Agrotis segetum had two distinct generations in Romania (Ionescu, 1986). In Egypt, two peak populations of A.ipsilon in May-June and September-November (Zanaty et al., 1987), three in April-May, June-July and from August onwards in Switzerland (Hachler, 1989) suggested completion of corresponding number of generations. The population dynamics of A.ipsilon and A.segetum was studied in Romania. Intermittant but steady flight was noticed from April to December in A.ipsilon, while A.segetum had two to three generations (Popescu, 1989).

## 2.5 Assessment of crop loss

Fletcher (1913b) described A.ipsilon as a serious pest of potato in Yucaud and reported 80 per cent crop loss despite practicing all methods of control. According to Sopotzko (1913), A.segetum destroyed about 13,632 acres of crops in Tula province of USSR. Woodhouse and Dutt (1913) claimed that A.ipsilon could cause a loss of worth over £ 20,000, if timely preventive measures are not applied.

From the available literature, it is apparent that no systematic and planned efforts have been made to assess crop loss in cotton due to cutworms. However, review on losses caused in other crops is briefed here.

In badly infested potato fields about 12 to 40 per cent damage has been reported (Chaudhuri, 1953; Nirula, 1961; Thygesen, 1968; Panchabhavi et al., 1972; Chandla et al., 1977; Verma and Chandla, 1977; Saxena and Misra, 1980 and Das and Ram, 1988). According to Neupane and Bhimsen (1976), A.segetum damaged 33 per cent of potato tubers and caused 24 per cent weight loss. Misra and Sharma (1987) indicated the yield losses of 2.70 to 6.10 q/ha of potato due to Agrotis spp. in Shimla hills in the absence of insecticidal spray while, Parihar and Singh (1988) revealed that one spray against A.ipsilon with chlorpyrifos 20 EC @ 2.0 litres/ha resulted in net profit ranging from Rs.626 to 947 in different potato cultivars.

By comparing the damage by Agrotis messoria Harris in tobacco between DDT drenched plot and untreated plot, the loss was assessed to be 17 per cent of the marketable tobacco crop, according to Cheng (1971). About 20 to 80 per cent crop loss was reported in tobacco by the first generation larvae of A.segetum (Vasilev, 1987).

Showers et al. (1983) reported that in maize 27 per cent of plants and 2.9 q/ha yield was lost when the density of A.ipsilon per meter row was one during the coleoptile to one leaf stage. The highest loss of 3.8 q/ha was recorded when the damage occurs on 11 to 15 days old seedlings (Rodriguez Del Bosque, 1986). Whitford et al. (1989) indicated that significant losses in yield generally occurred before four leaf stage. The recovery of maize seedlings from actual damage and manual damage differed. They further opined that the degree of yield reduction depended on the position of the growing point within the plant relative to where the plant had been severed.

The crop loss due to A.segetum in five important agricultural crops was to the extent of 20 to 100 million Dkr (Zethner, 1978). Among them red beet suffered the most losing about 30 per cent yield. According to Chaudhary and Malik (1981), at 40 days after sowing, 9.5 and 22.5 per cent of bengalgram plants were completely and partially destroyed, respectively.

## 2.6 Host preference

Rye (Secale cereale L.) was injured to a greater extent than wheat and early sown crops were more injured than the late sown crops by A.segetum (Makarov, 1916). Planting rye in strips as trap crop surrounding the main crop was

effective in reducing cutworm infestation. In Rhodesia according to Jack (1918), A.segetum feed on any plant but its preference was for potato, tobacco, maize, lettuce and some grasses of succulent nature.

During the outbreak of A.segetum in Germany in 1917, rye, tobacco, rape and root crops suffered most compared to potato, cereals (Kleine, 1920). Nikolova (1971) reported that among over 30 cultivated and 20 wild host plants, tobacco, beet, maize and vegetable crops were more preferred by A.ipsilon. In Korea, A.tokionis was the only species occurring on radish and rape, formed 75.2% of the cutworm population on maize, 64.3% on potato and 51.0% on red pepper but was not found at all on soybean where A.ipsilon predominated. The proportion of plants damaged by cutworms was highest for chinese cabbage and sesame and lowest for soybean and radish (Kim and Kim, 1981).

Link and Severo Pedrolo (1987) showed the preference of I instar larvae of A.ipsilon in Brazil to native weeds including Rumex obtusifolius L., Galinsoga parviflora cav., Coronopus didymus L., Rhaphanus sativus L. and Stachys arvensis L. Later the grown up larvae moved to cultivated crops including strawberries, maize, soybean, cabbage and rape.

## 2.7 Effect of host plants on the biology of cutworm

Nikolova (1961) reported complete mortality of newly hatched larvae of A.ipsilon on Turkish tobacco and 97 per cent on Virginia tobacco but only 8.0 to 9.5 per cent on lucerne, beet and maize. Larvae become full fed in 35 days on lucerne and beet and in 40 days on maize. The adult longevity was longest when the larvae had fed on beet and shortest on maize.

Though A.ipsilon fed on all hosts tested, Abdinbekova and Akhmedov (1971) noticed them to feed more on mixed foods. The larval period was shortest (20.9 days) on lucerne and longest (28.3 days) on castor. The larval food plant did not affect the pupal duration but affected the pupal weight. Females from larvae reared on sweet potato laid more eggs (1000) than on cotton (375) and maize (545) (El-Kifl et al., 1973a).

According to Busching and Turpin (1977), survival of larvae was highest on blue grass, Poa pratensis L., curled dock, Rumex crispus L. and wheat and no survival on gaint fox tail, Setaria faberii Herrm. or leaf debris. The larval development varied from 24.6 days on wheat to 47.0 days on annual morning glory, Ipomoea purpurea L.(Roth ). Nikolov(1977) inferred that the quality of food plant determined the length of the larval period. The larval stage of A.ipsilon

lasted 19 days on beet and Chenopodium album L. and 29.4 days on maize and the larval mortality was highest on the latter host. Larval food had no effect on pupal weight and adult life span but larval weight had direct bearing on fecundity. A direct relation was established between larval duration and larval weight on clover, pea and cauliflower, while partial inverse relation existed on lucerne, C.album and mixed food.

## 2.8 Behaviour

### 2.8.1 Dispersal of cutworms

Information on the dispersal pattern of cutworms is very scanty. From the studies on temporal and spatial distribution of A.ipsilon in maize and soybean by Story and Keaster (1982), the aggregation indices indicated that the distribution of larvae was random. Dispersal of western bean cutworm from the egg masses confirmed general observations of spotty damage in the field with linear regression indicating dispersal of 3.05 to 3.66 m in the release row and 2.45 to 3.05 m across rows (Blickenstaff, 1983).

### 2.8.2 Cutting instars

The stage of the larvae involved in cutting the seedlings has been reported to be III to VI instar in the case of A.segetum in cotton (Druzhelyubova and Makarova, 1971), IV to V instar in corn (Cabello and Hernandez, 1988)

and IV to VI instar in the case of A.ipsilon in maize (Showers et al., 1985). Kim et al. (1982) reported that the last three instars cut the plants at the base and pulled in to the soil.

### 2.8.3 Damage potential

In 12 to 15 days, 24.5, 23.6, 30.6 and 58.7 per cent maize plants were damaged when IV instar A.ipsilon larvae were released at one per four, two, one and half plant, respectively (Sechriest and York, 1967). Showers et al., (1983) showed that one larva per meter of row could damage 27 per cent of maize seedlings and the decrease in per cent plant stand and yield was directly proportional to the increase in larval density.

The feeding activity of IV to VI instar larvae of A.ipsilon on one to seven node cotton revealed that the number of plants cut by each larva was greatest for IV and V instars infesting one node cotton (4.6 to 5.8 seedlings) and decreased progressively with plant age to 1.6 seedlings for VI instar infesting five node cotton. Seven node cotton plants generally were not susceptible to attack even from VI instar larva (Foster and Gaylor, 1986). In no-till cotton and in barrier enclosed plots the extent of seedling cutting by the individual larva of A.ipsilon in cotton decrease progressively

with plant age from one (42.0%) to five (17.0%) node seedlings (Foster and Gaylor, 1987). Cabello and Hernandez (1988) stated that the percentage of plants cut was function of plant age and number of larvae per plant which decreased with increase in plant age.

#### 2.8.4 Cannibalism

Maxwell Lefroy and Ghosh (1907) and Dutt (1917) observed cannibalism among the grownup larvae of A.ipsilon which increased with the increase in larval size. Besides, confirming this behaviour, Malik and Chaudhary (1980) added that cannibalism began in the IV instar and was maximum in V and VI instar larvae. Even in the presence of food, V and VI instar attacked first three instars, while cannibalism within the stage was noticed in the absence of food (El-kifl et al., 1973b). Alnaji and Ghafoor (1988) reported cannibalistic behaviour in A.ipsilon even at low densities. A solitary report of high cannibalistic activity in older larvae of A.segetum has been documented by Ilichev and Galitsina (1981).

### 2.9 Chemical control

#### 2.9.1 Poison-baits

Earliest report on the use of the poison-bait is by Jack (1913) from South Rhodesia. Baits containing

paris green, molasses and bran were effective in the control of cutworms in tobacco. A number of studies till 1950 proved effectiveness of paris green. The other poison-baits tried were arsenic based (Thompson, 1926), Sodium fluosilicate (Lyle, 1927) and cryolite (Tunblad, 1947). Davis and Turner (1918) reported that saw dust was suitable carrier as bran in the preparation of poison-bait.

Later with the invention of organic insecticides, investigations were carried out to substitute the inorganic compounds and good control was obtained by using temephos (Biothion), fonofos, methomyl and chlorpyrifos (Sechriest and Sherrod, 1977 and Nikolov, 1981), trichlorphon (Otto et al., 1985), carbaryl (Sechriest and Sherrod, 1977; Chandla et al., 1977; Hill et al., 1983 and Misra et al., 1984) in the bait. Acephate, methyl parathion and profenofos (Nikolov, 1981), decamethrin and phoxim (Otto et al., 1985) and aldrin (Ves Losada et al., 1988) in the form of bait also gave an effective control.

#### 2.9.2 Soil application of insecticidal dusts and grannules

Various insecticidal dusts suggested by earlier workers include DDT (Kulash, 1947), endrin (Michel, 1957), aldrin (Michel, 1957; Nirula and Kumar, 1963 and Misra et al., 1984), heptachlor (Nirula, 1961 and Chaudhary and Malik ,1981),

chlordane (Saxena and Rawat, 1968) and toxaphene (Chaudhari, 1953).

Among the newer compounds tried, carbaryl (Pigatti, 1960), endosulfan (Thippeswamy et al., 1981b and Chavan, 1985) phosalone (Rajendran, 1986) and quinalphos (Thippeswamy et al., 1981b, Chavan, 1985 and Rajendran, 1986) offered good protection to crops from cutworms.

The soil application of dust mixtures of DDT and lindane (Ionescu et al., 1967) and malathion and endosulfan (Misra et al., 1984) resulted in good control of cutworms, while Patel (1981) suggested either aldrin dust followed by DDT spray or BHC dust followed by endosulfan spray.

Among the granular insecticides evaluated, isobenzan and heptachlor applied in bands at sowing protected cotton shoots from A.segetum effectively (Kulikova, 1964). Other granules that gave satisfactory control were diazinon (Apple, 1967), aldrin (Singh and Mavi, 1975), lannate, mocap and C-47-47-0 (Sechriest and Sell, 1968), fonofos (Alam and Ahmad, 1975), lindane (Rathore and Young, 1975), isazophos (Watson, 1981), phosfolan (El-Garhy et al., 1983), isofenphos (Rajendran, 1986), fenobucarb (Das, 1989), disulfoton (Alam and Ahmad, 1975), quinalphos (Rajendran, 1986) and monocrotophos (Singh and Misra, 1988). On the contrary, according to Misra et al. (1984), chlorfenvinphos, permethrin and OK-174 (Link et al., 1988) failed to give any protection against the cutworms.

### 2.9.3 Insecticidal drenches

Between early 1950's and 60's soil drenching with dieldrin, toxaphene, heptachlor, aldrin and DDT afforded good control of cutworms (Kamel and Shoeb, 1958; Srivastav and Khan, 1962; Kamel and Shoeb, 1964; Genchev, 1967 and Thygesen, 1968).

Carbaryl (Pigatti and Pigatti, 1966), phophamidon (Purohit et al., 1973), isobenzan, ditox-8 and endrin (Srivastav and Khan, 1962 and Hassanein et al., 1971), chlorpyrifos (Harris et al., 1978), dicrotophos and acephate (Chandla et al., 1977), isazophos (Watson, 1981), heptenophos and triazophos (Biase et al., 1988), thiodicarb (Link et al., 1988), phoxim (Rajendran and Verma, 1989), diazinon (Apple, 1967 and Sechriest and Sell, 1968) and leptophos, chlorfenvinphos (Ratual and Misra, 1979) were the new compounds that proved to be useful in the supression of cutworms.

Among the synthetic pyrethroids, permethrin, WL-41706 and WL-43775 (Harris et al., 1978; Hill et al., 1983 and Safaryan, 1986), decamethrin and fenvelarate (Hill et al., 1983 and Chandramohan and Nanjan, 1990), cypermethrin (Safaryan, 1986) and tralomethrine (Larson, 1989) protected the crops from cutworm damage.

#### 2.9.4 Test insecticides

##### 1) Endosulfan

Thimmaiah et al. (1972) reported that endosulfan spray (1kg a.i./ha) resulted in only 1.1 per cent seedling damage as compared to 10.0 per cent in untreated control. While, Ramson et al. (1977) suggested more than one spray of endosulfan for the best control of turnip moth, A.segetum, in GDR. According to Chandla et al. (1977), endosulfan when applied at 0.4 kg a.i./ha resulted in 5.5 per cent damaged plants and 3.1 q/ha damaged tubers compared to corresponding damage of 10.0 per cent and 13.6 q/ha in the untreated control.

Endosulfan @ 1 kg a.i./ha applied to the soil in equal split doses i.e. five days before sowing and at the time of sowing was highly effective and economical yielding 7.9 quintal as against 1.6 quintal in the untreated control in bengalgram (Vaishampayan and Veda, 1981). Patel (1981) found out that a spray of endosulfan @ 0.5 kg a.i./ha preceded by soil application of BHC dust @ 2.0 kg a.i./ha was effective against A.ipsilon in bengalgram. Tiwari (1983) recommended spraying foliage of potato and ridges with endosulfan @ 0.5 kg a.i./ha, whereas Chavan (1985) found lower dosage of 0.28 kg a.i./ha to be effective in the control of A.ipsilon

in tobacco nursery. Rajendran (1986) and Rajendran and Verma (1989) observed that a spray of endosulfan @ 1.25 and 1.5 litres per hectare, respectively, gave good control of Agrotis spp. in potato, while Chandramohan and Nanjan (1990) advocated the spray at 0.07 per cent in the evening hours with a high volume sprayer to protect vegetable crops, specially the crucifers in Nilgiris.

## 2) Carbaryl

Carbaryl (0.17%) sprayed to the base of potato plants reduced the survival of A.ipsilon in the soil (Pigatti and Pigatti, 1966), while on corn, the pest was controlled by applying 5 lb a.i./ha (Apple, 1967). Thimmaiah et al. (1972) recorded only 5.9 and 2.4 per cent seedling destruction when tobacco seedlings were drenched with carbaryl at 1.0 and 1.5 kg a.i./ha, respectively, as compared to 18.1 and 10.0 per cent destruction in the unsprayed plot.

About 6.6 per cent damaged plants and 8.5 q/ha damaged tubers of potato at 1.0 kg a.i./ha as compared to 10.0 per cent damaged seedlings and 13.6 q/ha damaged tubers in the untreated check was recorded by Chandla et al. (1977). However, Chavan (1985) suggested the chemical at 0.66 kg a.i./ha for the control of cutworms in tobacco.

Among the different insecticides evaluated against A.ipsilon in tobacco, Link et al. (1988) reported carbaryl at 2.0 litres/ha as quite effective.

3) Quinalphos

According to Chavan (1985), drenching of tobacco seedlings with quinalphos @ 0.2 kg a.i./ha at 15 and 35 days after transplanting gave satisfactory control of A.ipsilon. Rajendran and Verma (1989) suggested the dosage of 1.5 litres/ha to potato to minimize seedling and tuber damage.

4) Monocrotophos

El-sayed (1983) in Saudi Arabia found monocrotophos spray as promising against A.ipsilon, whereas Chavan (1985) highlighted the superiority of the insecticide when applied @ 0.24 kg a.i./ha in the control of cutworms on tobacco in India.

5) Phosalone

Thippeswamy et al. (1981b) reported that 4% dust when applied to soil before sowing of cotton resulted in 32.7 per cent damage as compared to 51.5 per cent in the untreated. Rajendran (1986) suggested 35 kg dust per hectare in reducing the tuber damage and increasing the yield in

potato crop. However, Vaishampayan and Veda (1981) obtained poor results with 40 kg dust per hectare applied at sowing in wheat and bengalgram. Efficacy of E.C. formulation, apparently, has not been evaluated.

#### 6) Phorate

Apple (1967) obtained good control of A.ipsilon in maize with phorate granules applied at 1.9 lb a.i./ha, but in potato much lower dosage of 0.5 lb a.i./ha protected the crop and increased the yield by 17.4 per cent (Alam and Ahmed, 1975). Rathore and Young (1975) and Borah et al. (1982) obtained effective control of cutworms in maize and potato by soil application of granules at 2.0 kg a.i./ha at sowing, whereas Rajendran (1986) noticed significant reduction in the plant and tuber damage in potato at 2.5 kg a.i./ha. Singh and Misra (1988) obtained maximum control of A.ipsilon at 1.0 kg a.i./ha in bhendi.

#### 7) Carbofuran

No much information is available on the use of carbofuran granule in the cutworm control except for the report of Singh and Misra (1988) who obtained good control of A.ipsilon in bhendi when applied at 0.9 kg a.i./ha.

8) BHC

Saxena and Rawat (1968) reported that 10% BHC @ 25 kg/ha was effective, persistent and economically cheap in the control of cutworm species infesting wheat. Thippeswamy et al. (1981b) recorded only 31.6 per cent seedling damage in the plots dusted at 30 kg/ha at sowing as compared to 51.5 per cent in the untreated control. On the contrary, Vaishampayan and Veda (1981) found out the dust as ineffective in controlling A.ipsilon on wheat and bengalgram.

9) Malathion

The only report on the effectiveness of malathion is by Borah et al. (1982). Dusting the soil at the time of planting at 2.0 kg a.i./ha was highly effective to A.ipsilon in potato.

10) Di-flubenzuron

Due to lack of information on the chitin inhibitor against Agrotis species, the review has been extended to cover other lepidopterous pests also.

Lipa (1976) found that dimilin caused heavy mortality of A.segetum larvae when used at 0.00025 per cent to 25 ppm concentration in the artificial diet. Mokrousova (1977) reported that 30 to 40 per cent mortality of A.ipsilon and

A.segetum larvae was noticed in field in USSR when the plants were sprayed at 0.1 to 0.01 per cent concentration. Similarly, Szatmari et al. (1978) tested the compound under field conditions in the control of A.ipsilon in corn.

Gong et al. (1986) in China made ultra structural and biochemical studies on integuments in relation to natural tolerance to diflubenzuron in A.ipsilon and armyworm, Mythimna separata (Walker). The LD<sub>50</sub> in ug/larva applied topically was 136.2 for the VI instar of A.ipsilon which was about 4.5 times that for M.separata. Thick cuticle (32.5 um) which was four times that of armyworm was said to be the cause for tolerance in the former species.

In India, the moult inhibitor has been tested extensively on many lepidopteran members. Review by Balasubramanian (1986) highlighted that diflubenzuron between 75 to 300 g a.i./ha controlled certain pests of cotton, groundnut, coconut, tobacco, etc., satisfactorily.

Natesan (1979) reported 84.3 per cent inhibition of egg hatch when Spodoptera litura (Fab.) eggs were treated with dimilin 25 W.D.P. at 100 ppm; while, 100 per cent mortality of Opisina arenosella Walker larvae was reported by Sundaramurthy (1980) when tested at 20 g a.i./tree in coconut. The compound was effective on all stages of Heliothis armigera (Hubner) at 1000 ppm as stomach poison (Balasubramanian et al., 1980)

caused 86.6 per cent mortality of Amsacta albistriga Wlk. at 20 g a.i./ha (Rabindra and Balasubramanian, 1985) and 96 to 100 per cent mortality of larvae of Achaea janata L. at 1g/litre (Rabindra and Balasubramanian, 1981) in Tamil Nadu.

Feeding final instar larvae of S.litura on castor leaves treated with diflubenzuron resulted in to 46 to 96 per cent inhibition of moulting and induced various degrees of morphological deformities in the resultant pupae (Sundaramurthy, 1977). Rao and Reddy (1984) observed that the chemical at 100 to 1000 ppm inhibited more than 75 per cent egg hatch, at 10 ppm and above there was total growth inhibition; while at 100 ppm and above 67 to 100 per cent reduction was noticed in adult emergence in both S.litura and A.janata.

**CHAPTER - III**

**MATERIAL AND METHODS**

### III. MATERIAL AND METHODS

Studies on the various aspects of eco-biology and control of cutworms envisaged in the introductory chapter were conducted in the laboratory and green house of the Department of Entomology and in the field at the Main Research Station (MRS), U.A.S., Dharwad from 1983 to 1986 and 1990 to 1991. The institute is situated at 15° 17' North latitude, 75° 05' East longitude and at an altitude of 731.8 meters above mean sea level (MSL). The campus lying in the transitional zone receives an annual rainfall of 825 mm, distributed well over the season. The monthly mean maximum temperature ranged from 37.8°C during April to 26.0°C during August, whereas the monthly mean minimum temperature varied from 12.8°C during January to 21.3°C during March. The relative humidity fluctuated between 93 and 63 per cent during the period of study.

#### 3.1 Species dynamics

In order to know the species dynamics of cutworms infesting major field crops, extensive collections were made from the infested fields during the cropping seasons from 1983 to 1986 and 1990 to 1991. Collections were made

from cotton, chillies, potato, greengram, cowpea, soybean, groundnut and onion in kharif ; safflower and bengalgram in rabi and amaranthus, cabbage and groundnut during summer from five localities namely, Dharwad, Savadatti, Haliyal, Shiggaon and Annigeri. The larvae, thus collected were reared on the respective hosts separately in the rearing cages for the emergence of moths. Freshly emerged moths were killed, mounted and sent to British Museum for identification. Subsequent collections on different hosts were compared with the holotypes kept in the department of Entomology, UAS, Dharwad to determine the species. The proportion of species in the laboratory reared adults was worked out.

### 3.2 Biology of cutworms

Larvae collected from the infested fields were reared in the laboratory to obtain moths. A pair of newly emerged male and female moths from the pure culture was introduced in to a transparent plastic jar (12 X 10 cm) and the mouth was covered with muslin cloth. Ten per cent honey was provided as food through cotton wad. As the female moth readily laid eggs on tied muslin cloth, neither seedlings nor any other substrate was provided for egg-laying. Thus, the pure culture of cutworm was obtained.

Freshly laid eggs were transferred to petricages provided with wet blotting paper at the bottom to protect the eggs from dessication to study the incubation period. Neonate larvae were reared individually in petricages of 9.5 cm ht X 13.0 cm diameter. Fresh cotton (Sharada variety) seedling were provided as food every day. The later instar larvae were provided with a layer of black soil to simulate the natural habitat. Petricages containing larvae were maintained in plastic tray with wet foam pads kept around so as to create desired micro-environment for the cutworms. The number of days occupied by each larval instar, pre-pupa and pupa was recorded. Measurements were taken of freshly laid fertile eggs, freshly moulted larvae of each instar, three day old pupa and mounted moths.

The pre-oviposition period, fecundity, oviposition period and adult longevity with and without food were studied by enclosing ten pairs of male and female moths separately into the plastic jars as described already. The duration from egg to adult emergence was considered as a generation period. Temperature and relative humidity that prevailed in the laboratory throughout the investigations were recorded.

Periodical observations were made on larval incidence throughout the year on different crops to estimate

the number of generations completed by the insect under field conditions.

### 3.3 Natural enemies

Field collected larvae from Dharwad, Savadatti, Haliyal, Shiggaon and Annigeri were reared in the laboratory in cages by providing all requirements to complete their development. The parasitoids emerged in the rearing cages were collected and preserved for further identification. A few dead larvae were also collected and preserved in the specimen tubes for identifying the microbial cause. Besides, creatures preying on the larvae in field were also collected and preserved. Later, these natural enemies were numbered serially and sent for identification.

### 3.4 Cannibalism

Investigation on cannibalistic behaviour of A.ipsilon and A.segetum was made under laboratory conditions by rearing II, IV, VI instar larvae separately and all instars together with and without food (cotton seedlings).

In each treatment 25 larvae of each species of each instar were reared separately in petricages. Observations on the number of surviving larvae were made for the period of four to twelve days in the case of II, IV and VI instar

and for four days where all the six instars were reared together. Mortality due to cannibalistic activity was analysed for test of significance.

### 3.5 Seasonal abundance

ICRISAT model light trap fitted with 200 watts mercury bulb (Plate 3 ) was operated from 1983 to 1986 from dusk to dawn in E block of MRS, Dharwad, to monitor the adult activity. Cotton was dipped in dichlorvos (DDVP) was used to kill the trapped moths. The population of moths trapped was transformed in to log (n+1) values for each standard week as suggested by Williams (1937) with the help of statistical tables (Fisher and Yates, 1963) and correlated with the temperature, relative humidity, rainfall and wind velocity. The field crops and their stages surrounding the light trap during the period of investigation were recorded.

### 3.6 Crop loss estimation

Assessment of crop loss in the form of per cent seedlings destroyed and yield reduction due to natural infestation of cutworms in cotton was made by raising the crop during kharif, 1983 and 1984. Cotton (G.hirsutum) Cv.Sharada was sown at 60 x 30 cm in 4.0 x 4.0 m plots following the

Plate 3. ICRISAT model light trap fitted with  
mercury bulb



recommended package of practices except plant protection measures against cutworms in the seedling stage. Four treatments that were replicated five times in RBD included:

1. Drenching of soil with endosulfan 35 EC at 1.5 ml per litre of water,
2. Application of carbofuran 3G to soil at the time of sowing at 25 kg per hectare,
3. Mechanical removal of larvae, and
4. Untreated check.

Drenching of soil with endosulfan was made at weekly interval starting from two days old seedlings by pouring the spray solution @ 125 ml/seedling at the base of seedlings. Carbofuran granules were applied at sowing along the rows at a distance of ten centimeter from the row on either side. In the mechanical removal treatment, the cutworms hiding in the soil at the base of seedlings were removed everyday in the morning. In the untreated check, the plants were completely exposed to damage by natural population of cutworms.

Number of seedlings cut with reference to initial count in each experimental plot was recorded daily for 30 days from the date of germination. Finally, the kapas yield was recorded in each picking at crop maturity.

### 3.7 Damage potential

To estimate the extent of damage caused by the last three instars which exhibit cutting behaviour, an experiment was laid in RBD with three replications. Cotton variety Sharada sown at 60 x 30 cm in 12 m<sup>2</sup> plot was imposed with seven treatments. The treatments included release of zero, two, four, six, eight, 10 and 12 fourth instar larvae per plot. The study was conducted during the off-season to avoid natural population interfering with treatments.

The experimental plots were guarded by 800 gauge polythene (Plate 4 ) to prevent the movement of cutworms from one plot to another. From the laboratory culture of cutworms, early fourth instar larvae were released in experimental plots in the evening hours on two days old crop according to the treatment details. Cotton was sown again after seven days in each plot adjacent to earlier sown plants with a view to provide younger seedlings throughout the cutting life span of larvae.

Observations were made daily for 15 days on the number of seedlings cut, seedlings completely consumed and seedlings partially consumed in both the sowings. The data was analysed for statistical significance after suitable transformation.

Plate 4. A view of experimental plots with polythene barrier to each plot to prevent the movement of larva



### 3.8 Feeding behaviour

Studies on the nature of feeding of A.segetum on cotton seedlings of different age was studied during 1984-85. For this purpose 50 each of two and seven days old seedlings raised in the aluminium tray ; 15, 21 and 30 days old seedlings raised in 4 x 4 m area in green house were used. Five larvae of each instar were released separately in both the aluminium trays and in green house.

In the case of first and second instars, the larvae were placed on the seedlings while the other instars were released at the base of seedlings. The observations on the nature of feeding such as scraping of chlorophyll, shot holes on the leaves in early instars and cutting of stems besides feeding on stem in later instars were made.

### 3.9 Dispersal behaviour of the larva

A field experiment was laid out (Plate 5 ) during the off-season of 1990-91 with five treatments replicated thrice. The size of the experimental plots was 25 m<sup>2</sup> and Sharada cotton was sown at 60 x 30 cm. The treatments involved release of fourth instar larva at the centre of plot having,

- 1) Seedlings throughout the plot.
- 2) no seedlings upto 1 m<sup>2</sup> in the centre of plot

Plate 5. A view of experimental field to  
study the dispersal of larva-  
Larva was released in marked area  
at the centre



- 3) no seedlings upto 4 m<sup>2</sup> in the centre of the plot
- 4) no seedlings upto 9 m<sup>2</sup> in the centre of the plot
- 5) no seedlings upto 16 m<sup>2</sup> in the centre of the plot.

Immediately after germination, the experimental plots were guarded by polythene barriers to prevent migration of larva from one plot to another. Two days later, single fourth instar larvae was released in the evening in each plot.

The observations were recorded on the time taken by the larva to travel to the site of damage from release point, number of seedling cut per day and distance travelled. The locations of cut seedlings in each treatment were noted in the graph sheet to map the movement of cutworm larva during its cutting life span of about 15 days.

### 3.10 Host preference

During kharif, 1984 and 1985, experiments were laid out in RBD by raising each host crop over 16 m<sup>2</sup> area replicated three times. Taking into consideration the number of days required for germination, various host crops were sown on different dates to synchronise emergence of all crops. The host crops studied for preference by the cutworm

larvae included cotton, potato, chillies, groundnut, soybean, safflower, cowpea, greengram, maize and wheat.

During 1984, there was severe incidence of cutworms and the host crops were subjected to natural infestation while, artificial release of fourth instar larvae @ five per plot was made on three days old seedlings during 1985 due to inadequate natural infestation. Initial plant stand and the number of seedlings cut every day in each of the host crop for 30 days were counted. The data on per cent seedlings damaged was subjected to analysis of variance after transformation.

### 3.11 Effect of host plants on the biology of cutworm

The study was carried out during 1984-85 by rearing A.segetum from early instar larvae till adult emergence on ten host plants listed in Table 20. After the emergence, male and female moths were caged separately and eggs were collected. When these eggs hatched, the larvae were transferred to the same host plants on which the previous generation was completed. Sixty larvae were studied in batches of 20 forming three replications for a single host plant. Fresh seedlings of different host crops were provided as food daily. The weight of the larvae was determined on the 10th and 20th day after hatching and of VI instar before reaching the

pre-pupal stage on each host plant. Similarly, the weight of three day old pupae was also recorded. The developmental periods of egg, larva, pre-pupa and pupa were recorded for each of the host plants.

Total developmental period, per cent pupation, growth index, per cent adult-emergence, sex ratio, adult longevity and fecundity on test hosts were determined. The growth index was worked out by dividing mean per cent pupation by mean larval period.

### **3.12 Control of cutworm**

#### **3.12.1 Effect of diflubenzuron**

Growth regulatory and insecticidal activity of diflubenzuron, a chitin synthesis inhibitor, in the form of 25 WDP at 0.00025, 0.00125, 0.0025, 0.005, 0.0075 and 0.0125 per cent was evaluated by (a) dipping of eggs in various test concentrations; (b) feeding the III, V and final instar larvae on treated cotton seedlings and (c) dipping of pupae.

One hundred and fifty eggs of one and three day old eggs, in three replications, of 50 each were dipped in different strengths for one minute, air dried and kept for hatching. Hatchability was recorded after five days and

egg mortality was computed. Eggs dipped in distilled water served as untreated control.

Cotton seedlings dipped in different concentrations of diflubenzuron for two minutes were fed to III, V and final instar larvae for 48 hours. The larvae were reared on untreated seedlings from third day in glass petri-cages. Fifty larvae were used in each treatment replicated three times. Observations on moulting were made everyday. Larval mortality counts were taken ten days after treatment and till pre-pupal stage. Counts on adult emergence was also made.

Two days old pupae were dipped in test concentrations of the compound for one minute and air dried. Thirty treated pupae in three group of ten each were kept for adult emergence. Observations were taken at 24 hours interval for normal adult emergence, deformed adult emergence and pupal mortality was computed.

The data on various parameters of growth and development were subjected to statistical analysis after suitable transformation.

### 3.12.2 Evaluation of insecticides

Field experiments were laid out during kharif, 1983, 1984, 1985 and 1991. Nine insecticide formulations consisting

of five soil drenches, two dusts and two granules were tested in the first two seasons (kharif, 1983 and 1984). During kharif, 1985, diflubenzuron at two dosages was tested in the form of food poison-bait along with other chemical toxicants. Whereas in 1991, the chitin inhibitor was tested as soil drench at two dosages along with two insecticide drenches, two poison-baits and one dust treatment. The details of treatments are furnished in Table 4.

Sharada cotton was sown at 60 x 30 cm in 16 m<sup>2</sup> plots replicated thrice in RBD. The trials of 1983 and 1984 were subjected to natural infestation while, five IV instar larvae were released in each plot during 1985 on two days old seedlings due to inadequate natural infestation. The chemicals were applied at the time of sowing in the case of granules, two and ten days after germination in the case of dusts and emulsifiable concentrates as soil drenches and two and seven days after germination in the case of diflubenzuron administered through bait. The recommended plant protection measures for the control of other pests and diseases were followed by commencing spray schedules from 30th day of the sowing.

#### 3.12.2.1 Preparation of poison-bait

Twenty five kilos of rice bran, 5 kg jaggary and required quantity of test products were mixed and water was sprinkled on the mixture until the bait attained dough consistency. Fresh bait was applied along the rows in the evening hours.

#### 3.12.2.2 Cost benefit ratio

Cost benefit ratio for the insecticidal control was worked out by dividing the total cost of control operation by the profit reaped due to additional investment.

Table 4. Details of the chemical treatments

Insecticide Name	Formulation	Dosage	Trade Name	Chemical Group	Source
1	2	3	4	5	6
<u>1983 and 1984 trial</u>					
Endosulfan	35 EC	@ 1.5 ml/lit. of water	Thiodon	Cyclodiene	Hoechst (India) Limited
Phosalone	35 EC	@ 1.5 ml/lit. of water	Zolone	Organophosphorus	Rhone-Poulenc
Carbaryl	40 EC	@ 1.5 ml/lit. of water	Sevimol	Carbamate	Union Carbide
Monocrotophos	36 WSC	@ 1.5 ml/lit. of water	Nuvacron	Organophosphorus	Ciba-Geigy Limited
Quinalphos	25 EC	@ 1.5 ml /lit. of water	Ekalux	Organophosphorus	Sandoz (India) Limited
Malathion	5% D	30 kg/ha	Malathion	Organophosphorus	Excel Industries, Limited
BHC	10% D	30 kg/ha	BHC	Organochlorine	Karnataka Pesticides
Carbofuran	3% G	25 kg/ha	Furadon	Carbamate	Rallis (India) Limited
Phorate	10% D	25 kg/ha	Thimath	Organophosphorus	Cynamid (India) Limited

1	2	3	4	5	6
<u>1985 Trial</u>					
Endosulfan	35 EC	@ 1.5 ml/lit. of water	Thiodon	Cyclodiene	Hoechst (India) Limited
Monocrotophos	36 WSC	@ 1.5 ml/lit. of water	Nuvacron	Organophosphorus	Ciba-Geigy Limited
Diflubenzuron	25 WDP	75 and 112.5 g a.i. per ha in poison- -bait	Dimilin	Benzoylated urea	Duphar B.V. Netherlands
Carbofuran	3% G	25 kg/ha	Furadon	Carbamate	Rallis (India) Limited
Phorate	10% G	25 kg/ha	Thimate	Organophosphorus	Cynamid (India) Limited
<u>1991 Trial</u>					
Diflubenzuron	25 WDP	@ 100 & 150 g a.i./ha as soil drench, @ 112.5 g a.i./ha in poison-bait	Dimilin	Benzoylated urea	Duphar B.V. Netherlands
Monocrotophos	36 SL	@ 0.225 kg a.i./ha in poison-bait	Nuvacron	Organophosphorus	Rhone-Poulenc
Endosulfan	35 EC	@ 1.5 ml/lit. of water	Thiodon	Cyclodiene	Hoechst (India) Limited
Methomyl	35 EC	@ 1.5 ml/lit. of water	Lannate	Carbamate	Coromandal Indag Limited
BHC	10% D	@ 30 kg/ha	BHC	Organochlorine	Karnataka Pesticides

**CHAPTER - IV**

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**EXPERIMENTAL RESULTS**

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#### IV. EXPERIMENTAL RESULTS

Results of the investigations carried out on the cutworms, Agrotis spp. in cotton with reference to the species dynamics, biology and natural enemies, seasonal abundance, crop loss estimation, host preference and its effects on the biology, behavioural studies on damage potentiality, dispersal and cannibalism and chemical control are presented hereunder.

##### 4.1 Species dynamics

Extensive collections made from different crops during the cropping seasons from 1983 to 1986 and 1990 to 1991 and subsequent rearing revealed occurrence of Agrotis segetum (Dennis and Schiffermuller) and A.ipsilon (Hufnagel). The former species was predominant in the region. Of the larvae from five localities and reared on 12 crops, 88.4 per cent (Table 5) belonged to A.segetum and the rest to A.ipsilon.

In cotton, on which cutworms are of meaning concern, A.segetum was the most dominant species in all the three localities with 96.8 per cent of the larvae belonging to it. Occurrence of A.ipsilon in cotton ecosystem was inconsequential. Agrotis segetum was the only species that infested

Table 5. Species dynamics of cutworms infesting different host crops  
(Period of study : 1983 to 86 and 1990 - 91)

Sl. No.	Collections made from	Locality	No. of larvae-completing development	% moths emerged	
				<u>A.segetum</u>	<u>A.ipsilon</u>
1.	Cotton	Dharwad Haliyal Savadatti	774	96.8	3.2
2.	Chillies	Dharwad Shiggaon Haliyal	572	87.4	12.6
3.	Onion	Dharwad	195	100.0	0.0
4.	Greengram	"	149	100.0	0.0
5.	Groundnut	"	82	100.0	0.0
6.	Cowpea	"	54	100.0	0.0
7.	Bengalgram	Dharwad Annigeri	250	100.0	0.0
8.	Safflower	"	177	93.8	6.2
9.	Soybean	Dharwad	37	64.9	35.1
10.	Potato	"	66	75.8	24.2
11.	Cabbage	"	106	96.2	3.8
12.	Amaranthus	"	183	45.9	54.1
Total			2840	88.4	11.6

groundnut, onion, cowpea, greengram and bengalgram and it was the principal species on chillies (87.4 %), cabbage (96.2 %), potato (75.8 %) and safflower (93.8 %).

On soybean and amaranthus both A.segetum and A.ipsilon were noticed in large numbers. While the proportion of A.segetum was slightly more than half on soybean (64.9 %), it was reversed in the case of amaranthus (45.9 %). On cotton, cabbage and safflower, - only 3.2, 3.8 and 6.2 per cent of larvae of A.ipsilon were collected and reared respectively.

#### 4.2 Biology

Biology of A.segetum and A.ipsilon was studied on cotton in the laboratory during September-October, 1983 and October-November, 1983, respectively. During the former period, temperature ranged from 19.4 to 28.4 °C and the RH varied from 75.6 to 93.8 per cent. While, in the latter period corresponding weather parameters fluctuated from 16.2 to 29.3 °C and 66.2 to 89.7 per cent, respectively.

##### 4.2.1 Egg

Both A.segetum and A.ipsilon moths laid the eggs singly and sometimes in groups of 20 to 50 with interspace between the eggs.

Freshly laid eggs of both the species were creamy white to light yellowish, shining and spherical with longitudinal ribs all around. On the second day of oviposition, an irregular pinkish patch developed around the egg. A day before hatching, entire egg turned pinkish in both the species. But in A.segetum, this pinkish patch turned dark few hours before hatching. At this stage, head and the pro-thoracic shield of larva could be seen through the transparent chorion under the stereobinocular microscope. Just before hatching, larva made a hole in the shell and pushed its head out. The unfertilized eggs were yellowish, failed to change in colour and shrivelled gradually. Eggs hatched during night hours.

The eggs of A.segetum and A.ipsilon measured 0.70 and 0.73 mm in length and 0.67 and 0.68 mm in width, respectively. The incubation period in the former species ranged from four to five days with an average of 4.3 days (Table 6) while, it varied from three to four days with an average of 3.3 days in A.ipsilon (Table 7).

#### 4.2.2 Larva

During its larval period, A.segetum moulted five times to complete six instars while, A.ipsilon moulted five and six times to pass through six to seven larval

Table 6. Biology of A.segetum on cotton - Duration of life stages and body measurements

Stage	Duration (days)		Body size in mm			
	Range	Average	Length		Width	
			Range	Average	Range	Average
1. Egg	4-5	4.3	0.50-0.80	0.7	0.64-0.70	0.67
2. <u>Larva</u>						
I Instar	2-3	2.7	1.9 - 2.5	2.1	0.2-0.4	0.3
II Instar	3-5	4.0	3.0 - 3.5	3.3	0.5-0.6	0.6
III Instar	3-6	4.3	3.7 - 6.0	4.5	0.7-1.0	0.8
IV Instar	3-6	4.6	7.5 -15.0	9.2	1.2-1.3	1.2
V Instar	3-6	4.8	14.5-22.5	18.4	1.5-1.8	1.7
VI Instar	7-10	8.5	24.5-40.0	33.6	2.7-3.8	3.1
Total	21-36	28.9				
3. Pre-pupa	2-3	2.3	15.5-18.0	16.2	4.0-5.5	4.5
4. Pupa	13-15	14.1	12.5-18.0	15.8	4.3-6.0	5.6
5. <u>Adult</u>						
a) Male	i. 7-15	10.1				
	ii. 3-7	5.4	28.0 - 36.0		33.9*	
	iii. 3-8	5.3				
b) Female	i. 8-12	11.9	30.0 - 39.0		36.5*	
	ii. 3-6	4.9				
	iii. 3-6	4.5				

i. With 10% honey solution as food; ii. Without food;  
 iii. With water; \* Wing expansion

Table 7. Biology of A.ipsilon on cotton - Duration of life stages and body measurements

Stage	<u>Duration (Days)</u>		<u>Body size in mm</u>			
	Range	Av.	<u>Length</u>		<u>Width</u>	
			Range	Av.	Range	Av.
1. Egg	3-4	3.3	0.63-0.77	0.73	0.60-0.75	0.68
2. Larva						
a) <u>Pentamoulter</u> Instar						
I	2-5	2.8	2.0-3.0	2.5	0.30-0.34	0.3
II	3-4	3.5	3.0-3.5	3.2	0.45-0.65	0.5
III	3-5	4.0	3.0-5.0	4.1	0.70-0.85	0.8
IV	4-6	4.9	6.0-10.0	6.8	1.20-1.50	1.3
V	4-7	6.0	10.0-15.0	12.4	1.50-1.70	1.5
VI	8-15	11.1	16.0-25.0	18.4	2.00-2.50	2.2
Total	24-42	32.3				
b) <u>Hexamoulter</u> Instar						
I	2-5	2.8	2.0-3.0	2.5	0.30-0.34	0.3
II	3-4	3.5	3.0-3.5	3.2	0.45-0.65	0.5
III	3-5	4.0	3.0-5.0	4.1	0.70-0.85	0.8
IV	4-6	4.9	6.0-10.0	6.8	1.20-1.50	1.3
V	4-7	6.0	10.0-15.0	12.4	1.50-1.70	1.5
VI	10-14	11.7	24.0-31.0	27.3	2.30-2.70	2.4
Total	30-48	38.2				
3. <u>Prepupa</u>	20-30	2.5	17.0-21.0	18.0	4.00-5.00	4.5
4. <u>Pupa</u>	12-15	13.2	16.0-19.0	17.5	5.50-6.50	5.9
5. <u>Adult</u>						
a) Male						
i.	7-14	9.8				
ii.	3-7	5.1	31.0-40.5	36.8*		
iii.	3-6	4.7				
b) Female						
i.	7-13	10.3				
ii.	2-6	4.8	35.0-43.0	40.5*		
iii.	3-6	4.4				

i. With 10% honey as food; ii. Without food; iii. With water \* Wing expansion

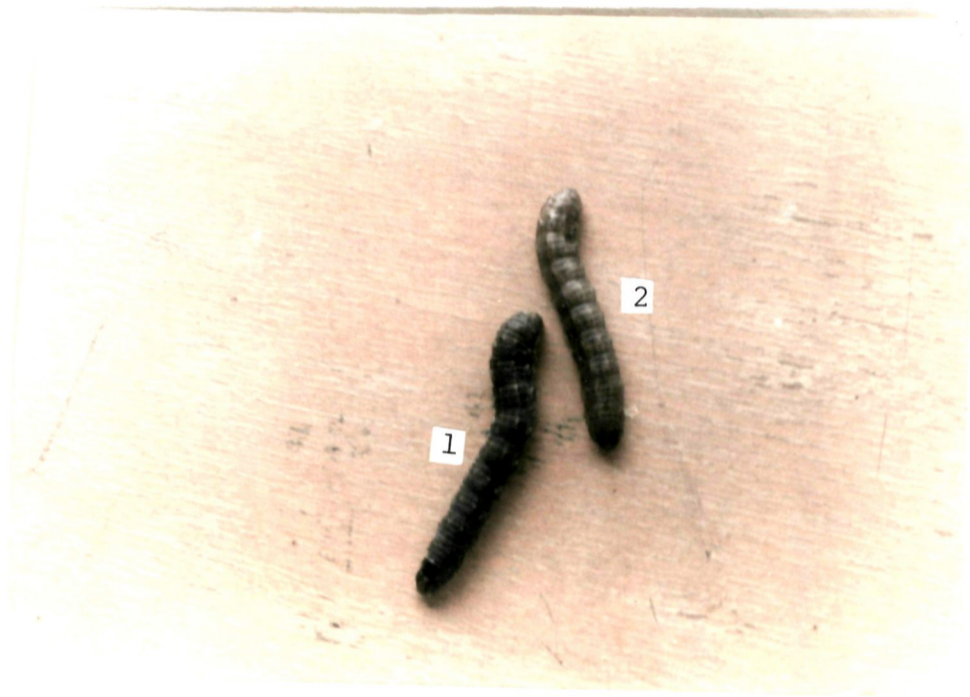
instars. Though there was variation in colour, grown up larva of A.segetum was dark grey to black with dots on the lateral sides with dark brown dorsal, sub dorsal and spiracular stripes and grey stripes on the pleuron. Whereas A.ipsilon larva was brownish or greyish with greyish dorsomedian streak and light brownish lateral stripes (Plate 6 ). A brief description of each instar is given below :

4.2.2.1 I instar : In A.segetum, the newly hatched larva was dull white with brown head while, it was greyish-yellow with shining black head in A.ipsilon. The larva of the former measured 2.1 mm long and 0.3 mm wide across the head capsule. The corresponding values for the latter species were 2.5 mm and 0.3 mm. The duration varied from two to three days with an average of 2.7 days and two to five days with an average of 2.8 days for A.segetum and A.ipsilon, respectively.

Immediately after hatching, neonate larvae of both the species scraped the green matter from the under-surface of the succulent leaves as a result the leaves turned to papery devoid of chlorophyll.

4.2.2.2 II instar : In both the species, it resembled the first instar except in size. Agrotis segetum measured 3.3 mm in length and 0.6 mm in width. The instar lasted for three to five days with an average of 4.0 days. On the

Plate 6. Grown-up larvae of A.segetum and  
A.ipsilon - No.1: A.ipsilon  
No.2: A.segetum



other hand, the larva of A.ipsilon measured 3.2 mm long and 0.5 mm wide at the head region. The larvae fed on young leaves by scraping the chlorophyll and completed the instar in 4.0 and 3.5 days in A.segetum and A.ipsilon, respectively.

4.2.2.3 III instar : Colour variation within the instar was observed from third instar onwards in both the species. This variation was quite distinct in A.ipsilon. The larvae exhibited light brown, green, light pink and reddish yellow colours, however, the head capsule was black in all cases. The larvae of A.segetum were generally light brown with greyish tinge and occasionally had black-grey and pinkish colour.

The length, width and duration of the instar in A.segetum was 4.5 mm and 0.8 mm and 4.3 days and 4.1 mm, 0.8 mm and 4.0 days in A.ipsilon. The larvae fed on leaves by making characteristic shot holes, while few of the individuals were found to feed on stems of young cotton seedlings.

4.2.2.4 IV instar : Increase in size and changes in colour were striking as the larvae moulted to fourth instar. Colour changed to black-grey or clay with dorsal and lateral stripes and spots on lateral sides becoming more distinct in A.segetum.

However, all colour forms noticed in the previous instar turned to dark brown with pinkish tinge with obscured longitudinal streaks all over the body in A.ipsilon.

The body measurements increased significantly in both the species but was more drastic in A.segetum. Length was doubled from 4.5 mm and width was increased by half time from 0.8 mm in A.segetum. While, A.ipsilon increased dimensions by 50 per cent more than in previous stage. The larvae fed by devouring the seedlings completely and entered into moulting after 4.6 and 4.9 days in the two species, respectively.

4.2.2.5 V instar : Longitudinal and lateral stripes in both the species became very distinct with setae spread all over the body. Light yellow stripes on the dorsum and black stripes on the pleuron were found in A.ipsilon whereas, light brown longitudinal stripes on the pleuron were found in A.segetum, but the general body colour remained as in fourth instar in both the species. Like in fourth instar, growth rate was high in both the species. Larvae of the latter species measured 18.4 mm long and 1.7 mm wide and completed development in 4.8 days and the corresponding values for the latter species were 12.4 mm, 1.5 mm and 6.0 days.

4.2.2.6 VI instar : The larvae of A.segetum appeared greyish black. The body was tight, shiny with prominent elevated black spots on the lateral side in triangular form on which single seta is borne. The head capsule was pale coloured and thoracic plates were brownish. The stripes present on the dorsal, sub dorsal and spiracular regions were more darker than in the previous instars. The lateral sides developed faint-dark lines with black and prominent spiracles. On the contrary, the full grown larvae of A.ipsilon were dark brown with greasy body. The longitudinal middorsal line was distinct and light grey while, the lateral stripe which was blackish in colour was quite thick and prominent.

The instar measured 33.6 mm in length and 3.1 mm in width at the head region and lasted for 8.5 days in A.segetum and the corresponding figures for A.ipsilon were 18.4 mm, 2.2 mm and 11.1 days in pentamoulters. The instar lasted for four to seven days with an average of 5.3 days with same measurements in hexamoulters. The larvae fed on the seedlings, devouring completely.

4.2.2.7 VII instar : In the case of A.ipsilon, about 10.0 per cent of the caterpillars moulted sixth time and thus had seven larval instars. This instar resembled completely

the previous one in all respects and lasted for 11.7 days. Body measured 27.3 mm in length and 2.4 mm in width.

4.2.2.8 Total larval period : The total larval period of A.segetum averaged to 28.9 days ranging from 21 to 36 days while, it varied from 24 to 42 days with an average of 32.3 days in pentamoulter and 30 and 48 days with an average of 38.2 days in hexamoulter in A.ipsilon. Thus, it was noticed that the latter species had longer destructive period than the former.

#### 4.2.3 Pre-pupa

At the end of last larval instar, the full grown larvae of both the species became inactive, ceased feeding, shrunk in their body and intersegmental areas became deeply constricted. They constructed oval earthen cell within which the larva transformed into pre-pupa. The pre-pupae lost the coiling habit, which was common feature in the late instars of larva, when disturbed.

The pre-pupa of A.segetum measured 16.2 mm in length and 4.5 mm in width, and lasted 2.3 days while, the length (18.0 mm) was slightly more but width (4.5 mm) remained same in A.ipsilon and the stage lasted for 2.5 days.

#### 4.2.4 Pupa

The pre-pupa transformed itself into an obtect pupa in the earthen cell (Plate 7 ) generally during night hours and exceptionally in the morning hours. In both the species, freshly formed pupa was whitish with light yellow tinge. After four to six hours of pupation, the pupa gradually turned to light brown and then to dark brown and became hard. The pupa was rounded at cephalic end and pointed posteriorly. Eyes slightly bulging, pale brownish initially and after five to six days of pupation turned black. Two to three days prior to the pupal eclosion, the entire body turned deep black due to the development of imago. Dorsally ten and ventrally six abdominal segments could be clearly seen with the posterior tip of abdomen possessing bifurcated cremasters.

The pupae of A.segetum were shorter in length (15.8 mm) and width (5.6 mm) than A.ipsilon. Pupal eclosion was earlier by nearly a day in the latter (13.2 days) than in the former (14.1 days).

#### 4.2.5 Total life cycle

Total life cycle from egg to adult emergence in A.segetum ranged from 40 to 59 days with an average of

Plate 7. Pupae taken out of earthern cell-  
To the left-male and to the right  
is female



49.6 days as compared to 41 to 64 days with an average of 51.3 days in pentamoulter and from 47 to 70 days with an average of 57.2 days in hexamoulter in the case of A.ipsilon.

#### 4.2.6 Adult

Adult emergence was common during night hours. The adults of A.ipsilon were slightly bigger and stouter than A.segetum. Moths of latter species possessed a reniform spot with brownish centre edging more towards coastal margin. An orbicular spot is present in the discal cell with black boarder and brownish centre on the forewing (Plate 8). A.ipsilon has similar markings, however, differentiating character from A.segetum is the presence of a conspicuous peg like black streak beyond the reniform marking (Plate 9). The hindwings in both the species and both the sexes are shiny white with the margin tinged brownish.

In both the species, males are smaller than females (Table 6 and 7). Adults of A.segetum lived longer (10.1 and 11.9 days) than A.ipsilon (9.8 and 10.3 days) when ten per cent honey was provided. The longevity was reduced by nearly half when the moths were provided with water or no food. Male always prepondered over females in both the species. However, the female to male ratio was high (1:2) for A.ipsilon as compared to A.segetum (1 : 1.5).

Plate 8. Male and female adult moths of

A.segetum

Plate 9. Male and female adult moths of

A.ipsilon



♀



♂



♀



♂

#### 4.2.6.1 Copulation

The male and female moths, in both the species, copulated in an end to end posture and the process lasted for about one to three hours.

#### 4.2.7 Oviposition

The eggs were laid both on soil (Plate 10 ) and seedlings at night. On seedlings, the moth laid eggs on stem bases (Plate 11 ), succulent shoots and abaxial and adoxial surface of leaves. When seedlings and moist soil were offered together for egg laying, the moths laid profusely on soil indicating its preference for soil. Interestingly, the moths preferred small clods of two to ten millimetre diameter than fine clay particles. Further, it was also observed in A.segetum that when soil and seedlings were provided together for egg laying, moths surprisingly laid eggs profusely on its own exuviae (Plate 12 ). The order of preference for egg laying was exuviae, soil and seedlings.

Females of A.segetum started ovipositing from second day onwards; however, pre-oviposition period was 3.1 days (Table 8 ) compared to 3.6 days in A.ipsilon (Table 9 ). The oviposition period lasted for slightly longer time in the latter species (5.0 days) than in the former (4.6 days).

Plate 10. Eggs laid on the soil

Plate 11. Eggs laid on stem base of cotton  
seedlings



Plate 12. Eggs laid on its own exuviae



Table 8. Reproductive biology of A. segetum

Sl. No.	Parameter	Range	Average*
1.	Pre-ovipositional period in days	2-4	3.1
2.	Ovipositional Period (OP) in days	3-6	4.6
3.	Eggs laid during first half of OP	287-900	604.0
4.	Eggs laid during second half of OP	201-588	383.4
5.	Fecundity	575-1250	987.4
6.	Number of eggs laid per day	57.5-359.5	207.1

\* Average of ten females

Table 9 .Reproductive biology of A.ipsilon

Sl. No.	Parameter	Range	Average*
1.	Pre-ovipositional period in days	3-5	3.6
2.	Ovipositional period (OP) in days	4-7	5.0
3.	Eggs laid during first half of OP	358-835	572.8
4.	Eggs laid during second half of OP	104-582	365.0
5.	Fecundity	463-1224	937.8
6.	Number of eggs laid per day	78.0-416.0	170.7

\* Average of ten females

#### 4.2.7.1 Fecundity

Considerable variation was observed in the number of eggs laid by each female in ten replications having a pair in each. The number of eggs laid by A.segetum swung from 575 to 1250 with an average of 987.4 (Table 8) and from 463 to 1224 with an average of 937.8 in A.ipsilon (Table 9). Fecundity per day was highest in the former (207.1) as compared to latter (170.7). The proportion of eggs laid during first half of the oviposition period was considerably higher than in the second half in both the species.

#### 4.2.8 Sexual dimorphism

Sexual dimorphism is well pronounced in both the species of cutworms in the pupal and adult stages and the distinguishing features are common to both the species. Genital opening is present on the elevated sclerite of ninth abdominal segment in male and in between eighth and ninth segments, locating more on eighth segment in female. Anal opening is located on tenth segment. Thus, the distance between two openings is more in female than in male.

In moths, the distinguishing features were wing colour and antenna. The female has dark grey to steel black coloured fore wings and setaceous antennae in contrast

to light brown forewings and bipectinate antennae in male (Plate 8 and 9)

#### 4.2.9 Development in the laboratory

With a view to ascertain continuity in the life history of cutworms, both the species were reared in the laboratory continuously throughout the year.

The study revealed that both the species breed continuously without undergoing any state of arrested growth and differentiation. Agrotis segetum was reared for a total of seven generations from June, 1984 through April, 1985 and from April, 1991 to May, 1991; while, A.ipsilon was reared for six generations from August, 1985 through April, 1986 and from April to May, 1991.

The developmental period from egg to adult emergence for A.segetum ranged from 45.9 days (Table 10) in February, April, 1985 to 51.5 days in November-December, 1984 during which periods the average temperature and RH were 27.9 °C and 66.9 per cent and 21.3 °C and 77.7 per cent, respectively. There was no major variation in the development of any of the life stages at different periods of the year. However, in general, development of larval stage was slow during peak winter.

Table 10. Developmental periods of A. segetum

Sl. No.	Period of rearing	Average duration in days			Temperature (°C)			RH (%)			
		Egg	Larva	Pupa	Total*	Min.	Max.	Av.	Min.	Max.	Av.
1.	June - July '84	4.2	31.6	12.9	48.7	18.7	33.9	23.6	51	100	90.1
2.	Aug - Sept. '84	4.1	30.5	13.0	47.6	17.5	32.2	23.1	55	100	87.1
3.	Sept. - Nov. '84	4.2	31.4	13.8	49.4	9.8	32.2	22.5	54	100	80.7
4.	Nov. - Dec. '84	4.2	33.1	14.2	51.5	9.8	31.5	21.3	54	100	77.7
5.	Jan. - Feb. '85	4.0	32.5	14.1	50.6	12.4	35.1	23.6	31	95	74.3
6.	Feb. - April '85	4.0	29.8	12.1	45.9	12.4	37.3	27.9	31	95	66.9
7.	April - May '91	4.0	30.6	13.5	48.1	12.3	39.9	28.0	43	92	69.9

\* Egg to Adult emergence

The variation in the developmental period for A.ipsilon during different periods of the year was by 3.7 days. Shortest period (47.0 days) (Table 11) was required at the beginning of summer, when the larval duration was cut short by 4.1 days from the longest period of 50.7 days during September-November. The mean temperature and RH recorded during the above periods were 28.2 °C and 69.9 per cent and 23.3°C and 79.7 per cent, respectively.

#### 4.2.9.1 Number of generations

Uninterrupted observation was made on the activity of cutworms on various host species in the field to assess the number of generations completed by the pest. The first generation commenced immediately after the receipt of monsoon rains during first week of June and the first two generations were completed on cotton and other allied hosts during June-September. Third generation was observed during October and November on rabi crops, particularly safflower and bengalgram. Fourth generation was completed during December to January on summer crops specially cruciferous vegetables like cabbage, groundnut, amaranthus etc.

From February onwards, the pest declined in number and continued its breeding at low ebb on alternate weed hosts such as parathenium, Parathenium hysterothorus Linnaeus,

Table 11. Developmental periods of A. ipsilon

Period of rearing	Average duration in days			Total*	Temperature(°c)			Relative Humidity (%)		
	Egg	Larva	Pupa		Min.	Max.	Av.	Min.	Max.	Av.
1. Aug.- Sept. '85	3.4	33.0	12.0	48.4	17.6	32.5	23.5	57	100	85.2
2. Sept. Nov. '85	4.2	33.5	13.0	50.7	11.2	32.5	23.3	52	100	79.7
3. Nov.- Dec. '85	4.0	32.5	12.5	49.0	10.9	32.3	22.5	52	93	76.1
4. Dec. '85 to Feb. '86	3.5	34.6	12.4	50.5	10.9	34.7	22.8	47	100	72.6
5. Feb.- April '86	3.5	30.5	13.0	47.0	12.3	39.7	28.2	38	91	69.9
6. April- May '91	3.8	32.9	12.7	49.4	12.3	39.9	28.0	43	92	69.9

\* Egg to adult emergence

Conyza sp. and Commelina benghalensis Linnaeus, during which period both the species of cutworms were successfully reared in the laboratory with the developmental periods of 45.9 and 48.1 days (Table 10) and 47.0 and 49.4 days (Table 11) during Feb. to April and April to May in A.segetum and A.ipsilon respectively.

#### 4.3 Natural enemies

##### 4.3.1 Parasitoids

Rearing of large number of field collected larvae from different localities in the laboratory enabled collection of parasitoids which were got identified at British Museum, London.

##### 4.3.1.1 Larval endoparasitoids

###### 1) Apanteles ruficrus Haliday (Hymenoptera : Braconidae)

The incidence of the parasitoid (Plate 13 ) was noticed on the later instar cutworm larvae. The per cent parasitization varied from 10.0 to 12.0.

###### 2) Ichneumon sp. (Hymenoptera : Ichneumonidae)

The parasitoid emerged from the later instar larvae and the extent of parasitization was very low (1.3%).

Plate 13. Larval endoparasitoid of cutworm  
larvae, Apanteles ruficrus



4.3.1.2 Larval-pupal parasitoids3) Turanogonia chinensis Wiedemann (Diptera : Tachinidae)

Solitary parasitoids (Plate 14 ) emerged from the pupae of cutworms. Extent of parasitization was very low ranging from 2.1 to 4.0 per cent.

4.3.2 Predators1) The ground beetle, Anthia sexguttata Fabricius

(Coleoptera : Carabidae)

The adult beetle was observed to prey on grownup cutworms in heavily infested cotton field.

4.3.3 Pathogens1) Nuclear polyhedrosis virus

The incidence of NPV was noticed in few of the field collected grownup larvae. The infected larvae were sluggish with shining integument and the caterpillars died later in the laboratory. When body of such of the dead larvae was ruptured, a dull white milky fluid oozed out.

2) Pathogens associated with the larvae under laboratory conditions

- a) white muscardine, Beauveria bassiana (Bals.) Vuill
- b) Penicillium waksmanii zaleski
- c) Aspergillus tamari kita

Plate 14. Larval-pupal parasitoid of cutworms,  
Turanogonia chinensis



#### 4.4 Cannibalism

Both the species of cutworms exhibited cannibalistic behaviour. The average rate of cannibalism in A.segetum and A.ipsilon was 17.5 and 44.7 per cent (Table 12), respectively. Cannibalism was quite high in the absence of food in both the species. Between the species, apparently A.ipsilon was more aggressive and per cent cannibalism with (17.5) and without food (72.0) was far higher than in A.segetum. The magnitude of cannibalism was nearly three times more in the former species than the latter. The difference in their cannibalistic rate, when analysed statistically, was found to be significant.

#### 4.5 Seasonal abundance

Cutworm moths were monitored through ICRISAT model light trap fitted with mercury vapour lamp during the period from June 1983 to October, 1986, barring the period from November, 1984 to April, 1985 and November, 1985 to May, 1986. As it was not possible to distinguish the moths of two cutworm species in the trapped catches due to the frequent removal of scales from wings, they were counted as Agrotis spp. The details of the studies are presented in Table 13.

Table 12. Cannibalism in A.ipsilon and A.segetum

Sl. No.	Rearing instars	Rate of Cannibalism				
		<u>A.ipsilon</u>		<u>A.segetum</u>		
		Number surviving after the study*	Per cent cannibalism	Number surviving after the study	Per cent cannibalism	
1.	I to VI together with food	I	7	30.0	20	7.3
		II	10		20	
		III	18		24	
		IV	20		25	
		V	25		25	
		VI	25		25	
2.	I to VI together without food	I	00	80.0	12	32.0
		II	00		08	
		III	00		20	
		IV	05		15	
		V	05		22	
		VI	20		25	
3.	VI with food	22	12.0	23	8.0	
4.	VI without food	07	72.0	17	32.0	
5.	IV with food	20	20.0	24	4.0	
6.	IV without food	08	68.0	20	20.0	
7.	II with food	23	8.0	24	4.0	
8.	II without food	08	68.0	17	32.0	
Average Cannibalism rate			: 44.7		17.4	
with food			: 17.5		5.8	
without food			: 72.0		29.0	
Cal. t			: 2.3			
Table t at 5%			: 2.14			

\* 25 larvae of each instar were kept in studies.

Table 13. Weekly catches of cutworm moths in light trap and weather factors

Sl. No.	Period	No. of moths trapped		Weather factors						
		Actual	Log (n+1)	Min. temp. (°C)	Max. temp. (°C)	RH morning (%)	RH evening (%)	Rain fall (mm)	Wind velocity (km/hr)	
1	2	3	4	5	6	7	8	9	10	
<u>1983</u>										
1.	June	I	0	0.00	21.86	34.79	92.14	54.43	0.00	16.70
2.	"	II	0	0.00	21.91	35.00	92.75	49.75	2.95	13.49
3.	"	III	1	0.30	21.11	28.26	97.75	86.13	7.50	17.01
4.	"	IV	1	0.30	17.27	24.24	99.57	94.86	36.19	18.20
5.	July	I	3	0.60	21.11	28.01	95.43	84.00	1.59	15.84
6.	"	II	6	0.85	20.80	29.14	92.50	79.50	0.88	14.66
7.	"	III	5	0.78	20.95	26.48	97.50	86.75	9.19	17.61
8.	"	IV	16	1.23	20.78	27.18	94.75	85.50	0.51	14.09
9.	Aug.	I	1	0.30	21.03	28.06	95.00	84.57	1.46	15.16
10.	"	II	9	1.00	20.16	25.34	100.00	92.13	9.53	17.53
11.	"	III	27	1.45	20.91	27.15	98.00	85.75	2.15	14.38
12.	"	IV	33	1.53	20.79	28.15	95.13	71.38	0.36	9.71
13.	Sept.	I	18	1.28	20.4	27.6	94.9	84.9	0.00	10.9
14.	"	II	46	1.67	20.4	27.9	94.6	81.7	1.51	10.6
15.	"	III	2	0.48	19.7	26.6	98.8	85.8	5.6	13.2
16.	"	IV	10	1.04	20.1	27.7	94.1	77.0	8.11	10.9
17.	Oct.	I	0	0.00	19.83	29.00	93.0	73.0	0.13	11.3
18.	"	II	0	0.00	18.50	30.13	91.3	60.5	0.00	8.1
19.	"	III	7	0.90	17.00	30.2	89.0	63.3	1.13	5.51
20.	"	IV	13	1.15	19.30	27.9	95.1	79.1	3.74	9.51
21.	Nov.	I	14	1.18	18.1	28.0	90.4	72.4	2.8	6.0
22.	"	II	8	0.95	12.1	28.4	75.9	55.4	0.00	5.6
23.	"	III	0	0.00	12.6	28.7	70.4	58.4	0.00	5.3
24.	"	IV	1	0.30	12.9	28.4	83.0	65.0	0.00	7.0
25.	Dec.	I	0	0.00	13.4	27.4	87.0	69.3	0.00	8.4
26.	"	II	0	0.00	14.8	28.5	86.4	62.6	0.00	7.6
27.	"	III	2	0.48	14.2	27.8	88.5	66.0	0.00	9.5
28.	"	IV	3	0.60	18.0	28.1	96.6	71.1	0.00	6.2
<u>1984</u>										
29.	Jan.	I	0	0.00	16.3	29.4	92.9	65.0	0.00	5.4
30.	"	II	0	0.00	14.5	29.1	88.9	65.9	0.00	7.3
31.	"	III	0	0.00	13.9	31.0	87.4	64.4	0.10	5.7
32.	"	IV	0	0.00	15.2	31.3	87.3	69.6	0.00	6.0
33.	Feb.	I	0	0.00	16.2	31.4	86.9	61.6	0.00	9.2
34.	"	II	2	0.48	18.4	30.8	87.3	65.4	0.00	8.1
35.	"	III	1	0.30	14.0	21.5	75.4	39.0	0.2	7.5
36.	"	IV	0	0.00	17.0	33.8	85.5	43.9	0.00	8.2

Table 13 Contd.

1	2	3	4	5	6	7	8	9	10	
37.	March	I	0	0.00	14.5	31.5	83.6	52.0	0.00	11.0
38.	"	II	0	0.00	19.7	34.5	84.0	57.5	0.6	7.6
39.	"	III	0	0.00	18.9	36.3	88.6	47.5	0.00	8.1
40.	"	IV	0	0.00	20.9	35.9	88.7	46.9	1.4	9.0
41.	April	I	0	0.00	21.1	36.5	91.3	50.6	0.00	9.7
42.	"	II	22	1.36	20.7	35.4	90.0	58.5	0.7	9.8
43.	"	III	1	0.30	21.4	36.5	90.8	50.9	0.3	11.0
44.	"	IV	5	0.78	20.3	26.7	91.1	55.4	0.00	13.4
45.	May	I	2	0.48	21.0	37.8	91.4	51.5	0.7	13.2
46.	"	II	2	0.48	21.2	38.1	89.9	48.5	0.3	14.4
47.	"	III	1	0.30	21.7	37.9	90.3	49.0	1.3	15.3
48.	"	IV	0	0.00	21.7	35.4	91.7	50.9	0.0	18.1
49.	June	I	0	0.00	20.5	31.4	95.7	69.1	1.9	38.4
50.	"	II	0	0.00	20.3	28.6	97.4	84.7	5.7	17.1
51.	"	III	0	0.00	20.6	23.9	91.0	81.6	6.2	20.4
52.	"	IV	0	0.00	18.9	27.7	93.4	82.3	2.6	17.4
53.	July	I	5	0.78	20.0	24.8	99.1	92.0	27.2	17.3
54.	"	II	8	0.95	19.6	27.8	96.6	83.4	4.8	13.0
55.	"	III	9	1.00	19.9	25.8	96.8	88.3	3.8	15.8
56.	"	IV	4	0.70	19.6	26.6	98.6	91.4	0.6	14.3
57.	Aug.	I	12	1.11	19.5	26.0	99.0	84.0	2.5	16.3
58.	"	II	14	1.18	19.6	25.7	97.1	85.6	2.1	17.4
59.	"	III	16	1.23	19.3	26.8	96.8	79.8	1.2	15.3
60.	"	IV	10	1.04	18.7	25.7	98.9	83.1	1.7	13.6
61.	Sept	I	15	1.20	21.2	26.6	95.1	75.1	1.0	13.3
62.	"	II	13	1.15	18.3	26.7	95.6	79.1	5.5	12.4
63.	"	III	23	1.38	19.5	29.4	91.0	66.4	3.1	7.5
64.	"	IV	26	1.43	19.4	28.4	94.8	75.8	12.3	6.0
65.	Oct.	I	11	1.08	20.1	29.6	93.9	66.0	4.9	6.4
66.	"	II	0	0.00	18.6	27.6	96.9	76.8	4.2	7.3
67.	"	III	9	1.00	18.7	29.3	93.1	66.5	3.4	7.2
68.	"	IV	8	0.95	17.5	24.7	91.3	66.5	0.0	4.7
1985										
69.	May	I	0	0.00	20.7	35.9	89.5	49.4	0.0	12.2
70.	"	II	0	0.00	20.6	36.8	92.4	46.9	5.2	12.1
71.	"	III	2	0.48	20.7	34.9	91.8	47.6	4.1	13.1
72.	"	IV	0	0.00	20.6	31.5	94.7	63.9	0.2	17.2

Table 13 Contd.

1	2	3	4	5	6	7	8	9	10	
73.	June	I	0	0.00	20.6	30.8	93.3	68.9	0.4	15.6
74.	"	II	0	0.00	20.0	29.0	93.7	72.9	1.3	17.1
75.	"	III	0	0.00	19.6	27.3	96.3	80.4	6.3	18.0
76.	"	IV	0	0.00	20.4	26.4	98.3	86.1	3.4	18.3
77.	July	I	6	0.85	20.6	25.8	97.0	84.5	2.5	18.3
78.	"	II	12	1.11	20.5	27.3	92.3	78.0	0.2	16.8
79.	"	III	5	0.78	20.0	25.8	94.8	86.4	4.7	12.0
80.	"	IV	13	1.15	20.0	25.8	94.0	93.1	3.0	14.8
81.	Aug.	I	11	1.08	20.2	24.4	96.8	88.5	12.4	16.6
82.	"	II	18	1.28	20.2	25.3	97.1	89.0	3.0	15.1
83.	"	III	14	1.18	19.6	26.9	96.1	81.0	0.2	11.2
84.	"	IV	11	1.08	19.6	27.5	94.5	75.6	1.8	12.1
85.	Sept.	I	6	0.85	19.2	28.2	94.4	70.6	0.3	9.1
86.	"	II	13	1.15	19.4	27.9	93.3	73.9	0.6	11.7
87.	"	III	16	1.23	18.6	29.3	91.9	63.4	0.0	9.8
88.	"	IV	8	0.95	19.5	31.2	92.4	64.4	0.8	8.4
89.	Oct.	I	3	0.60	20.2	27.4	98.4	83.6	12.3	9.3
90.	"	II	0	0.00	18.9	28.1	93.1	69.6	3.0	8.4
91.	"	III	0	0.00	16.3	29.3	90.5	65.1	0.0	6.2
92.	"	IV	0	0.00	14.4	30.4	88.3	56.9	0.0	6.9
<u>1986</u>										
93.	June	I	0	0.00	20.5	32.3	90.4	56.5	1.0	10.9
94.	"	II	0	0.00	21.4	33.6	92.1	58.3	6.9	15.1
95.	"	III	0	0.00	20.6	27.4	96.8	80.3	2.2	17.5
96.	"	IV	0	0.00	20.6	26.3	99.4	87.6	7.0	18.6
97.	July	I	0	0.00	20.4	18.3	96.5	84.3	1.0	10.9
98.	"	II	12	1.11	19.9	26.9	96.0	84.0	6.9	15.1
99.	"	III	17	1.26	20.0	24.9	97.4	90.8	2.2	17.5
100.	"	IV	8	0.95	19.5	27.2	94.9	77.0	7.0	18.6
101.	Aug.	I	11	1.08	19.7	26.1	97.3	88.3	6.2	15.0
102.	"	II	16	1.23	19.7	24.2	98.5	90.1	4.7	16.5
103.	"	III	24	1.40	18.9	26.7	94.8	77.5	0.5	12.6
104.	"	IV	36	1.57	17.5	29.1	91.1	65.9	0.0	8.2
105.	Sept.	I	11	1.08	18.2	28.7	93.1	68.7	0.0	9.9
106.	"	II	9	1.00	18.7	18.6	90.0	67.3	0.0	11.7
107.	"	III	21	1.34	19.7	29.7	93.0	66.8	6.4	6.4
108.	"	IV	14	1.18	20.1	30.1	93.1	61.4	4.5	8.1
109.	Oct.	I	10	1.04	19.8	30.3	93.9	62.8	3.8	7.3
110.	"	II	20	1.32	21.0	32.2	90.8	56.9	0.0	7.0
111.	"	III	11	1.08	17.7	36.0	90.3	57.0	0.0	6.0
112.	"	IV	6	0.85	17.5	30.9	90.3	58.1	0.0	8.7

#### 4.5.1 Seasonal activity

The light trap was operated for a total of 112 weeks commencing from I week of June, 1983 to IV week of October, 1986. From the data it was noticed that the moth activity started from June III week and continued till October with declined activity from December to June. The number of moths attracted during different standard weeks varied from no attraction to a maximum of 46 moths while, monthwise fluctuation ranged from zero to 87 moths.

During 1983, the number of moths trapped ranged from one in June III week to 46 moths in September II week. The total number of moths attracted in different months from June to December was 2, 30, 70, 76, 20, 23 and 25, respectively, with maximum attraction of 76 moths in September. During 1984, the monthly catches from January to October was 0, 3, 0, 28, 5, 0, 26, 52, 77 and 28, respectively. Weekly attraction varied from a minimum of one to a maximum of 26 moths, highest being in the IV week of September. While during the year 1985, the weekly trapping varied from 2 to 18 moths. The highest number of moths (18) were trapped during August II week. The total number of moths attracted to the light trap during various months from May to October, 1985 was 2, 0, 36, 54, 43 and 3, respectively. During 1986, a total of 0, 37, 87, 55 and 47 moths were

trapped in June, July, August, September and October, respectively. During this period the catches ranged from six moths in IV week of October to 36 in III week of August.

The data on the moth catches indicate that moth activity was quite high during the kharif season comprising of July, August, September and October months, in all the four years of study during which period there would be heavy larval infestation of cutworms on different agricultural and horticultural crops. Interestingly, in all the four years, the peak attraction of moths was during August and September during which period the preferred hosts such as cotton, cowpea, greengram, chillies, potato, etc. were available in plenty in the seedling stage. The decline in moth catches from December onwards was apparently attributed to reduced larval activity due to the decrease in the availability of hosts in the seedling stage. However, the pest was carried over in the off-season on alternate weed hosts and on few of the summer vegetable crops which has been indicated by the stray catches from February to June.

#### 4.5.2 Relationship between weather factors and moth catches

The relationship between weather factors viz., minimum and maximum temperature, morning (RH1) and evening (RH2)

relative humidity, rainfall and wind velocity and trap catches (log (n+1) values) for the study period of 112 standard weeks was established by multiple linear regression analysis. The correlation between weekly catches and minimum temperature, morning RH and evening RH was positive and significant (r values of 0.18, 0.31 and 0.37, respectively). Maximum temperature exerted negative and significant effect on the weekly catches. While there existed positive association between moth activity and rainfall (r=0.07), wind velocity had negative impact (r=-0.1), however, the association was not significant. The multiple regression model for the moth activity was :

$$Y = -1.330 - 0.009 X_1 - 0.053 X_2 - 0.001 X_3 + 0.019 X_4 - 0.008 X_5 + 0.085 X_6$$

(0.01)      (0.011)      (0.018)      (0.005)

(0.013)      (0.032)

where,

Y = Weekly moth catch;  $X_1$  = rainfall;  $X_2$  = wind velocity;  $X_3$  = morning RH (RH1);  $X_4$  = evening RH (RH2);  $X_5$  = maximum temperature and  $X_6$  = minimum temperature and the values in the parentheses in the regression equation are standard error of respective coefficients.

The multiple regression model indicated highly significant positive correlation between moth catches and

evening RH ( t value 3.45 ) and minimum temperature ( t value 2.59). While, highly significant negative correlation was observed between moth catches and wind velocity ( t value -4.60). There was 30 per cent variability in the moths trapped as explained by the variables included in the regression model ( $R^2=0.30$ ) which was significant at 5 per cent level of significance.

When individual weather factor was considered, keeping other factors constant and regression equation computed, minimum temperature, maximum temperature, morning and evening RH were found to have significant influence on the moth catches. The regression equations for the above variables were :

$$Y = -0.234 + 0.045 X_1$$

(0.023)

$$Y = 1.485 - 0.029 X_2$$

(0.012)

$$Y = -2.507 + 0.033 X_3$$

(0.009)

$$Y = -0.386 + 0.014 X_4$$

(0.003)

Where,  $X_1$  = minimum temperature;  $X_2$  = maximum temperature;  $X_3$  = morning RH and  $X_4$  = evening RH. On the other hand, rainfall and wind velocity failed to influence the moth catches significantly .

#### 4.6 Crop loss estimation under field conditions

##### 4.6.1 Seedling damage

The data on the seedling damage during two consecutive field experiments conducted to assess the loss is presented in Table 14. Initial plant stand during both the years was uniform in all the three treatments and an untreated check.

During kharif 1983, drenching the plant base with endosulfan recorded significantly lowest seedling damage (6.2 %) followed by carbofuran granule application to soil with 14.7 per cent damage. Continuous removal of larvae mechanically for one month still permitted 17.3 per cent seedlings to be cut, yet was statistically at par with carbofuran treatment. Untreated check recorded significantly highest (36.3 %) seedling damage.

The experiment when repeated in 1984 recorded marginally higher larval incidence. Natural infestation caused 39.0 per cent seedling damage in control. All the treatments differed significantly with reduction in damage being highest (86.2 %) in endosulfan treatment followed by 65.1 per cent in carbofuran granule application to soil and 54.8 per cent in the mechanical control.

Table 14. Estimation of loss due to cutworms in cotton

Sl. No.	Treatments	Initial plant population		% seedlings cut at 30 DAG		% reduction in damage over control		Kapas yield					
		1983	1984	1983	1984	1983	1984	1983		1984			
								Kg/plot	Q/ha	% increase over control	Kg/plot	Q/ha	% increase over control
1.	Soil drenching with endosulfan 35 EC	89.4	89.2	6.2 <sup>a</sup> (14.48)*	5.3 <sup>a</sup> (13.28)	82.8	86.2	1.38 <sup>b</sup>	8.6	81.7	2.07 <sup>c</sup>	12.9	120.1
2.	Soil application of Carbofuran 3G	89.8	89.4	14.7 <sup>b</sup> (22.51)	13.6 <sup>b</sup> (21.60)	59.5	65.1	1.16 <sup>b</sup>	7.3	52.6	1.24 <sup>b</sup>	7.8	31.8
3.	Mechanical removal of larvae	89.8	89.4	17.3 <sup>bc</sup> (24.55)	17.6 <sup>c</sup> (24.82)	52.2	54.8	1.06 <sup>ab</sup>	6.6	39.6	1.18 <sup>b</sup>	7.4	25.5
4.	Untreated check	89.6	89.6	36.3 <sup>d</sup> (36.99)	39.0 <sup>d</sup> (38.65)	-	-	0.76 <sup>a</sup>	4.8	-	0.94 <sup>a</sup>	5.9	-
	S.Em. ±	0.4	0.6	0.87	0.82			0.13			0.07		
	C.D. at 5%	NS	NS	2.67	2.52			0.39			0.20		
	C.V. %	1.0	1.4	7.87	7.44			25.78			6.08		

\* Figures in the parenthesis are angular transformations. Means followed by same alphabet do not differ significantly.

The trend in the treatmental efficacy over untreated check remained constant in both trials.

#### 4.6.2 Yield

Seed cotton yield (Table 14) in different treatments during both the years, in the decreasing order was : endosulfan soil drench (8.6 and 12.9 q/ha), carbofuran soil application (7.3 and 7.8 q/ha), mechanical removal of larvae (6.6 and 7.4 q/ha) and untreated control (4.8 and 5.9 q/ha).

The increase in yield over untreated control was drastic in the endosulfan drenching (81.7%) followed by carbofuran application to soil (52.6 %) and mechanical control (39.6 %) during 1983. However, it was quite interesting to note that the three treatments recorded statistically at par yield; while, the untreated check recording significantly least yield was also at par with mechanical control treatment. During the season, the avoidable loss of 28.3, 34.4 and 44.9 per cent in kapas yield in the untreated check was observed over mechanical removal of larvae, carbofuran granule as soil application and endosulfan as soil drench, respectively.

During kharif, 1984, endosulfan soil drench recorded highest yield of 12.9 quintals and differed significantly over rest of the treatments. This was followed by carbofuran soil application (7.8 q) and mechanical removal of larvae

(7.4 q) which failed to differ statistically, however, were significantly superior to untreated check (5.9 q). Once again, it was striking to note that yield in the endosulfan drenched plot was slightly more than double, while in the other two treatments, it ranged from one fourth to one third over untreated check.

The yield loss in untreated check was 20.3, 24.1 and 54.5 per cent when compared to mechanical removal of larvae, carbofuran soil application and endosulfan soil drench, respectively. Computation of average yield loss from two years study revealed that avoidable loss in the untreated check was to the tune of 24.3, 29.3 and 49.7 per cent over mechanical removal of larvae, carbofuran soil application and endosulfan soil drench treatments, respectively.

#### 4.6.3 Correlation between per cent seedlings cut and yield

The pooled data of two seasons was subjected to correlation and regression analysis. The correlation between per cent seedlings cut and kapas yield was negative and significant ( $r=-0.84$ ). The regression equation for the two variables was :  $Y = 1.724 - 0.025 x$ . For every increase in seedlings cut by one per cent, the kapas yield was reduced by 0.025 kg per plot.

#### 4.7 Damage potential of *A.segetum*

##### 4.7.1 Extent of damage

In order to measure the damage potential, a field experiment was conducted during the off-season, 1991 by releasing the larvae at varying density and the results are tabulated in Table 15.

The number of damaged seedlings ranged from 33.7 where two larvae were released to 156.7 at density of 12 larvae per plot. No damage in the control plot is suggestive of absence of natural incidence. The extent of seedling damage increased progressively with corresponding increase in larval number per unit area. While two larvae were able to cut 9.4 per cent of the seedlings available, 43.2 per cent of seedlings were damaged when the larval density reached 12 per plot.

There was significant difference in the number of seedlings cut among different treatments. Each treatment differed significantly both from the preceding and succeeding treatments. The per cent increase in number of seedlings cut over the treatment with minimum pest load of two larvae per plot varied from 41.6 (four larvae/plot) to 365.3 (12 larvae/plot). However, the average number of seedlings cut by each larva in different treatments remained almost same.

Table 15. Extent of damage caused by A.segetum in cotton

Treat- ment No.	No. of Larvae released/plot	Av.No.of seedlings made avai- lable in each repli- cation	No. of seedlings cut in 15 days	% seed- ling damage	% increase over treat- ment two	Av. No. of seed- lings cut per larva
1.	0	370.7	0.0 <sup>a</sup> (1.0)*	0.0	-	0.0
2.	2	359.3	33.7 <sup>b</sup> (5.9)	9.4	-	16.8
3.	4	355.7	47.7 <sup>c</sup> (7.0)	13.4	41.6	11.9
4.	6	364.0	60.0 <sup>d</sup> (7.8)	16.5	78.2	10.0
5.	8	371.0	82.7 <sup>e</sup> (9.1)	22.3	145.5	10.3
6.	10	369.3	123.7 <sup>f</sup> (11.2)	33.5	267.3	12.3
7.	12	362.7	156.7 <sup>g</sup> (12.6)	43.2	365.3	13.0
S.Em. $\pm$			0.12			
C.D. at 5%			0.36			
C.V. %			2.62			

\* Figures in the parenthesis are  $\sqrt{x+1}$  transformations  
Means followed by same alphabet do not differ significantly

#### 4.7.2 Correlation between larval density and seedling damage

Correlation between the number of larvae released and per cent seedlings cut during the cutting period of 15 days was positive and significant ( $r=0.97$ ). The regression equation for the two variables was  $Y = -2.49 + 12.37 x$  indicating that for every increase in the larval number by one unit, the per cent seedling damage increased by 12.37 units per plot.

#### 4.7.3 Relationship between the larval density and yield

Using the two regression equations ( $Y=1.724-0.025 X$  and  $Y=-2.49+12.37 X$ ) the relationship between larval density and yield was established by extrapolating the observations on per cent seedlings cut in two different experiments through correlation and regression analysis. The correlation so computed between the larval number and yield was negative and significant ( $r=-0.98$ ). The regression equation for the two variables was  $Y=1.73 - 0.09 X$  and it suggested that with every increase in the number of larvae by one, yield would decrease by 0.09 kg per plot.

### 4.8 Larval behaviour

#### 4.8.1 Damage in relation to age of seedlings

The data on the preference of larva for seedlings of two ages are presented in Table 16. Observations on damage

Table 16. Extent of damage in relation to seedling age

Treatment No.	No. of larvae released per plot	Mean number of seedlings damaged	Per cent damage to	
			1 to 7 day old seedlings	8 to 15 day old seedlings
1.	0	0.0 <sup>a</sup> (1.0)*	0.0	0.0
2.	2	33.7 <sup>b</sup> (5.9)	73.8	26.2
3.	4	47.7 <sup>c</sup> (7.0)	72.3	27.7
4.	6	60.0 <sup>d</sup> (7.8)	73.7	26.3
5.	8	82.7 <sup>e</sup> (9.1)	80.8	19.2
6.	10	123.7 <sup>f</sup> (11.1)	72.2	27.8
7.	12	156.7 <sup>g</sup> (12.6)	76.8	23.2
S.Em. $\pm$		0.12	Cal " t "	: 3.75
C.D. at 5%		0.36	Table "t" at 5%	: 2.18
C.V. %		2.60		

\* Figures in the paranthesis are  $\sqrt{x+1}$  transformations  
Means followed by same alphabet do not differ significantly

to one to seven (younger) and eight to 15 days (older) aged seedlings were recorded when both one day and eight days old seedlings were available as free choice and this was continued for next seven days.

At all levels of larval density, per cent seedling damage was high in the younger seedlings which averaged to 74.9 per cent. While, the proportion of older seedlings damaged was one out of every four seedlings. The differences in the damage to seedlings of two ages was significant to conclude that one to seven day seedlings were most preferred than eight to 15 days when there is choice.

#### 4.8.2 Feeding pattern

While studying the extent of damage, observations were made on the nature of feeding on each cut seedling. It was found that larva after cutting the seedling either devoured the seedling completely or partially.

At two and four larvae per plot, more number of seedlings were consumed completely. With the further increase in larval load, the pattern of feeding reversed by increasing number of seedlings partially fed. Secondly, the partial consumption rate itself varied from 12.3 to 83.0 seedlings (Table 17), out of the total of seedlings damaged ranging

Table 17. Larval density and feeding pattern

Treatment No.	Density per plot	Total number of seedlings cut	Number of seedlings consumed			
			Completely		Partially	
			(Total)	By each larva	(Total)	By each larva
1.	0	0.0 (1.0)*	0.0 <sup>a</sup> (1.0)	0.0	0.0 <sup>a</sup> (1.0)	0.0
2.	2	33.7 (5.9)	21.3 <sup>b</sup> (4.7)	10.6	12.3 <sup>b</sup> (3.6)	6.1
3.	4	47.7 (7.0)	27.3 <sup>c</sup> (5.3)	6.8	20.3 <sup>c</sup> (4.6)	5.0
4.	6	60.0 (7.8)	29.3 (5.5)	4.8	30.6 <sup>d</sup> (5.6)	5.1
5.	8	82.7 (9.1)	39.6 (6.3)	4.9	43.0 <sup>e</sup> (6.6)	5.3
6.	10	123.7 (11.2)	60.3 (7.8)	6.0	63.3 <sup>f</sup> (8.0)	6.3
7.	12	156.7 (12.6)	73.6 (8.6)	6.1	83.0 <sup>g</sup> (9.1)	6.9
Average :			41.9		42.1	
S.Em. $\pm$			0.12	0.07	0.07	
C.D.at 5%			0.36	0.21	0.20	
C.V. %			2.60	7.51	9.70	

\* Figures in the parenthesis are  $\sqrt{x+1}$  transformations.

Means followed same alphabet do not differ significantly

from 33.7 to 156.7 in different treatments. The partial consumption rate was considerably low at the larval density of two (36.6%) and four per plot (42.7%). At higher larval density, partial consumption rate had a clear edge over complete feeding of the seedlings with more than 50 per cent of the cut seedlings partially fed in the treatments with eight larvae (52.0%), ten larvae (51.2%) and 12 larvae (53.0%) per plot. The study indicated that out of every two seedlings cut larvae fed one partially. These facts suggest that the cutworms spoil more food than they consume.

#### 4.8.3 Correlation between the larval number and consumption pattern

The relation between the larval number and consumption pattern of both types was positive and significant ( $r=0.96$  and  $0.98$  for complete and partial consumption, respectively). The regression equations for the two variables were :

$$Y = 4.82 + 5.38 X \text{ (Complete consumption)}$$

(0.88)

$$Y = -7.41 + 7.07X \text{ (Partial consumption)}$$

(0.65)

These equations indicated that for every increase in larval number by one, complete and partial consumption rates increased by 5.38 and 7.07 times, respectively.

#### 4.9 Nature of feeding behaviour

The larva exhibits differential behaviour of feeding as it grows. Early instars are less destructive and migratory in contrast to later ones. The details are presented instarwise as follows :

4.9.1 I instar : Scraping of chlorophyll from the lower surface (Plate 15) of leaves on seedlings aged two to 21 days.

4.9.2 II instar : Scraping of chlorophyll like I instar with occasional biting on succulent portion (epidermis) of younger seedlings.

4.9.3 III instar : Larvae cut the seedlings up to 7 days old above the surface, while on the older seedlings they attempted to bite succulent part of the shoots by climbing over the seedling. Besides, the larvae were found feeding on the leaves of younger seedlings after effecting cut by making characteristic holes (Plate 16) and later devouring the succulent stems.

4.9.4 IV instar : Behaved like typical cutworm by cutting the plants at base (Plate 17) in two and seven days old seedlings. Larvae completely devoured the succulent stems of younger seedlings and fed on the leaves partially, after inflicting the cut. However, attempt to cut 15 and 21 days plants was futile.

Plate 15. Scraping of chlorophyll by I and II  
instar larvae

Plate 16. Feeding damage by III instar larva



Plate 17. Typical nature of damage by the  
cutting instars from IV to VI



4.9.5 V instar : Cut the seedlings up to 15 days old and made unsuccessful attempt of cutting 21 days old seedlings. Feeding on tender stems completely associated with partial feeding of leaves was also common.

4.9.6 VI instar : The larvae exhibited typical cutworm behaviour of cutting seedlings upto 21 days old at the base and on older plants confined to biting on the stem. Younger seedlings were devoured completely.

#### 4.10 Dispersal behaviour of the larva

The dispersal behaviour of larva of A.segetum in relation to the availability of food was studied under field conditions during the off-season (summer). The results are presented in Table 18.

##### 4.10.1 Dispersal rate

Irrespective of nearness of seedlings, the larva travelled to the site of seedling and damaged it within 12 hours (Table 18). A number of cut seedlings were observed early in the morning following the release of larvae in the previous evening. Thus, it is apparent that the dispersal rate of the larva was related to the availability of food, no matter how far the seedlings were located.

Table 18. Dispersal behaviour of A. segetum in cotton

Sl. No.	Treatments	Time taken to travel to the site of damage (in hr.)	Number of seedlings cut during 10 days		Distance travelled per day (in cm)	
			Range	Av.	Range	Av.
1.	Release of larva at the centre with seedlings available throughout the plot	12	22-27	23.6	99.4-132.0	111.0
2.	Release of larva at the centre with no seedlings up to 1 m <sup>2</sup> in the centre of the plot	12	21-24	22.3	100.6 -129.2	111.3
3.	Release of larva at the centre with no seedlings upto 4 m <sup>2</sup> in the centre of the plot	12	19-21	20.0	146.3 -191.0	169.3
4.	Release of larva at the centre with no seedlings up to 9 m <sup>2</sup> in the centre of the plot	12	13-16	14.6	193.5-207.4	202.0
5.	Release of larva at the centre with no seedlings up to 16 m <sup>2</sup> in the centre of the plot	12	6-11	8.6	220.9-245.7	234.0

#### 4.10.2 Dispersal pattern

In general, the dispersal pattern of the larva was random. In treatments 1 and 2, the damage was concentrated more near the release points (App.1 & 2) and therefore, the mean distance travelled by the larva per day was less (111.0 and 111.3 cm/day). But as the distance between release point and availability of seedlings increased in treatments 3, 4 and 5 from 1.0 to 2.0 m, the larva dispersed further from 169.3 to 234.0 cm/day in search of seedlings and damaged. The seedlings damaged were not in any definite direction or pattern, instead were found in all direction (App.3, 4 & 5). In treatment 5 (16 m<sup>2</sup> gap area), where very few seedlings were available in a row, the movement was quite erratic (App.5). In all the treatments, the dispersal was both along the row and across the rows.

#### 4.10.3 Destruction potential

When the seedlings were available in few inches ( $T_1$ ), the extent of damage was highest (23.6 seedlings) which decreased to 8.6 seedlings in  $T_5$ , where the larva had to move a minimum of two metre distance in search of seedlings. But, the decrease in number of cuts from  $T_1$  to  $T_5$  was gradual.

#### 4.11 Host preference under field conditions

The results on the number of seedlings damaged till 30 days after germination (DAG) in each of the ten hosts, given as free choice, are presented in Table 19.

##### 4.11.1 Kharif 1984

The range in the per cent seedlings damaged from 0.0 to 23.3 per cent suggest that while wheat was least preferred, cotton was most preferred by the cutworm larvae. The two crops differed significantly from each other and rest of the crops. The results reveal marked variation in the preference for field crops by the larvae.

Based on per cent seedlings damaged cowpea (11.5%), safflower (10.7%) and chillies (8.8%) were preferred next to cotton, however, were statistically at par with each other but differed significantly from the rest. Soybean (2.3%), maize (2.5%) and potato (3.3%), which were at par with each other, were significantly more preferred than wheat. Potato (3.3%), groundnut (5.2%), greengram (5.7%) and chillies (8.8%) were moderately preferred.

##### 4.11.2 Kharif 1985

Infestation level during kharif, 1985 was slightly higher than in the previous season. Cutworm incidence in the

Table 19. Host preference by the cutworm larvae under field conditions

Sl. No.	Host Crops	Initial plant population		% seedlings cut at 30 DAG	
		1984	1985	1984	1985
1.	Cotton	89.3	91.3	23.3 <sup>f</sup> (4.9)*	30.3 <sup>h</sup> (5.5)
2.	Potato	101.0	104.3	3.3 <sup>bc</sup> (1.9)	8.1 <sup>cd</sup> (2.9)
3.	Chillies	79.7	79.3	8.8 <sup>de</sup> (3.0)	10.5 <sup>def</sup> (3.3)
4.	Groundnut	209.3	204.3	5.2 <sup>cd</sup> (2.4)	7.0 <sup>bc</sup> (2.7)
5.	Soybean	248.3	248.7	2.3 <sup>b</sup> (1.7)	5.0 <sup>ab</sup> (2.3)
6.	Safflower	96.3	101.3	10.7 <sup>e</sup> (3.3)	14.2 <sup>g</sup> (3.8)
7.	Cowpea	148.0	154.3	11.5 <sup>e</sup> (3.5)	12.9 <sup>f</sup> (3.7)
8.	Greengram	206.3	205.7	5.7 <sup>cd</sup> (2.5)	8.7 <sup>cde</sup> (3.0)
9.	Maize	90.7	94.7	2.5 <sup>b</sup> (1.6)	3.3 <sup>a</sup> (1.9)
10.	Wheat	308.3	318.7	0.0 <sup>a</sup> (0.7)	3.0 <sup>a</sup> (1.9)
	S.Em. <sub>±</sub>			0.22	0.16
	C.D.at 5%			0.66	0.48
	C.V. %			15.24	9.00

\* Figures in the parenthesis are  $\sqrt{x+0.5}$  transformations.

Means followed by same alphabet do not differ significantly

experiment reached highest of 30.3 per cent in cotton. Preference difference among test crops was significant and the trend remained same as in the previous season study.

#### 4.12 Effect of host plants on the biology of A.segetum

Effects of ten species of hosts on the biology of A.segetum was studied in the laboratory and the results are presented in Tables 20, 21 and 22.

##### 4.12.1 Incubation period

Incubation period ranged from a minimum of 3.9 days on potato to a maximum of 4.5 days on wheat. The differences in the durations on different hosts were statistically significant. Wheat, maize, chillies, soybean, greengram and groundnut had no differential influence on the larval development in the eggs. Similarly, cotton, cowpea, potato and safflower belonged to other group that had significantly varied effect, but allowed the egg development in significantly less time.

##### 4.12.2 Larval period

The larval period was shortest on potato (27.2 days) and longest on wheat (39.4 days). Potato, cotton and safflower permitted the larvae to grow in significantly shorter time followed by cowpea, groundnut, greengram and

Table 20. Effect of host plants on the duration of life stages of A. segetum. (Mean of 60 observations from 3 replications)

D<sub>2</sub>  
(2 rows)

Sl. No.	Host plants	Duration (days)				Total developmental period (days)
		Egg	Larva	Pre-pupa	Pupa	
1.	Cotton	4.1 <sup>abc</sup>	28.9 <sup>ab</sup>	1.6 <sup>ab</sup>	13.5 <sup>ab</sup>	48.1
2.	Cowpea	4.1 <sup>abc</sup>	30.1 <sup>b</sup>	2.2 <sup>cd</sup>	12.7 <sup>a</sup>	49.1
3.	Groundnut	4.2 <sup>bcd</sup>	30.7 <sup>bc</sup>	2.0 <sup>bc</sup>	13.7 <sup>abc</sup>	50.6
4.	Greengram	4.5 <sup>d</sup>	30.6 <sup>bc</sup>	1.9 <sup>abc</sup>	13.8 <sup>bc</sup>	50.8
5.	Potato	3.9 <sup>a</sup>	27.2 <sup>a</sup>	1.4 <sup>a</sup>	13.6 <sup>abc</sup>	46.1
6.	Safflower	4.0 <sup>ab</sup>	28.9 <sup>ab</sup>	1.5 <sup>ab</sup>	13.9 <sup>bc</sup>	48.3
7.	Soybean	4.3 <sup>bcd</sup>	32.4 <sup>cd</sup>	2.0 <sup>bc</sup>	14.1 <sup>bc</sup>	52.8
8.	Chillies	4.4 <sup>cd</sup>	32.8 <sup>d</sup>	2.7 <sup>de</sup>	14.6 <sup>c</sup>	54.5
9.	Maize	4.5 <sup>d</sup>	39.2 <sup>e</sup>	2.7 <sup>e</sup>	16.0 <sup>d</sup>	62.4
10.	Wheat	4.5 <sup>d</sup>	39.4 <sup>e</sup>	2.7 <sup>e</sup>	14.6 <sup>c</sup>	61.3
S.Em. $\pm$		0.11	0.66	0.17	0.34	
C.D. at 5%		0.31	1.97	0.52	1.01	

Means followed by same alphabet do not differ significantly

safflower. While maize and wheat, being at par with each other, prolonged the larval period significantly more than on other hosts.

#### 4.12.2.1 Larval mortality

Larval mortality was highest (46.7 %) on maize and lowest (6.7%) on greengram while, all the test insects successfully completed development on cotton, potato and safflower. Wheat, chillies, cowpea, soybean and groundnut were the next in decreasing order to follow maize in non-suitability of hosts with larval mortality ranging from 20.0 to 43.4 per cent.

#### 4.12.2.2 Larval weight

Weight of the larvae recorded at ten and 20 days after feeding on the hosts and during VI instar differed significantly (Table 21). The weight at two earlier intervals was considerably reduced on maize, wheat and chillies. Larvae reared on safflower, potato, cotton, cowpea, soybean, greengram and groundnut gained considerable weight. The range in weight gained was very wide from the lowest of 87.6 g on maize and 391.6 g on chillies - to the highest of 461.8 and 733.3 g on safflower on 20th day and in VI instar, respectively. With the exception of soybean, chillies, maize and wheat; weight difference between other crops at 20th day and in VI instar were significant.

Table 21. Effect of host plants on the larval and pupal weight of A. segetum (Mean of 60 observations from 3 replications)

Sl. No.	Host Plants	Weight of larva (in grams)					Weight of pupa (in grams)	
		On 10th day	On 20th day	Per cent increase over 10th day	VI instar *	Per cent increase over 20th day		Per cent increase over 10th day
1.	Cotton	105.3 <sup>e</sup>	218.8 <sup>c</sup>	107.7	723.3 <sup>f</sup>	230.5	586.7	318.3 <sup>d</sup>
2.	Cowpea	96.6 <sup>d</sup>	214.1 <sup>c</sup>	121.5	568.3 <sup>de</sup>	165.3	487.9	228.3 <sup>a</sup>
3.	Groundnut	76.0 <sup>c</sup>	174.3 <sup>b</sup>	129.3	600.0 <sup>e</sup>	244.1	689.4	298.3 <sup>cd</sup>
4.	Greengram	77.0 <sup>c</sup>	180.1 <sup>b</sup>	133.9	483.3 <sup>bc</sup>	168.2	527.7	261.6 <sup>ab</sup>
5.	Potato	94.8 <sup>d</sup>	224.3 <sup>c</sup>	136.5	515.0 <sup>cd</sup>	129.5	443.0	303.3 <sup>cd</sup>
6.	Safflower	93.5 <sup>d</sup>	461.8 <sup>d</sup>	393.9	733.3 <sup>f</sup>	58.7	684.3	326.6 <sup>d</sup>
7.	Soybean	75.3 <sup>c</sup>	185.1 <sup>b</sup>	145.8	413.3 <sup>a</sup>	123.2	448.6	273.3 <sup>bc</sup>
8.	Chillies	55.1 <sup>b</sup>	108.1 <sup>a</sup>	96.0	391.6 <sup>a</sup>	262.0	609.9	276.6 <sup>bc</sup>
9.	Maize	48.0 <sup>a</sup>	87.6 <sup>a</sup>	82.5	408.3 <sup>a</sup>	365.7	750.1	273.3 <sup>bc</sup>
10.	Wheat	48.8 <sup>ab</sup>	97.1 <sup>a</sup>	99.0	426.6 <sup>ab</sup>	339.1	773.7	270.0 <sup>bc</sup>
Average :		77.0	195.1	153.2	526.3	169.6	582.9	284.9
S.E.m.+		2.25	8.57		21.61			12.17
C.D.at 5%		6.69	25.47		64.18			36.15

\* In VI instar larvae the weight was recorded on VII day after V moulting.

Means followed by same alphabet do not differ significantly.

Increase in weight, in per cent, when computed at 20th day and VI instar over previous interval revealed interesting facts. Astonishingly, weight gained on safflower on 20th day was nearly four times that at previous interval. Next to follow in decreasing order were soybean, potato, greengram, groundnut, cowpea and cotton, but the increase in weight was slightly more than double. The weight increase being less than the double on maize, wheat and chillies was paradox of the effect of host plants on larval weight. The scenario on the weight increase at VI instar over 20th day was totally in contrast to the above. The trend in per cent increase in weight was reversed from that at previous interval. These results, in general, suggest that growth rate was highest on some hosts between 10th and 20th day and 20th day and VI instar.

#### 4.12.3 Pre-pupal period

The pre-pupal period differed statistically between the hosts studied. Potato recorded significantly least (1.4 days) followed by safflower (1.5 days) and cotton (1.6 days) as against the longest period of 2.7 days on wheat, maize and chillies.

#### 4.12.4 Pupation and pupal duration

Results presented in Table 22 reveal that all the larvae reared on cotton, potato and safflower transformed

Table 22. Effect of host plants on the growth, development and reproduction of *A.segetum* (Mean of 60 observations from 3 replications)

Sl. No.	Host Plants	Per cent pupation	Growth index*	Per cent adult emergence	Adult longevity		Fecundity per female	Sex ratio m : f
					Male	Female		
1.	Cotton	100.0 <sup>d</sup> (90.0)**	3.4 <sup>ef</sup>	100.0 <sup>g</sup> (90.0)	9.4	10.8	950.0 <sup>d</sup>	1:0.6
2.	Cowpea	63.3 <sup>ab</sup> (52.8)	2.1 <sup>c</sup>	84.4 <sup>bc</sup> (66.9)	7.4	10.0	654.8 <sup>a</sup>	1:0.5
3.	Groundnut	80.0 <sup>c</sup> (64.6)	2.6 <sup>d</sup>	92.9 <sup>de</sup> (74.2)	8.5	9.7	821.7 <sup>c</sup>	1:0.5
4.	Greengram	93.3 <sup>d</sup> (83.8)	3.1 <sup>e</sup>	94.7 <sup>e</sup> (76.8)	9.0	9.1	753.6 <sup>b</sup>	1:0.6
5.	Potato	100.0 <sup>d</sup> (90.0)	3.6 <sup>f</sup>	100.0 <sup>g</sup> (90.0)	5.2	8.5	839.5 <sup>c</sup>	1:0.7
6.	Safflower	100.0 <sup>d</sup> (90.0)	3.4 <sup>ef</sup>	99.6 <sup>fg</sup> (88.0)	5.7	6.8	832.8 <sup>c</sup>	1:0.7
7.	Soybean	73.3 <sup>bc</sup> (58.9)	2.2 <sup>cd</sup>	98.5 <sup>f</sup> (84.4)	9.0	9.3	725.2 <sup>b</sup>	1:0.5
8.	Chillies	60.0 <sup>ab</sup> (50.8)	1.8 <sup>bc</sup>	88.9 <sup>cd</sup> (70.5)	8.5	9.9	611.3 <sup>a</sup>	1:0.4
9.	Maize	53.3 <sup>a</sup> (46.9)	1.3 <sup>a</sup>	74.7 <sup>a</sup> (59.8)	7.4	8.1	600.3 <sup>a</sup>	1:0.5
10.	Wheat	56.6 <sup>ab</sup> (48.8)	1.4 <sup>ab</sup>	80.1 <sup>ab</sup> (63.5)	7.8	8.6	591.4 <sup>a</sup>	1:0.4
S.Em. $\pm$		3.49	0.14	1.40	0.27	0.37	20.80	
C.D. at 5%		10.37	0.44	4.17	0.80	1.12	61.79	

\* Growth index = per cent pupation / larval period

\*\* Figures in the parenthesis are angular transformations.  
Means followed by same alphabet do not differ significantly.

to pupae, while only 53.3 and 56.6 per cent larvae on maize and wheat, respectively, reached pupal stage. Significant difference in per cent pupation was recorded among different hosts. The pupal duration ranged from a minimum of 12.7 days on cowpea to a maximum of 16.0 days on maize. Cotton, potato, groundnut, greengram, safflower did not prolong the pupal period but soybean extended the period slightly followed by chillies and wheat.

#### 4.12.4.1 Pupal mortality

The mortality in the pupal stage was highest (25.3%) when the larvae were reared on maize followed by wheat (19.9%) and cowpea (15.6%). While no mortality occurred in case of hosts, cotton and potato, a moderate level of mortality was noticed when the larvae were reared on chillies, groundnut and greengram.

#### 4.12.4.2 Weight of pupa

The weight ranged from 228.3 g on cowpea to 326.6 g on safflower. Safflower (326.6 g), cotton (318.3 g), potato (303.3 g) and groundnut (298.3 g), which were at par statistically, differed significantly from the rest. On the contrary, cowpea and greengram, being at par each other, recorded significantly lowest weight. The weight recorded on remaining hosts was intermediate.

#### 4.12.5 Total developmental period

Total developmental period of A.segetum was lowest (46.1 days) on potato and highest (62.4 days) on maize. The variation between cotton (48.1 days), safflower(48.3 days), cowpea (49.1 days) and potato (46.1 days) was marginal. In contrast, maize and wheat extended the period beyond 60 days indicating unsuitability of these hosts as food plants. Other hosts like groundnut, greengram and soybean were intermediate in their effect on the developmental period.

#### 4.12.6 Growth index

From the table 22, it is evident that growth index was maximum on potato (3.6) and minimum on maize (1.3). Cotton and safflower which registered identical index (3.4) were statistically at par with potato and all these hosts recorded significantly higher index over the rest excepting greengram (3.1). The latter host was at par with cotton and safflower and significantly different from potato. Maize, wheat and chillies served as poor hosts by recording lowest growth index.

#### 4.12.7 Adult emergence and longevity

Adult emergence was cent per cent on cotton and potato followed by safflower(99.6%) and soybean (98.5%) which

however, were at par statistically. Only 74.7 per cent of the pupae transformed to moths when the larvae were reared on maize. Thus, the pupal mortality was highest (25.3%).

Male moths developed on potato lived for shortest period (5.2 days) followed by safflower. Longevity was highest on cotton followed by greengram and soybean. On the other hand, the female longevity varied from a minimum of 6.8 days on safflower to a maximum of 10.8 days on cotton.

#### 4.12.8 Sex ratio and fecundity

More number of males emerged from the larvae reared on wheat, chillies, maize, soybean and cowpea. The ratio of female to male was narrow on safflower and potato.

Fecundity ranged from lowest of 591.4 eggs per female on wheat to a highest of 950.0 eggs on cotton. Total number of eggs laid by moths reared on cotton was significantly higher than in the rest of the nine hosts followed by potato, safflower and groundnut. Fecundity was drastically reduced when wheat, maize, chillies and cowpea formed larval hosts.

#### 4.13 Management

##### 4.13.1 Efficacy of diflubenzuron in laboratory

Aqueous solutions of diflubenzuron at concentrations ranging from 0.00025 to 0.0125 per cent were tested against egg, larvae and pupae of A.segetum and the results are presented in the tables from 23 to 27.

###### 4.13.1.1 On egg hatch

Diflubenzuron at all concentrations tried inhibited egg hatch significantly, in both one day and three day old eggs; but the degree of inhibition was higher in one day old eggs than in three day old eggs. Mortality in the stage ranged from 2.0 to 64.0 per cent in the treated eggs (Table 23) as against natural mortality of 2.6 per cent noticed in the control. At every successive increase in the dosage of the chemical, the inhibition per cent increased significantly except between 0.005 and 0.0075 per cent. As against steady increase in the inhibition of egg development in general, a phenomenal increase (64.0%) was evident when the dosage was raised from 0.0075 per cent to 0.0125 per cent. Lowest dosage had no effect on larval development and hence allowed as many eggs to hatch as in control.

Three day old eggs were less sensitive to the action of chitin inhibitor where the highest dosage resulted

Table 23. Evaluation of diflubenzuron for ovicidal action  
(Mean of 150 eggs from 3 replications)

Sl. No.	Concentration in per cent	Mean per cent inhibition of egg hatch	
		One day old eggs	Three days old eggs
1.	0.00025	2.0 <sup>a</sup> (8.1)*	2.3 <sup>ab</sup> (8.5)
2.	0.00125	4.6 <sup>b</sup> (12.4)	1.3 <sup>a</sup> (5.2)
3.	0.0025	20.0 <sup>c</sup> (26.5)	2.3 <sup>ab</sup> (8.7)
4.	0.005	26.3 <sup>de</sup> (30.8)	5.3 <sup>bc</sup> (13.3)
5.	0.0075	27.3 <sup>e</sup> (33.6)	10.0 <sup>c</sup> (18.4)
6.	0.0125	64.0 <sup>f</sup> (53.1)	18.0 <sup>d</sup> (25.0)
7.	Control	2.6 <sup>ab</sup> (9.0)	1.6 <sup>a</sup> (6.0)
	S.Em.±	1.26	1.74
	C.D. at 5%	3.91	5.38

\* Figures in the parenthesis are angular transformations.  
Means followed by same alphabet do not differ significantly

in only 18.0 per cent egg mortality. All dosages upto 0.005 per cent failed to differ significantly from untreated check.

#### 4.13.1.2 On larvae

The effect of diflubenzuron on the larvae was studied by administering the compound through treated cotton seedlings. The results (Tables from 24 to 26) reveal distinctive action of the chemical on the larval stage.

The compound elicited larval moult inhibition and caused morphological deformities in different stages of larvae studied. In III and V instar larvae, the effect of chemical manifested two to three days after treatment, which was indicated in the form of yellow ooze coming through the anus (Plate 18). The mortality was quite high at higher concentrations (from 0.005 to 0.0125%) with more than 90 per cent (Table 24 and 25) on the 10th day after treatment (10 DAT). On the other hand, at lower concentrations (from 0.00025 to 0.0025%), the mortality though recorded maximum at 10 DAT, continued beyond 10 DAT till pupal stage.

The cumulative mortality in the III instar at different concentrations varied from 55.6 per cent at 0.00025 per cent to 100.0 per cent from 0.005 per cent

Table 24. Effect of diflubenzuron on III instar larvae of A.segetum  
(Mean of 150 observations from 3 replications)

Sl. No.	Concentration in per cent	Per cent mortality			Per cent adult emergence		
		of larvae	of pupae	Cumulative	Normal	De-formed	
		up to 10 DAT	10-DAT to pre-pupal stage	From pupation to adult emergence			
1.	0.00025	44.0 <sup>b</sup> (41.5)*	3.0 <sup>b</sup> (1.8)**	8.6 <sup>c</sup> (3.0)**	55.6 <sup>b</sup> (48.2)*	35.6 <sup>c</sup> (36.6)*	8.6 <sup>c</sup> (3.0)**
2.	0.00125	62.0 <sup>c</sup> (51.9)	5.0 <sup>bc</sup> (2.3)	7.0 <sup>c</sup> (2.7)	74.0 <sup>c</sup> (59.3)	11.0 <sup>b</sup> (19.3)	15.0 <sup>d</sup> (3.9)
3.	0.0025	82.6 <sup>d</sup> (65.5)	8.3 <sup>c</sup> (2.9)	4.0 <sup>b</sup> (2.0)	95.0 <sup>d</sup> (77.2)	0.0 <sup>a</sup> (0.0)	5.0 <sup>b</sup> (2.3)
4.	0.005	98.6 <sup>e</sup> (86.1)	1.3 <sup>a</sup> (1.1)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)
5.	0.0075	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)
6.	0.0125	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)
7.	Control	6.0 <sup>a</sup> (14.0)	0.6 <sup>a</sup> (1.0)	0.0 <sup>a</sup> (0.7)	6.6 <sup>a</sup> (14.9)	93.3 <sup>d</sup> (75.1)	0.0 <sup>a</sup> (0.7)
	S.E.m.+	1.54	0.22	0.16	0.94	0.74	0.16
	C.D.at 5%	4.76	0.69	0.50	2.91	2.29	0.48

\* Figures in the parenthesis are angular transformations.

Means followed by same alphabet do not differ significantly

\*\* Figures in the parenthesis are  $\sqrt{x+0.5}$  transformations

Table 25. Effect of diflubenzuron on V instar larvae of *A.segetum*  
(Mean of 150 observations from three replications)

Sl. No.	Concentration in per cent	Per cent mortality				Per cent adult Emergence	
		Up to 10 DAT	10 DAT to pre-pupal stage	of larvae	of pupae	Normal	De-formed
1.	0.00025	34.6 <sup>b</sup> (30.0)*	5.3 <sup>b</sup> (1.7)**	11.0 <sup>c</sup> (3.3)**	51.0 <sup>b</sup> (45.5)*	41.3 <sup>c</sup> (40.0)	7.6 <sup>c</sup> (2.8)**
2.	0.00125	50.0 <sup>c</sup> (45.0)	5.6 <sup>b</sup> (2.4)	11.3 <sup>c</sup> (3.4)	67.0 <sup>c</sup> (54.9)	22.6 <sup>b</sup> (28.4)	10.3 <sup>c</sup> (3.2)
3.	0.0025	78.6 <sup>d</sup> (62.6)	5.6 <sup>b</sup> (2.4)	11.3 <sup>c</sup> (3.4)	95.6 <sup>d</sup> (78.6)	0.6 <sup>a</sup> (3.8)	3.6 <sup>b</sup> (1.9)
4.	0.005	88.6 <sup>e</sup> (70.3)	6.6 <sup>b</sup> (2.6)	4.6 <sup>b</sup> (2.2)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)
5.	0.0075	100.0 <sup>f</sup> (90.0)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
6.	0.0125	100.0 <sup>f</sup> (90.0)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)
7.	Control	0.6 <sup>a</sup> (2.7)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.7)	0.6 <sup>a</sup> (2.7)	99.3 <sup>d</sup> (87.2)	0.0 <sup>a</sup> (0.7)
	S.Em.±	1.47	0.31	0.12	1.61	1.36	0.16
	C.D.at 5%	4.55	0.98	0.37	4.98	4.19	0.51

\* Figures in the parenthesis are angular transformations.

Means followed by same alphabet do not differ significantly

\*\* Figures in the parenthesis are  $\sqrt{x+0.5}$  transformations

Table 26. Effect of diflubenzuron on VI instar larvae of A. segetum  
(Mean of 150 observations from 3 replications)

Sl. No.	Concentration in per cent	Per cent mortality of		Cumulative	Per cent normal	Per cent deformed
		larvae	pupae			
1.	0.00025	23.0 <sup>b</sup> (28.6)*	4.6 <sup>b</sup> (2.2)**	27.6 <sup>b</sup> (33.7)*	58.6 <sup>c</sup> (50.0)*	13.6 <sup>b</sup> (21.6)*
2.	0.00125	32.3 <sup>c</sup> (34.6)	5.6 <sup>c</sup> (2.4)	37.9 <sup>c</sup> (37.4)	37.6 <sup>b</sup> (37.8)	24.3 <sup>c</sup> (29.5)
3.	0.0025	83.3 <sup>d</sup> (65.7)	4.6 <sup>b</sup> (2.2)	87.9 <sup>d</sup> (70.5)	1.6 <sup>a</sup> (10.0)	10.3 <sup>b</sup> (18.4)
4.	0.005	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
5.	0.0075	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
6.	0.0125	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.7)	100.0 <sup>e</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
7.	Control	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.7)	0.0 <sup>a</sup> (0.0)	100.0 <sup>d</sup> (90.0)	0.0 <sup>a</sup> (0.0)
	S.Em.±	1.81	0.11	1.75	1.22	1.26
	C.D. at 5%	5.44	0.36	5.19	3.78	3.90

\* Figures in the parentheses are angular transformations.

\*\* -do-  $\sqrt{x+0.5}$  "

Means followed by same alphabet do not differ significantly.

Plate 18. Dead V instar larvae (A:0.00025% ;  
B: 0.0125% concentration) with the  
characteristic yellow ooze at the  
anal end



A



B



UNTREATED

TREATED

concentration onwards and differed statistically between dosage levels. It ranged from 51.0 to 100.0 per cent at the same dosage of diflubenzuron in the V instar. Thus, with the increase in concentration there was increase in mortality in both the instars.

First three concentrations of diflubenzuron induced significant differences in the mortality of III instar larvae at 10 DAT, while the latter three dosages failed to do so among themselves. Natural mortality in control amounted to 6.0 per cent. A very low mortality values beyond 10 DAT in lower concentrations suggest that the chemical had least effect. A similar phenomenon was observed in the VI instar also.

Normal adult emergence was maximum (93.3 and 99.3% from III and V instar larvae, respectively) in the untreated control, while it varied from 11.0 to 35.6 per cent in III instar larvae and 0.6 to 41.3 per cent in V instar larvae, at lower concentrations. Conversely, percentage of deformed adults followed reverse trend with that of normal adult emergence.

In the VI instar larvae, the observations were made on mortality till pupation and from pupation to adult emergence. The mortality upto pupation varied significantly

from 23.0 to 100.0 per cent. Increase in mortality was very low when the concentration was enhanced from 0.00025 to 0.00125 per cent. However, the effect was striking when the dosage was doubled to 0.0025 per cent. All the test insects were killed at 0.005 per cent and hence, the dosages beyond this level failed to differ. All the larvae entered into pupation in control. The moult inhibition was well pronounced at lower concentrations (from 0.00025 to 0.0025 %) by inducing production of larval-pupal intermediates. But at the higher concentrations (from 0.005 to 0.0125%), death of the larvae was rapid and occurred before the treated larvae transformed in to pupae.

Adult emergence was highest (100.0%) in the untreated control followed by 0.00025 per cent (58.6%) and 0.00125 per cent (37.6%).

#### 4.13.1.3 On pupae

The results on the adult emergence from pupae that were dipped in different concentrations of diflubenzuron are presented in Table 27.

Normal adult emergence was highest in untreated control (100.0%). While, the compound had no deliterious effects at 0.00025 per cent concentration, it prevented

Table 27. Effect of diflubenzuron on the pupae of A. segetum  
(Mean of 30 observations from 3 replications)

Sl. No.	Concentration in per cent	Adult emergence in per cent		
		Normal adults	Deformed adults*	No emergence
1.	0.00025	100.0 <sup>d</sup> (90.0)**	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
2.	0.00125	76.6 <sup>c</sup> (61.9)	23.3 <sup>b</sup> (28.0)	0.0 <sup>a</sup> (0.0)
3.	0.0025	56.6 <sup>b</sup> (48.9)	43.3 <sup>c</sup> (41.0)	0.0 <sup>a</sup> (0.0)
4.	0.005	6.6 <sup>a</sup> (12.2)	76.6 <sup>d</sup> (61.2)	16.6 <sup>b</sup> (23.8)
5.	0.0075	0.0 <sup>a</sup> (0.0)	43.3 <sup>c</sup> (41.1)	56.6 <sup>c</sup> (48.8)
6.	0.0125	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)	100.0 (90.0)
7.	Control	100.0 <sup>d</sup> (90.0)	0.0 <sup>a</sup> (0.0)	0.0 <sup>a</sup> (0.0)
	S.Em. $\pm$	4.09	3.33	1.15
	C.D. at 5%	12.62	10.27	3.55

\* With crippled wings

\*\* Figures in the parenthesis are angular transformations  
Means followed by same alphabet do not differ significantly

the adult emergence completely at 0.0075 per cent. Successive increase in concentration from 0.005 per cent had significant effect on pupal eclosion till 0.0125 per cent (with 16.6 to 100.0% of the pupae failing to eclude). Conversely, with the increase in concentration from 0.00025 to 0.005 per cent, there was increase (from 23.3 to 76.6%) in the emergence of deformed adults with crippled wings. But from 0.005 to 0.0125 per cent there was decrease in emergence of deformed adults associated with failure of pupal eclosion. Statistical difference existed among various test dosages in both the parameters.

#### 4.13.2 Evaluation of insecticides

##### 4.13.2.1 Seedling damage

Results of the experiments conducted during 1983 and 1984 are presented in Table 28.

Pre-treatment count of seedlings was made on the second day after germination. The observation on per cent seedlings cut revealed significant difference among the different treatments during both the years. During kharif 1983, all the toxicants were significantly superior to untreated control in reducing the seedling damage that ranged from 10.9 per cent in endosulfan treated plot to 39.3 per cent in control. The treatments receiving endosulfan

Table 28 Efficacy of insecticides against cutworm and on yield in cotton

Sl. No.	Treatment	Initial Plant population		% seedlings cut at 30 DAG		% reduction in damage over control		Kapas yield		Cost: benefit ratio					
		1983	1984	1983	1984	1983	1984	1983	1984						
								Kg/plot	q/ha						
<u>Soil drenching with</u>															
1.	Endosulfan	88.3	90.0	10.9 <sup>a</sup> (19.3)	11.8 <sup>a</sup> (20.0)	72.1	67.3	1.40	8.7	1.85	11.5	1.63 <sup>d</sup>	10.1	69.8	1:2.6
2.	Phosalone	88.6	89.3	18.8 <sup>cd</sup> (25.6)	22.3 <sup>b</sup> (28.2)	52.1	38.1	1.22	7.6	1.73	10.8	1.47 <sup>bcd</sup>	9.1	53.1	1:1.9
3.	Monocrotophos	89.6	89.0	13.7 <sup>b</sup> (21.7)	11.2 <sup>a</sup> (19.5)	65.0	68.9	1.56	9.7	1.75	10.9	1.65 <sup>d</sup>	10.3	71.8	1:1.5
4.	Sevimol	89.0	89.6	16.8 <sup>c</sup> (24.2)	20.8 <sup>b</sup> (27.1)	57.1	42.5	1.66	10.3	1.73	10.8	1.70 <sup>d</sup>	10.6	77.1	1:2.7
5.	Quinalphos	88.0	89.0	12.1 <sup>ab</sup> (20.3)	10.8 <sup>a</sup> (19.2)	69.1	69.9	1.15	7.1	1.72	10.7	1.44 <sup>bcd</sup>	9.0	50.0	1:1.3
<u>Soil application of dusts</u>															
6.	Malathion	88.6	90.0	27.0 <sup>e</sup> (31.3)	30.3 <sup>d</sup> (33.4)	31.1	16.0	1.67	10.4	0.95	5.9	1.31 <sup>bc</sup>	8.1	36.5	1:5.5
7.	BHC	89.0	88.6	27.2 <sup>e</sup> (31.4)	30.4 <sup>d</sup> (33.4)	30.7	15.9	1.37	8.5	1.10	6.8	1.24 <sup>ab</sup>	7.7	29.1	1:5.2
<u>Soil application of granules</u>															
8.	Carbofuran	88.6	89.3	21.0 <sup>d</sup> (27.3)	25.8 <sup>c</sup> (30.5)	46.4	28.5	1.15	7.1	1.41	8.8	1.28 <sup>ab</sup>	8.0	33.3	1:1.7
9.	Phorate	88.6	89.3	20.2 <sup>d</sup> (26.7)	22.3 <sup>b</sup> (28.2)	48.4	38.1	1.19	7.4	1.42	8.8	1.31 <sup>bc</sup>	8.1	36.5	1:1.8
10.	Untreated control	89.0	89.3	39.3 <sup>f</sup> (38.8)	36.1 <sup>e</sup> (36.9)	-	-	1.09	6.8	0.82	5.1	0.96 <sup>a</sup>	6.0	-	-
S.E.m. <sub>t</sub>		0.7	0.4	0.63	0.70			0.20			0.02		0.10		
C.D.at 5%		NS	NS	1.86	2.09			NS			0.07		0.32		
C.V. %		1.5	0.9	4.0	4.4			27.1			2.9		13.5		

\* Figures in parenthesis indicate angular transformations. Means followed by same alphabet do not differ significantly

(10.9%) and quinalphos (12.1%) as soil drenches were at par but differed significantly from rest of the treatments. Monocrotophos drench (13.7%), being at par with quinalphos, was next to endosulfan. Drenching with sevimol (16.8%) and phosalone (18.8%) were inferior to above treatments.

The granular insecticides phorate (20.2%) and carbofuran (21.0%), which were equally effective, were significantly superior to dusts but, were inferior to drenching with emulsifiable concentrates. Malathion and BHC dusts permitted 27.0 and 27.2 per cent seedlings to be cut and hence were the least effective among all the toxicants and formulations tried. It is evident from the results that drenching with liquid formulations of five test products was nearly 50 to 100 per cent more effective than granule and dust applications, respectively.

During kharif 1984, seedling damage between treatments varied from 10.8 to 36.1 per cent. Like in the previous season, all the toxicants fared significantly better than the untreated control and the effectiveness of different toxicants was in the same order except between granular formulations. Phorate established its superiority over carbofuran. The reduction in damage to the use of toxicants varied from 15.9 per cent in BHC treated to 69.9 per cent

in quinalphos drenched plots. Efficacy of formulations over two seasons in reducing the seedling damage was of the same and in the following order :

Drenches > granules > dusts

#### 4.13.2.2 Kapas yield

It is evident from the table 28 that the kapas yield did not differ significantly among different treatments during 1983. But during kharif 1984, the yield difference was significant where endosulfan as soil drench outyielded (1.85 kg/plot) all other treatments. In contrast, all other chemicals used as soil drenches had no influence in altering the yield and hence, recorded statistically equal yield. Granular formulations of both toxicants were at par and inferior to soil drenches. Dusts performed poorly by recording significantly least yield (0.95 and 1.1 kg/plot, in malathion and BHC treated plots, respectively) of all treatments. However, they were superior to untreated control.

The pooled data of 1983 and 1984, however, was significant enough to discriminate the treatment effects. Kapas yield per plot ranged from 0.96 kg (6.0 q/ha) in untreated control to 1.7 kg (10.6 q/ha) in sevimol treated

plots. All the treatments that received soil drenches, namely, sevimol, monocrotophos, endosulfan, phosalone and quinalphos were at par in recording statistically the same kapas yield, but were quite superior to granules and dusts. The latter formulations, however were at par. Neither dusting BHC to soil nor carbofuran granular application to soil increased the yield significantly over untreated control.

The increase in yield of kapas over untreated control varied from 50.0 to 77.1 per cent in soil drenches, 33.3 to 36.5 per cent in granules and 29.1 to 36.5 per cent in dusts.

#### 4.13.3 Evaluation of diflubenzuron as poison-bait

##### 4.13.3.1 Seedling damage

Results of the experiment conducted during kharif 1985 are presented in Table 29. All the toxicants including baits were significantly superior to untreated control in reducing seedling damage. The poison-baits made of diflubenzuron were intermediate in efficacy (21.1 and 22.2% seedling damage in  $D_2$  and  $D_1$ , respectively) and significantly inferior to soil drenches with monocrotophos (12.1%) and endosulfan (13.2%) but superior to carbofuran granular application (26.5%) and untreated control (51.6%). Soil drenching with monocrotophos and endosulfan offered best

Table 29. Efficacy of diflubenzuron against cutworm\* and on yield in cotton

Sl. No.	Treatments	Initial plant population	% seedlings cut at 30 DAG	% decrease over control	Kapas yield		% increase over control
					kg/plot	Q/ha	
1.	Diflubenzuron at 75 g a.i./ha in poison bait	90.3	22.2 <sup>b</sup> (28.1)**	56.9	1.34 <sup>c</sup>	8.3	61.0
2.	Diflubenzuron at 112.5 g a.i./ha in poison bait	90.3	21.1 <sup>b</sup> (27.3)	58.9	1.52 <sup>d</sup>	9.5	83.0
3.	Drenching with monocrotophos	90.0	12.1 <sup>a</sup> (20.3)	76.4	1.67 <sup>e</sup>	10.4	101.0
4.	Drenching with endosulfan	89.6	13.2 <sup>a</sup> (21.3)	74.3	1.67 <sup>e</sup>	10.4	101.1
5.	Application of carbofuran to soil	89.3	26.5 <sup>c</sup> (30.9)	48.6	1.11 <sup>b</sup>	6.9	33.7
6.	Application of phorate to soil	89.6	25.2 <sup>bc</sup> (30.2)	51.0	1.12 <sup>b</sup>	7.0	34.8
7.	Control	89.6	51.6 <sup>d</sup> (45.9)	-	0.83 <sup>a</sup>	5.1	-
	S. Em. ±	0.61	0.92		0.02		
	C.D.at 5%	NS	2.83		0.07		
	C.V. %	1.1	5.5		2.9		

\* Artificial infestation of IV instar larvae @ 5 larvae/plot

\*\* Figures in the parenthesis are angular transformations

Means followed by same alphabet do not differ significantly

protection to the seedlings from cutworm damage. The efficacy of different chemicals was in the order of : drenches poison-bait granules with 48.6 and 76.4 per cent reduction in cut seedlings damage over control.

#### 4.13.3.2 Kapas yield

Plot yield ranged from a lowest of 0.83 kg (5.1q/ha) in untreated control to the highest of 1.67 kg (10.4 q/ha). Soil drenching with endosulfan and monocrotophos registered significantly highest yield over rest of the treatments. Poison-bait with diflubenzuron at 112.5 g a.i./ha was superior (1.5 kg) to lower concentration (1.3 kg), but both of them were significantly inferior to drenches and superior to granules in increasing the kapas yield.

The untreated control which was subjected to damage by the larve yielded significantly least (0.83 kg). The yield in soil drenched plots was doubled over untreated control, while the increase in other treatments ranged from 34 to 83 per cent.

#### 4.13.4 Evaluation of diflubenzuron as soil drench

##### 4.13.4.1 Seedling damage

During kharif 1991, diflubenzuron was tested as soil drench and through bait along with other chemical

toxicants. The data (Table 30) revealed that seedling damage in the plots treated with diflubenzuron drench at both the dosages (32.6 and 33.0%) and poison-bait (30.3%) was significantly less than in control (58.0%). Methomyl drench proved to be most effective by recording least seedling damage (11.3%) followed by monocrotophos poison-bait (14.3%) and endosulfan soil drench (15.3%).

Untreated control suffered heavy damage by losing 58.0 per cent seedlings. Efficacy measured in per cent reduction in seedlings cut over control revealed highest reduction in methomyl (80.4 %) and lowest in diflubenzuron soil drench.

From the results of 1983, 1984, 1985 and 1991 on the efficacy of different chemical toxicants and formulations, it is evident that endosulfan as soil drench performed consistently well with less seedling damage due to cutworms and higher kapas yield.

#### 4.13.5 Cost benefit ratio

The figures computed in Table 28 indicate striking differences in the benefit from each treatment. While the monetary return for rupee spent was over five fold where dusts were used, it declined to 2.7 and 2.6 times in the case of sevimol and endosulfan drenching. In the rest of the treatments benefit derived was half to double the investment made.

Table 30. Comparative efficacy of insecticides, formulations and a chitin inhibitor in the control of cutworms\* (1991-92)

Sl. No.	Treatments	Per cent seedlings cut at 30 DAG	Per cent decrease over control
1.	Soil drenching with diflubenzuron @ 100 g a.i./ha	33.0 <sup>d</sup> (35.0)**	43.1
2.	Soil drenching with diflubenzuron @ 150 g a.i./ha	32.6 <sup>d</sup> (34.8)	43.6
3.	Diflubenzuron food poison-bait @ 112.50 g a.i./ha	30.3 <sup>cd</sup> (33.4)	47.7
4.	Monocrotophos poison-bait @ 0.225 kg a.i./ha	14.3 <sup>ab</sup> (22.3)	75.2
5.	Soil drenching with endosulfan	15.3 <sup>b</sup> (23.0)	73.5
6.	Soil drenching with methomyl	11.3 <sup>a</sup> (19.6)	80.4
7.	Soil application of BHC	27.6 <sup>c</sup> (31.7)	52.2
8.	Control	58.0 <sup>e</sup> (49.6)	-
	S.Em.+	0.91	
	C.D. at 5%	2.76	
	C.V. %	5.0	

\* Artificial infestation of IV instar larvae @ 5 larvae/plot

\*\* Figures in the parenthesis are angular transformations.  
Means followed by same alphabet do not differ significantly

**CHAPTER - V**

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**DISCUSSION**

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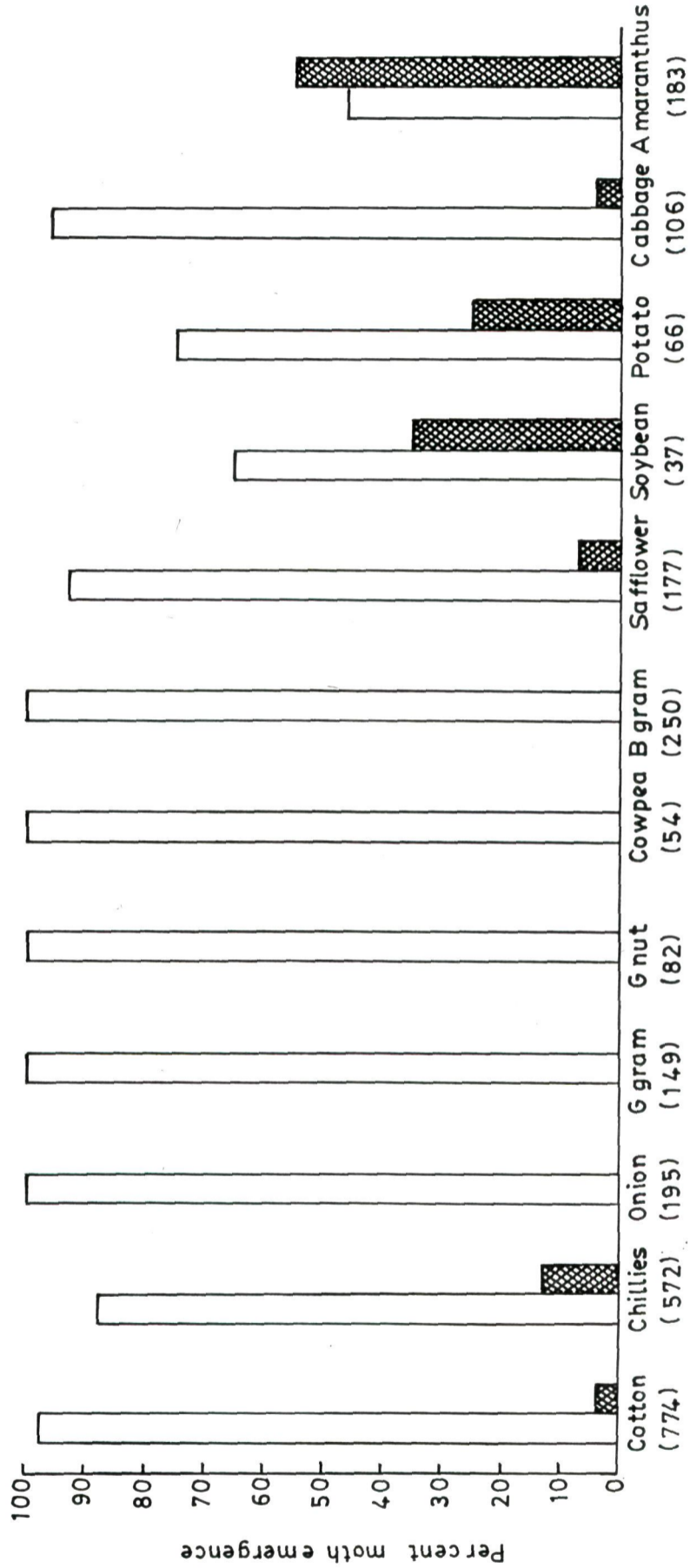
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## V. DISCUSSION

### 5.1 Species dynamics

Of the two species of cutworms recorded in all the five localities of Dharwad, Belgaum and North Kanara districts, Agrotis segetum was predominant (Fig. 2 ). Among the field collected larvae, irrespective of the crop, major proportion (88.4 %) belonged to A.segetum. While it was the only species to infest bengalgram, onion, greengram, cowpea and groundnut, the species was dominant on cotton, cabbage, safflower and chillies. Though A.ipsilon was noticed to a considerable extent on soybean and potato, it had an edge over A.segetum on amaranthus. During the present studies, A.segetum has been recorded for the first time and as a principal species of cutworm on cotton from the region. Though, A.ipsilon and A.segetum were recorded to infest cultivated crops in the early part of the century by Fletcher (1917 and 1919), A.spinifera has been reported as a pest of cotton seedlings for the first time by Mathur in 1942. Later, Pramanik and Basu (1971) recorded A.ipsilon causing considerable damage to cotton for the first time in West Bengal. Similarly, A.segetum was recorded as pest of cotton by Dastur et al. (1960). First report of A.segetum in Karnataka on coffee in 1925 by Kannan was confirmed by Usman (1953).

□ A. segetum  
 ▨ A. ipsilon



(Figures in the parenthesis are the number of field collected larvae from the respective host that completed development)

FIG.2. SPECIES DYNAMICS OF CUTWORMS INFESTING DIFFERENT HOST CROPS.

Subsequently, Devaiah (1973) recorded A.ipsilon on bhendi and potato from Bangalore, Dharwad and Kolar; A.segetum on tobacco and potato from Belgaum, Mysore and Bangalore and A.spinifera on ragi. Contrary to the claim of Devaiah (1973), who reported A.ipsilon and A.spinifera as the new records from the state, the former species was already recorded as pest of tobacco by Thimmaiah et al. (1972). Further, the latter authors in 1978 noticed the incidence of A.ipsilon on cotton, chillies, bengalgram, sunflower, bhendi and jowar, and later Thippeswamy et al. (1981a) observed cutworms as serious pests of cotton in Dharwad region and the species recorded was A.ipsilon only. It is interesting that until 1985 A.segetum was not recorded from Karnataka on cotton despite its occurrence elsewhere in the state on other hosts. It was Reddy and Puttaswamy (1985) who observed it to be major pest of chillies in nursery along with A.ipsilon.

Results on the dominance of A.segetum in the present study are also contrary to the reports of Thimmaiah et al. (1972 and 1978), Devaiah (1973) and Thippeswamy et al. (1981a) who recorded A.ipsilon as the only species concerned. According to Fletcher (1919), Nagpur was the southern limit of distribution of A.ipsilon, but by the later 60's the pest had spread to South India beyond Karnataka and became the predominant species by late 70's. On the other hand, A.segetum hitherto not reported in the northern transitional

region was first noticed during the period 1970-72 on tobacco in Belgaum district (Devaiah, 1973) and on chillies in Dharwad (Reddy and Puttaswamy, 1985).

In the present studies, since 1984, A.ipsilon was hardly noticed on already recorded hosts including cotton as 96 per cent of larvae infesting several fields, crops belonged to A.segetum, while on few of the host crops only A.segetum was noticed. One of the possible reasons for this might be competitive displacement of A.ipsilon by A.segetum in the crop ecosystems of the region. Rabb et al. (1984) analysed that if an immigrant species comes into competition with a resident one for at least one limiting resource, there are three possible outcomes; the resident species can exclude the immigrant species, the immigrant can displace the resident, or the two can coexist, specially when environmental conditions are cyclical favouring each of the competitors part of the time. While there are several examples of such nature, the classical instances of competitive displacement in the phytophagous insects are the displacement of mediterranean fruitfly, Ceratitidis capitata (Wied.) by the oriental fruitfly in Hawaii (Keiser et al., 1974) and displacement of migratory grasshopper Melanoplus bilituratus (Sauss.) by the differential grasshopper, M.differentialis (Thos.) during the period of supernormal precipitation and vice-versa when the physical conditions turn to sub-normal precipitation (Wakeland, 1961).

As a matter of fact, like the two species of fruitflies, the cutworms, A.ipsilon and A.segetum are the ecological equivalents having identical niche requirements and therefore, there lies a distinct possibility of displacement of A.ipsilon by A.segetum in different crop ecosystem of the region depending upon the limiting resource factors such as food, space and abiotic components. This phenomenon has to be confirmed through large scale sampling of larvae in as many areas as possible, over time, before asserting the above conclusion.

## 5.2 Biology

### 5.2.1 Biology of A.segetum and A.ipsilon

#### 5.2.1.1 Oviposition site

There was no difference between the two species in the oviposition behaviour. The female laid the eggs singly, often in groups of 20 to 50 with interspace on moist soil, seedlings preferably on stem bases or shoots. This habit of the pest has been well documented (Dutt, 1915; Jack, 1918; Theobald, 1927; Rekach, 1933; Devaiah, 1973; Hill, 1975; Malik and Chaudhary 1980 and Thippeswamy et al., 1981a). However, laying of eggs on larval exuvium in the laboratory by A.segetum was an interesting observation. The moths preferred

moist soil over seedlings and exuviae over moist soil for egg laying. Thus the order of preference was exuviae, soil and seedlings.

Preference for exuviae might possibly be due to chemical cues originating from the cast skin. Egg laying on muslin cloth, cotton wad and soil provided under enclosure indicate that physical requirement apparently decides the acceptance of a site for egg laying than conditioning by chemical cues. Therefore, the assumption of chemical guidance from the exuviae is not easily conceivable.

#### 5.2.1.2 Fecundity (Ovipositional studies)

The fecundity per female averaged 987.4 and 937.8 in A.segetum and A.ipsilon, respectively. The fecundity studies of A.segetum are in agreement with Rekach (1933) and Hill (1975) and of A.ipsilon with Shahid and Khan (1977) and Thippeswamy et al. (1981a). However, the range in fecundity has swung from lowest of 264 to 345 eggs in A.ipsilon (Nasr et al., 1964; Zhao, 1985 and Alnaji and Ghafoor, 1988) to highest of 1200 to 2250 for both the species (Jack, 1918; Ustinov, 1932; Devaiah, 1973; Malik and Chaudhary, 1980 and Santos and Nakano, 1982). Obviously, the extensive host range that cutworms have and the adult food provided should account for the greater disparity between the early workers and with present findings.

Non-significant variations in the pre-oviposition period and oviposition period between the two species are in confirmity with the findings of Devaiah (1973), Malik and Chaudhary (1980) and Thippeswamy et al. (1981a). The fecundity during the first half of oviposition period was quite high than in the second in both the species. Rate of oviposition was more in A.segetum and lower rate in A.ipsilon perhaps was due to longer oviposition period.

#### 5.2.1.3 Developmental stages

Incubation period of 4.3 days in A.segetum and 3.3 in A.ipsilon is in agreement with most of the early reports. In the present study, A.ipsilon larvae hatched from same batch of eggs moulted five and six times during 32.3 (pentamoulter) and 38.2 days (hexamoulter). Occurrence of penta- and hexamoulters has been documented in the literature. While these findings are in agreement with Thippeswamy et al. (1981a) and others, differed considerably from Rivnay (1964), Shahid and Khan (1977) and Zhao (1985) who recorded varying durations ranging from 21 to 65 days. Duration of a life stage is influenced by host and climatic conditions and therefore, differences in these factors could account for disparity in the observations.

Agrotis segetum moulted five times during 28.9 days. The pre-pupa with shrunken body constructed oval earthen cell within which it transformed into pupa in both the species and this has been placed on record by Devaiah (1973) and Thippeswamy et al. (1981a). The duration of pre-pupa (1 to 3 days) and pupa (12 to 15 days) is in accordance with the above workers. However, extended pupal period from 13-38 days by Rivnay, 1964 was due to the decline in temperature from 26° to 15°C. Similarly, a lower duration of 10-12 days was recorded by Ilichev and Galitsina (1981) and Shahid and Khan (1977).

The total life cycle from egg to adult emergence on cotton averaged to 49.6 days in A.segetum, 51.3 days in pentamoulter and 57.2 days in hexamoulter of A.ipsilon. If pentamoulter of A.ipsilon is compared with A.segetum, there is no significant variation in the total life cycle. Shahid and Khan (1977) reported a shorter life-cycle of A.ipsilon (38 days) on tobacco which is quite contradictory to the present results. Thus, it may be stated that the nature of food and perhaps climatic conditions did influence the life cycle. Similar variation in the life-cycle duration of A.segetum can be found in the studies of Rekach (1933) and Devaiah (1973) where both host plants and climatic factors were different. The observations made by other previous workers on this aspect on both the species are in close agreement with the present investigation.

#### 5.2.1.4 Adult

Description of adults of two species of cutworms did not deviate from the pioneer reports of Thompson (1894) and South (1907) and of Devaiah (1973) and Thippeswamy et al. (1981a). The adult longevity of 10.1 and 11.9 days and 9.8 and 10.3 days in male and female of A.segetum and A.ipsilon, respectively, in the presence of food was comparable to that of Devaiah (1973), Shahid and Khan (1977), Malik and Chaudhary (1980) and Thippeswamy et al. (1981a). Conflicting reports on longevity of adults are noticed in the literature. Rekach (1933) observed A.segetum adults to live for 15 days, Nasr et al. (1964) found it to be six to seven days in A.ipsilon, while the longest duration of 15 days in A.segetum was recorded by Ilichev and Galitsina (1981). The difference in the longevity may be attributed to the food provided to moths and prevailing weather factors and not to the larval food since in all the three latter studies biology was investigated on cotton.

#### 5.2.1.5 Sexual dimorphism

Pronounced sexual dimorphism has been reported by Devaiah (1973), Kumar and Verma (1980), Malik and Chaudhary (1980) and Thippeswamy et al. (1981a) in the two species in pupal and adult stages and the present investigations

are in accordance with them excepting the description of antenna in female A.segetum by Devaiah (1973) which was reported to be filiform as against setaceous nature.

#### 5.2.2 Seasonal influence and pest succession

The present investigations revealed that both the species could be reared throughout the year in the laboratory. The developmental period from egg to adult emergence all round the year is lacking in the literature excepting Thippeswamy et al. (1981a) who studied developmental periods of A.ipsilon on cotton from August to January during 1979-80.

#### 5.2.3 Number of generations

Constant observation made on the number of generations under field conditions based on larval infestation and rearing of such larvae in the laboratory till moth emergence to confirm the completion of a particular generation revealed four generations from June-July to January-February. This period covering three seasons coincided with availability of one or the other host seedlings. On cotton, two generations were noticed during June-August and August-September when cotton seedlings were available to the pest. Beyond September, in rabi season, availability of seedlings

of bengalgram, safflower etc., enabled the pest to complete two more generations. Shahid and Khan (1977) reported six generations of A.ipsilon in a year on tobacco as against four in A.ipsilon on chickpea from October to mid May by Malik and Chaudhary (1980). Results of present studies corroborate the latter report.

Cutworm population declined from February onwards but continued breeding, though at lower ebb, on the alternate weed hosts, namely, Commelina benghalensis. Conyza sp. and Parthenium which are new record to the literature.

### 5.3 Natural enemies

Apanteles ruficrus Ichneumon sp. and Turanogonia chinensis parasitoids were recorded as a cause of biotic pressure on the cutworm multiplication.

Except A.ruficrus, whose parasitization varied from 10.0 to 12.0 per cent, others were of casual occurrence. Bishara (1932) reported A.ruficrus parasitizing the larvae of A.ipsilon, but the intensity of parasitization was quite high (15 to 34%). Similarly, about 22 per cent parasitization of A.ipsilon larvae was reported by El-herneidy and Hassanein (1987) in vegetable ecosystem in Egypt. Though Singh (1982) recorded the same parasitoids from A.ipsilon larvae in Punjab, he failed to quantify the extent of parasitization. Salamov (1974) from USSR in cotton ecosystem, Rao and Barwal (1983) from Manipur and Misra and Agarwal from India (1988)

recorded a larval endoparasitoid belonging to genera Ichneumon on the two species of cutworms.

Low per cent parasitization by T.chinensis observed in the present studies is also corroborated by Singh (1982) and Thippeswamy et al. (1983) on A.ipsilon. A ground beetle, Anthia sexguttata was found preying cutworm larvae in the field. The literature lacks mention of this species as predator. However, other species viz., Broscus punctatus (Fletcher, 1913), Microlestis discoidalis (Mathur et al., 1971) and Anisodactylus signatus (Berim and Novikov, 1983) have been recorded. The incidence of NPV noticed on grown larvae in nature is in conformity with the reports on A.ipsilon in China (Tsai et al., 1978), India (Santharam and Kumarswamy, 1984), Denmark (Qgaard, 1988) and in GDR (Schliephake, 1989). Chandramohan and Nanjan (1990) reported NPV as one of the important population regulating factor in A.ipsilon and A.segetum in the vegetable ecosystems in Nilgiris. In addition to this, white muscardine, Beauveria bassiana, Penicillium waksmani and Aspergillus tamari were also noticed in the laboratory rearing.

#### 5.4 Cannibalism

Both A.ipsilon and A.segetum exhibited cannibalistic behaviour. In all environments studied, A.ipsilon exhibited

significantly higher cannibalistic behaviour than A.segetum (Fig.3). Cannibalistic behaviour was more aggressive in the absence of food. When all the instars (I to VI) were reared together, there were more victims of first three instars than the later ones. As the cannibalism behaviour prevailed irrespective of the availability of natural food, it could be said that cannibalism is an inherited behaviour than a conditional learning for survival.

Cannibalism is one of the important factors in the regulation of insect population. Though the effect of cannibalism on population build up under natural conditions is difficult to isolate from other mortality factors (Walker, 1984), in the case of back swimmer, Notonecta hoffmanni L., Fox (1985) established that cannibalism can be a major mortality factor with more than 50 per cent of I instar being victims. Agrotis ipsilon and A.segetum are no exception to this phenomenon of population regulation by inbuilt cannibalistic behaviour in these cutworm species. Observations have been made on the cannibalism in cutworms by quite a few workers (Maxwell Lefroy and Ghosh, 1907; Dutt, 1917; Malik and Chaudhary, 1980 and Ilichev and Galitsina, 1981). Observations of El-kifl et al. (1973b) on rearing intra- and inter instar larvae of A.ipsilon corroborate the present findings.

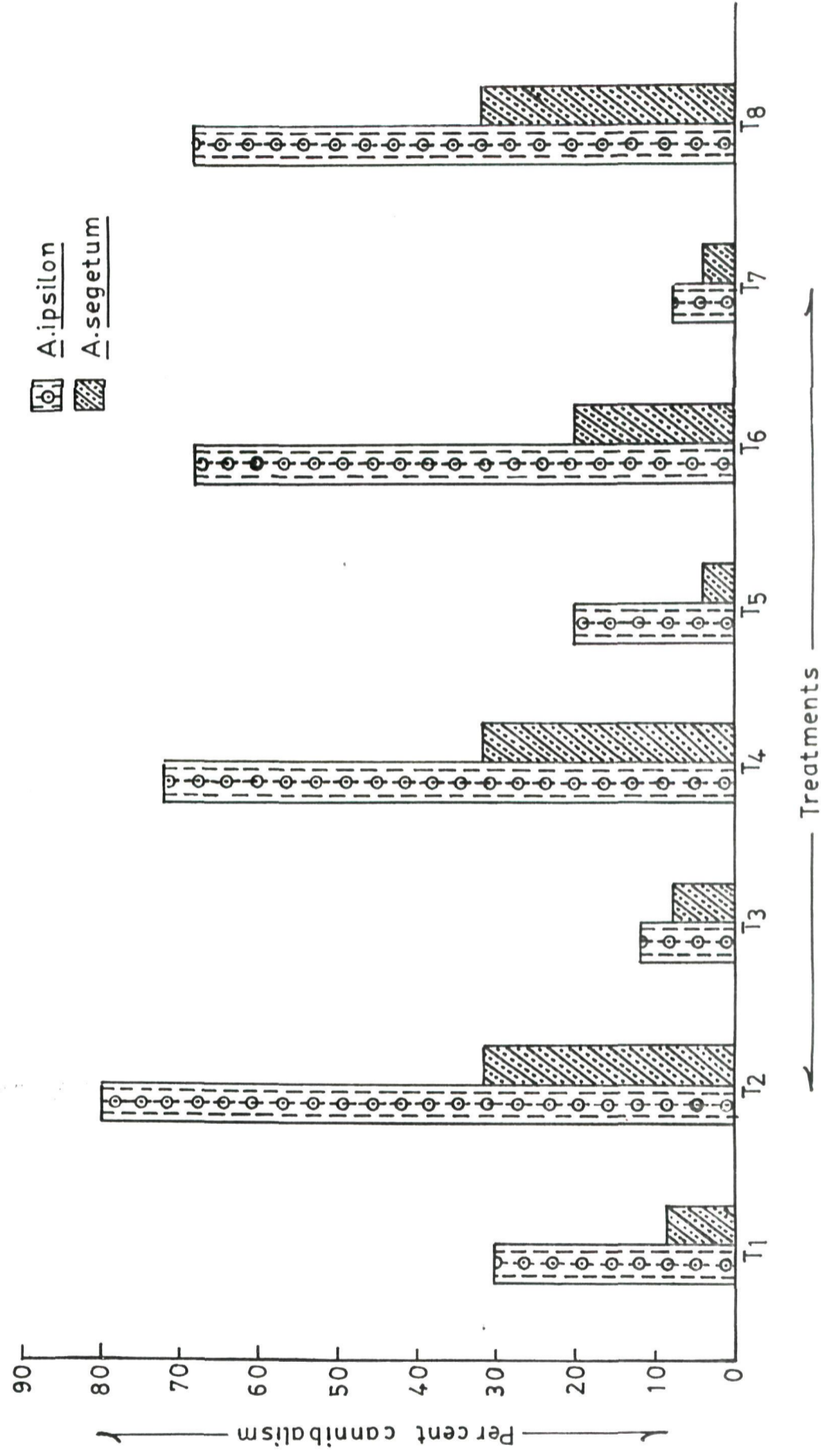


FIG. 3. CANNIBALISTIC BEHAVIOUR OF A. ipsilon AND A. segetum.

In grain feeding insects, the first larva to occupy a grain may attack and kill any other that follow (Crombie, 1944), while in the corn earworm (Heliothis zea Boddie), a larva occupying an ear tolerates no companions even though the food supply is sufficient for several and cannibalism limits the population well below the limits of food resources (Barber, 1936). These two instances justify the statement 'cannibalism has self-evident population stabilizing effects and has never been mistaken for self-sacrifice' made by Walker (1984).

#### 5.5 Seasonal abundance of moths

The investigations revealed a high degree of activity during kharif and early part of rabi seasons. The moth activity during this period (July to October) and the number of generations arrived at, based on the larval infestations in the present studies are closely related. The studies made by Hanna (1973), Blair (1982), Hu (1982) and Kim et al. (1982) highlight the flight fluctuation with the season and recorded three to five generations from May to October.

Highest moth catch (Fig. 4 ) was observed during II week of September, 1983 and three peaks were observed during August, September and July in decreasing order.

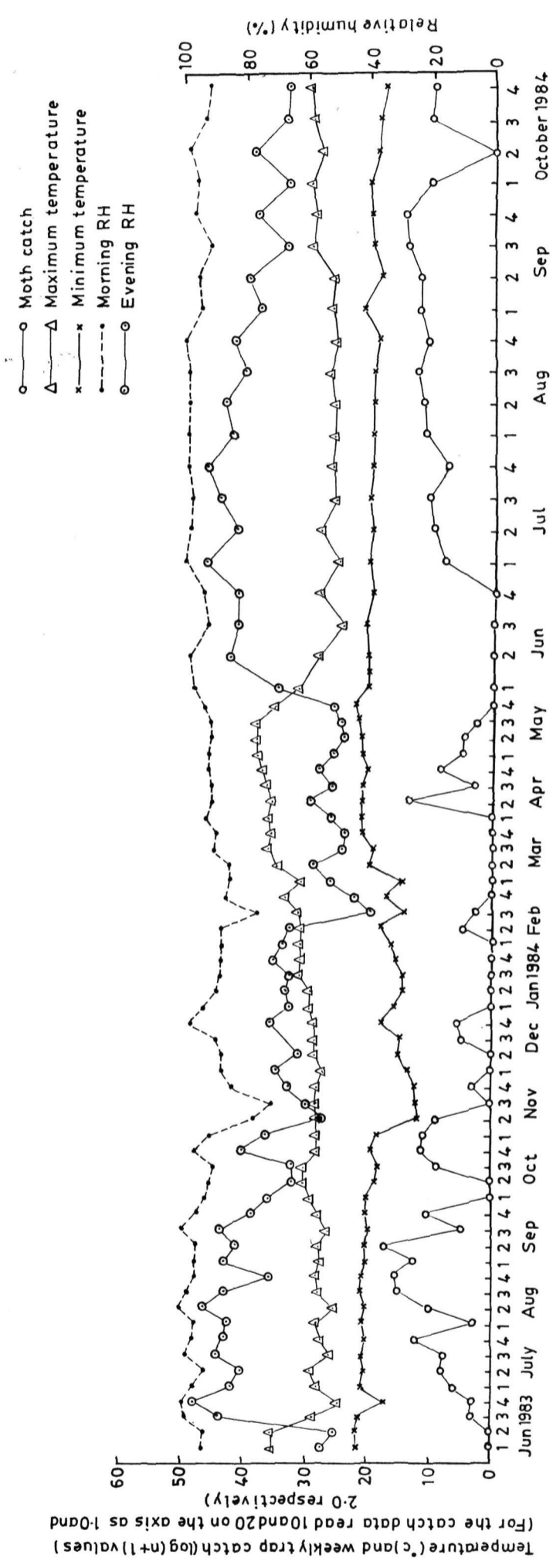


FIG. 4 . INFLUENCE OF MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE, RELATIVE HUMIDITY-I AND RELATIVE HUMIDITY -II ON THE MOTH ACTIVITY ( FROM JUNE 1983 to OCTOBER 1984 )

Yadav et al. (1984) and Gul and Chaudhary (1986) though reported same number of population peaks in A.ipsilon, the period of peak occurrence (February-May) was quite contrary to the present findings. This variation is possibly due to the host crop availability coupled with environmental factors. In addition, record of two peaks made by Hassanein et al. (1972), Ionescu (1985) and Zanaty et al. (1987) are also contrary.

From the data it was noticed that moth activity declined from November onwards (Fig. 4,5 & 6). This highlight that attraction of moths to the light trap was from resident population and population decline was obviously to the non-availability of host seedlings from December onwards. However, as the pest survived on weed hosts, continuity of moth trapping during December, February, April and May was possible.

#### 5.5.1 Relationship between weather factors and light trap catches

Significant positive correlation was observed between weekly moth catch and minimum temperature, morning RH ( $RH_1$ ) and evening RH ( $RH_2$ ), while there was significant but negative correlation between moth catch and maximum temperature. The rainfall and wind velocity had no significant ( $r=0.07$  and  $-0.1$ , respectively) effects on the moth

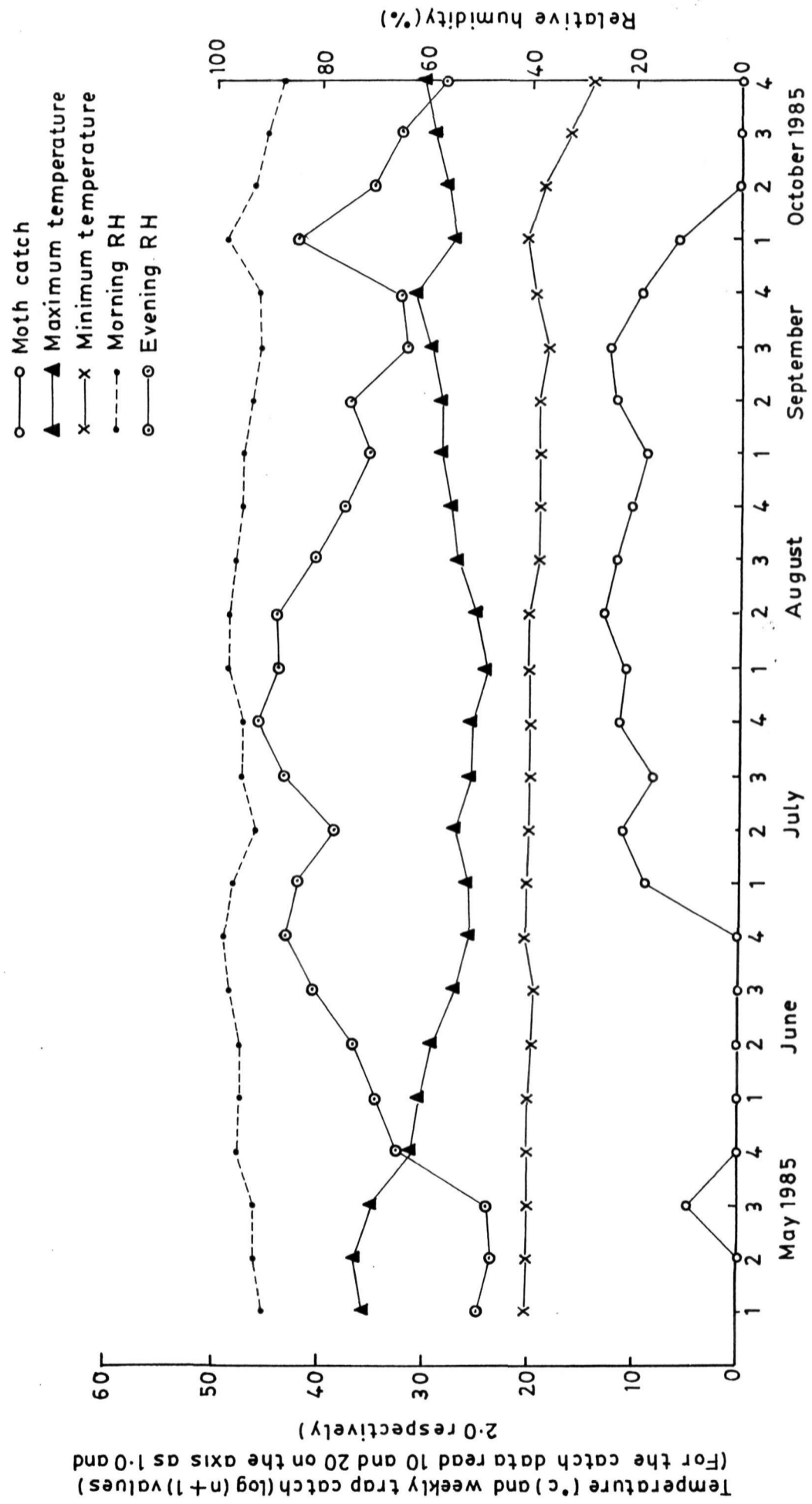


FIG. 5. INFLUENCE OF MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE, RELATIVE HUMIDITY-I AND RELATIVE HUMIDITY-II ON THE MOTH ACTIVITY (FROM MAY 1985 to OCTOBER 1985).

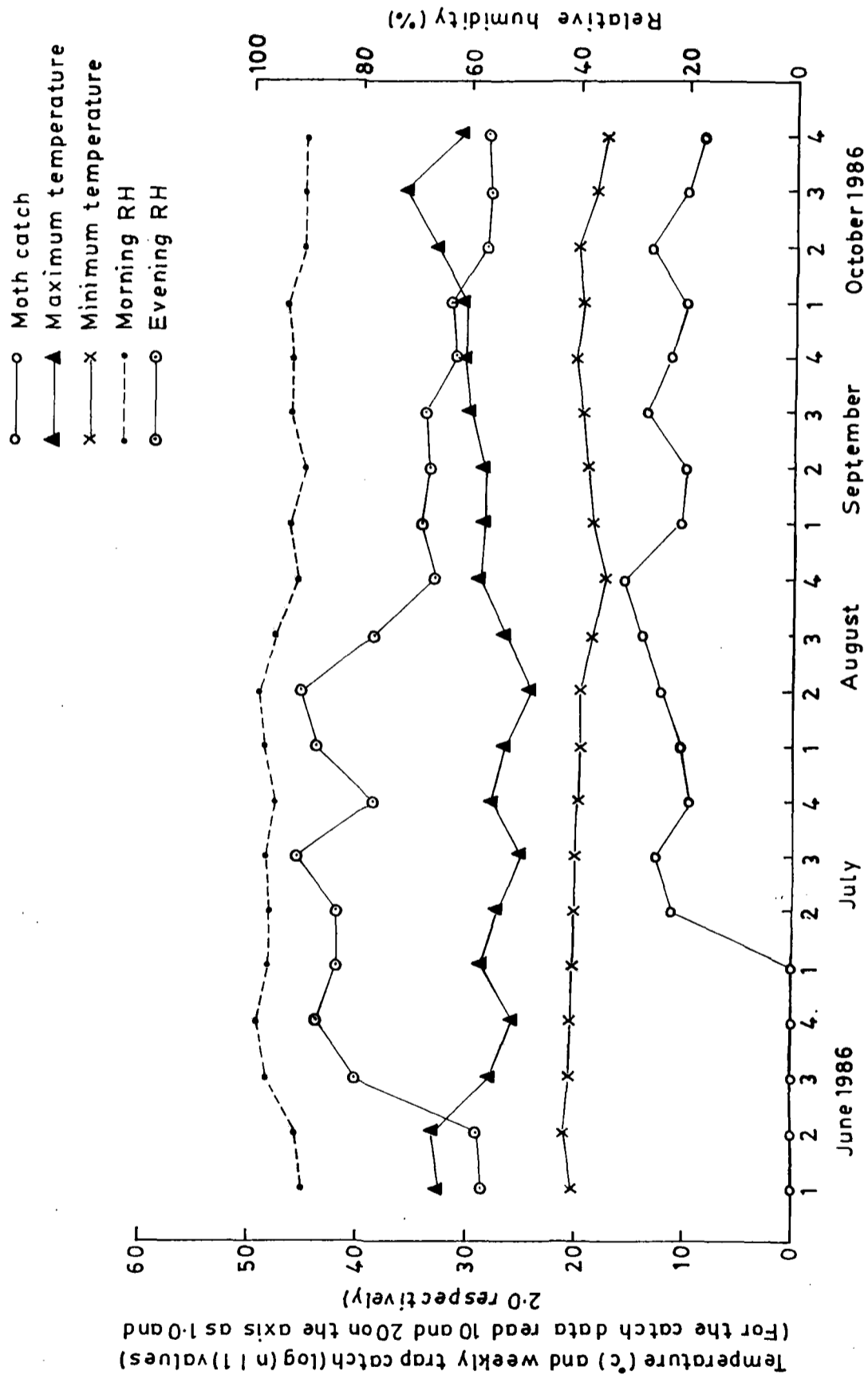


FIG.6. INFLUENCE OF MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE, RELATIVE HUMIDITY -I AND RELATIVE HUMIDITY-II ON THE MOTH ACTIVITY (FROM JUNE 1986 to OCTOBER 1986 ).

activity. In the multiple regression analysis, it was revealed that significant positive correlation existed between moth catch, evening RH and minimum temperature, while negative and significant correlation was noticed between the moth catches and wind velocity. When individual weather factor was considered by the process of eliminating other factors, minimum temperature ( $y = -0.234 + 0.045 X$ ), maximum temperature ( $Y = 1.485 - 0.029 X$ ), morning RH ( $Y = -2.507 + 0.033 X$ ) and evening RH ( $Y = -0.386 + 0.014 X$ ) were found to influence the moth catches.

Depletion of moth catches with the increase in wind velocity and increase in the attraction with increase in minimum temperature, as evidenced from multiple regression analysis, are in conformity with the findings of Hanna (1973). However, positive and significant relationship with evening RH established in the present investigation is contradictory. The findings of Yadav et al. (1984) also confirm the positive effect of minimum temperature on moth activity from February to May in chickpea ecosystem in Haryana. Similarly, McClanahan and Elliott (1977) correlated the peak activity of A.ipsilon with temperature but did not indicate the nature of relationship.

From the foregoing discussion, two important inferences emerge : Light trap is a sound tool in monitoring

moth flight and peak activity of cutworms to time the control measures. This factual truth has been well documented by Cook (1928), one of the pioneer scientists, who rightly described light traps as ' indicators ' of cutworm moth populations. Secondly, the moth attraction in the light trap is collectively influenced by different weather components, wherein the individual weather factor exerts varying degree of effects on the pest activity.

#### 5.6 Crop loss estimation

Quantitative estimation of crop loss due to insect-pests is a pre-requisite for formulating any pest control strategy in visualising economically higher returns. Unlike the foliage feeders where there would be partial damage with scope for recoupment in the infested plant, the damage inflicted by the cutworms is total and irreparable. Secondly, the damage caused by the cutworms is not merely the food requirement but the sum total of need and instinct for cutting. Therefore, what is required is precise experimentation to establish the relationship between pest density and damage on one hand; and the crop damage and actual yield loss on the other. The present study is an effort in that direction.

The treatment receiving endosulfan as soil drench received lowest damage followed by granular application of carbofuran (Fig. 7). In the mechanical control, despite the constant removal of larvae, over 17 per cent of the seedlings were cut and this was due to failure to detect hiding larvae in the soil. The untreated check recorded nearly six times more damage as compared to endosulfan drenching, which was statistically significant over the rest of the treatments imposed to create graded damage. The same trend was maintained in recording the kapas yield with endosulfan drenching but the magnitude of increase over untreated check was not of the same order as per cent reduction in seedling damage (Fig. 7). Perhaps undamaged seedlings in control getting better growth requirements due to reduced plant stand per unit area resulted in higher yield as compared to the plant stand in best treatment. This effect is easily noticed when yield is calculated per plant basis. There was no statistical significance between the mechanical control and carbofuran treatment and this was due to same amount (13 to 17 per cent) of seedling damage recorded in the two treatments. The mean avoidable loss of kapas (Fig. 7) over two seasons in the control was 24.3, 29.3 and 49.7 per cent when computed from yield obtained from mechanical control, carbofuran soil application and endosulfan drenching, respectively.

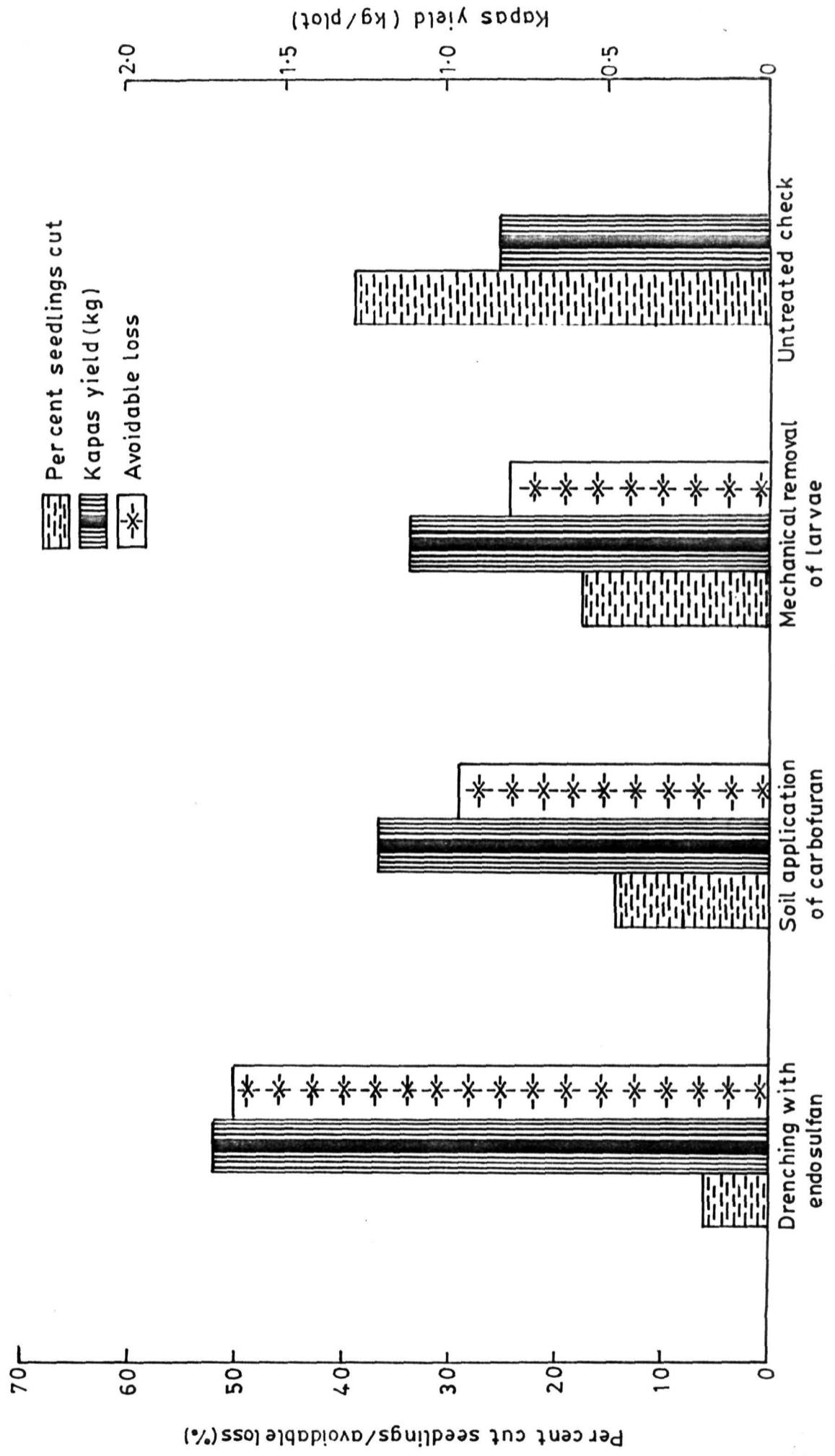
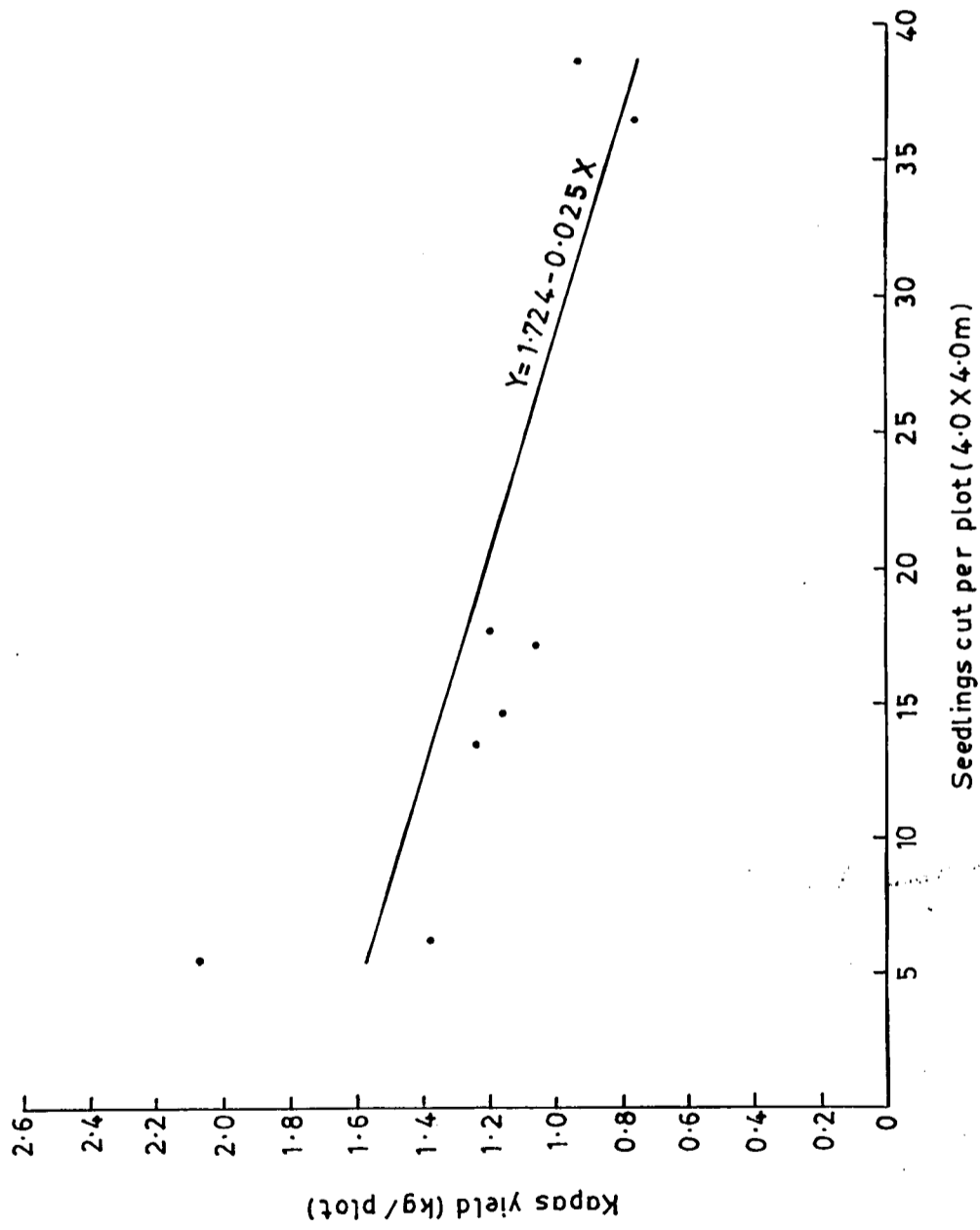


FIG. 7. EXTENT OF DAMAGE AND YIELD LOSS DUE TO CUTWORMS IN COTTON.

The correlation between the number of seedlings cut and kapas yield of pooled data for two seasons was negative and significant and the regression equation (Fig. 8 ) hinted that for every increase in number of seedlings damaged by one per cent the kapas yield was reduced by 0.025 kg per plot (15.6 kg/ha). Comparisons of these results lack due to obscured literature.

Though the loss caused by the cutworms has not been estimated on cotton, it has been quantified in potato, tobacco and maize. In India, much of the reports are from potato, wherein about 12 to 40 per cent loss has been reported (Chaudhary, 1953; Nirula, 1961; Panchabhavi et al., 1972 and Saxena and Misra, 1980 etc.), while, Parihar and Singh (1988) reported differential reduction in the form of net profit due to the insecticidal treatment in four varieties of potato crop. Showers et al. (1983) and Rodrigues Del Bosque (1986) estimated an yield loss of 2.9 q/ha and 3.8 q/ha, respectively, when maize crop was attacked by cutworms during coleoptile to one leaf stage. Whitford et al. (1989) indicated that significant yield losses occur before four leaf stage.

Similarly, 17 per cent (Cheng, 1971) and 20 to 80 per cent (Vasilov, 1987) of tobacco crop was lost due to A.messoria and A.segetum infestation, respectively. The



**FIG.8.RELATIONSHIP BETWEEN NUMBER OF SEEDLINGS CUT AND KAPAS YIELD  
IN COTTON ( TWO SEASONS DATA )**

avoidable loss computed with reference to different protective methods is well within range of reported results.

## 5.7 Damage potential of larva

### 5.7.1 Extent of damage

The seedling damage in a period of 15 days over a plot size of 16 m<sup>2</sup> varied from 33 (2 larvae) to more than 156 seedlings (12 larvae) (Fig. 9). The increase in seedling damage was progressive with the increase in larval density and the findings are in complete agreement with the reports made by Sechriest and York (1967) and Showers et al. (1983) who observed similar trend in maize against the larvae of A.ipsilon.

The relationship between the larval density and number of seedlings cut (Fig.10) was positive and significant. The regression equation for the two variables indicated an increase in seedling damage by 12.37 numbers per plot during 15 days period, for every increase in the larval density by one. Such prediction model for cutworms either in cotton or in other crops has not been developed.

### 5.7.2 Larval density and yield loss

The correlation computed between the variables using two regression equations  $Y=1.724-0.025 X$  for number of

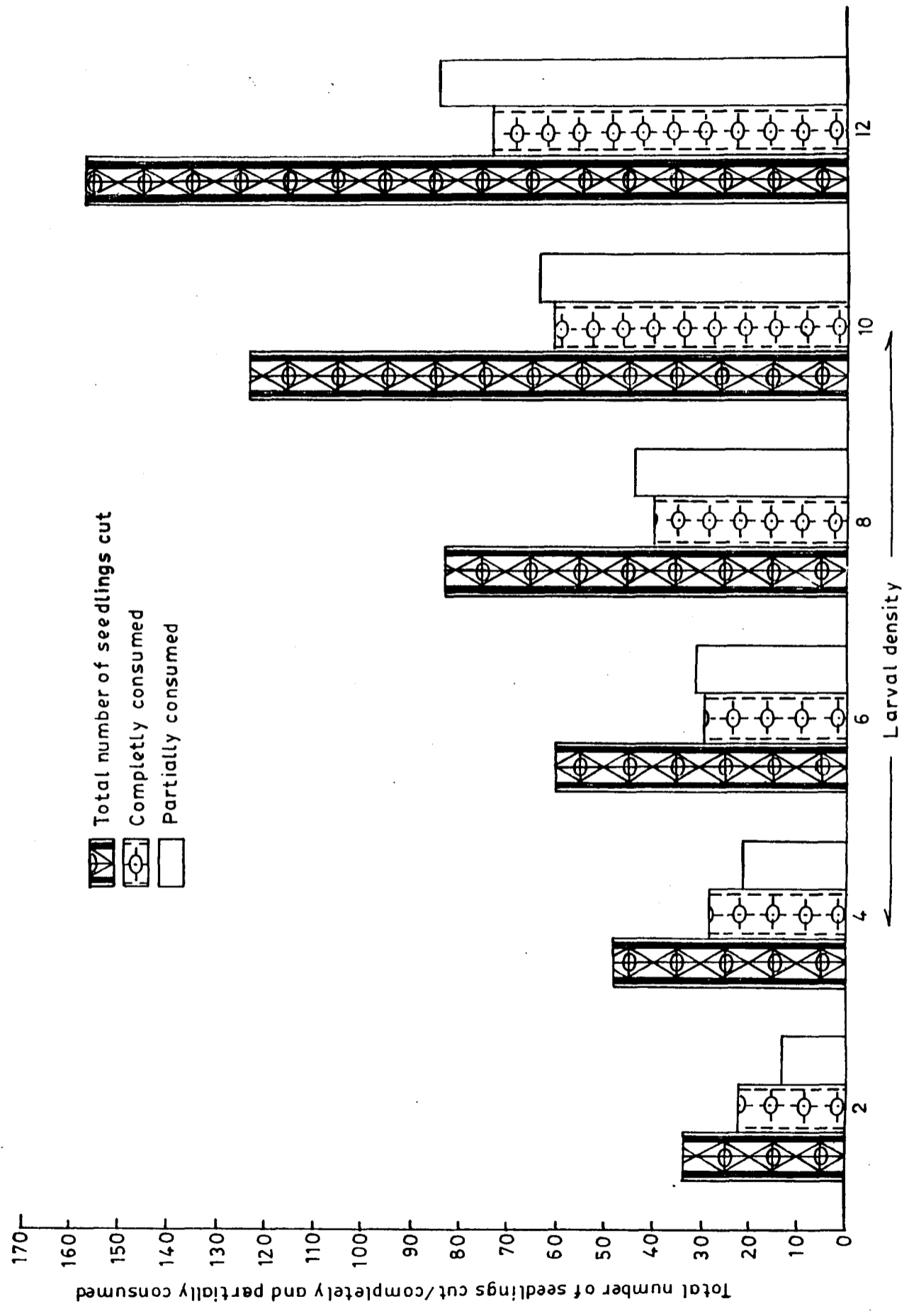


FIG. 9. DAMAGE POTENTIALITY OF *A. segetum* LARVA.

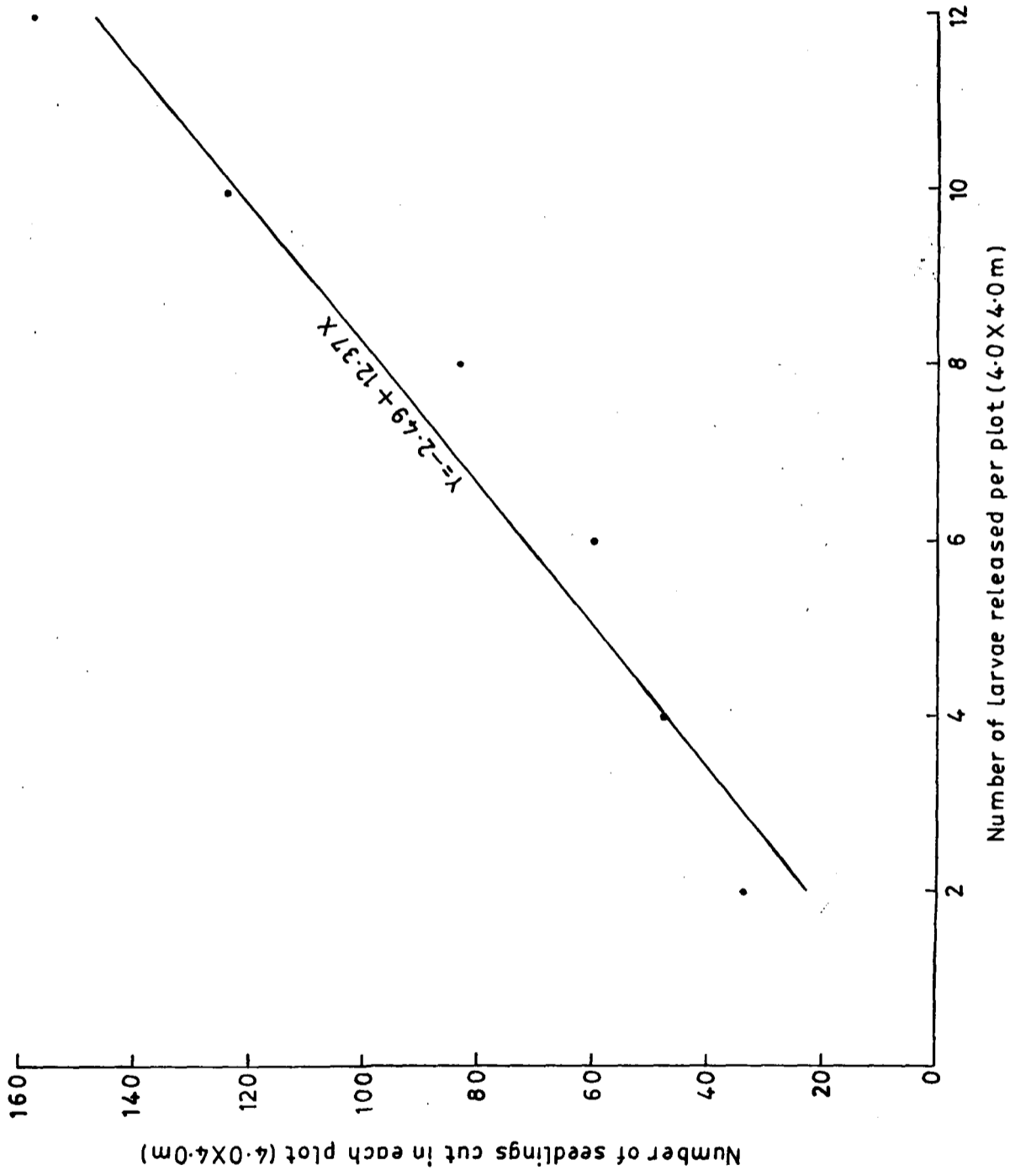


FIG.10.RELATIONSHIP BETWEEN LARVAL NUMBER AND SEEDLINGS CUT.

seedlings cut and yield and  $Y = -2.49 + 12.37 X$  for larval density and seedlings cut, was negative and significant. The estimated regression equation for the two variables,  $Y = 1.73 - 0.09 X$  indicated that for every increase in larval density by one, the yield reduction would step up by 0.09 kg per 16.0 m<sup>2</sup> area (52.6 kg/ha). The relationship between larval density and yield reduction is estimated one using two other relationships, namely, seedling damage and yield ( $Y = 1.724 - 0.025 X$ ) and larval density and seedling damage ( $Y = -2.49 + 12.37 X$ ), arrived for a smaller area (16.0m<sup>2</sup>). Thus, the yield estimate in relation to larval density on hectare basis cannot become a realistic one. This is mainly due to confounding of experimental error several times (625) and therefore, estimated yield reduction per every unit increase in larval density has to be worked out in a planned experiment for the purpose. The literature on hand reveals no such relationships. Yield loss in any crop is always a function of pest density. Cutworm activity year after year in a locality is neither constant nor can it be predicted with high accuracy. Therefore, the results of finding are applicable to situation when the incidence measured in terms of seedling damage is slightly less than 40 per cent. To arrive at more reliable data, perhaps, study needs to be carried out over years to cover varied pest density situations.

### 5.7.3 Damage in relation to seedling age

The studies on the preference of larvae to young and old seedlings revealed that the number of seedlings cut in 1 to 7 day old seedlings was significantly high compared to 8 to 15 day old seedlings, irrespective of the larval density. Against differential population of larvae from 2 to 12, the percentage of seedlings cut in 1 to 7 day seedlings ranged from 72.2 to 80.8, while it varied from 19.2 to 27.8 per cent in 8 to 15 days seedlings. These results are in accordance with the findings of Foster and Gaylor (1986 and 1987) who observed that the number of cotton plants cut per larva (VI instar) in the green house study decreased from 5.8 seedlings in one node cotton to 1.6 seedlings in five node cotton, while seven node seedlings were not susceptible. In no-till cotton, in barrier enclosed plots the authors observed that the percentage of seedlings cut decreased progressively from 42 to 17 per cent as the age of the plant increased from one node to five node.

The results indicate that the larvae when provided with seedlings of different age prefer younger seedlings that are quite succulent. As the plant age increases beyond 10 days, stem gets hardened with increase in its girth and hence are less preferred. The proportion of damage to younger seedlings (1 to 7 days old) remained same irrespective of

larval load (from 2 to 12 larvae) when adequate seedlings were available. Secondly,  $\frac{3}{4}$ th of damage was inflicted within 7 days of seedling emergence while the remaining  $\frac{1}{4}$ th damage was caused after 8 days of emergence. These observations justify the general statement that cutworms are pest at seedling stage.

#### 5.7.4 Feeding pattern

The observation on the nature of feeding (Fig. 9) on each cut seedling revealed that the larva after cutting the seedling either devoured it partially or completely. At lower larval density (2 and 4 larvae/16m<sup>2</sup>) complete consumption of seedling was slightly more and as the density increased from eight onwards, more than 50 per cent seedlings cut were partially fed. When the feeding pattern is viewed irrespective of larval density, the larvae fed one seedling partially out of every two cut seedlings. This proves the fact that the pest damages more seedlings than it consumes. It is evident from the findings that the consumption behaviour of cutworm larvae was influenced by the pest population. It is conceivable that when the larval density increases, the proportion of seedlings damaged would increase more than it consumes vis-a-vis at lower density. Thus, it can be inferred that cutworm larvae at increased density exhibit more of wandering habit by cutting

than consuming the cut seedlings. The other explanation could be that a seedling if it is partially eaten is perhaps not accepted for feeding by the other.

From the available information, it appears that no such systematic experimentations on the pattern of feeding have been made. However, some observations on the cutting instinct of the larvae of A.ipsilon resulting in more spoilage have been made by Woodhouse and Dutt (1913).

The relationship between the larval density and consumption patterns was positive and significant (Fig. 11). Regression analysis revealed that every increase in a larva, partial and complete consumption rates increase by 7.07 and 5.38 times, respectively. Such computations to regress out the quantum of feeding in two patterns of feeding are lacking for cutworms.

#### 5.8 Nature of feeding

First and II instar larvae were associated with scraping of green leafy matter, preferably from the under surface of leaves and were designated as 'scraping instars'

Fourth, V and VI instar larvae exhibited characteristic behaviour of stem cutting in less than 20 days old seedlings at or slightly below the soil surface to feed on

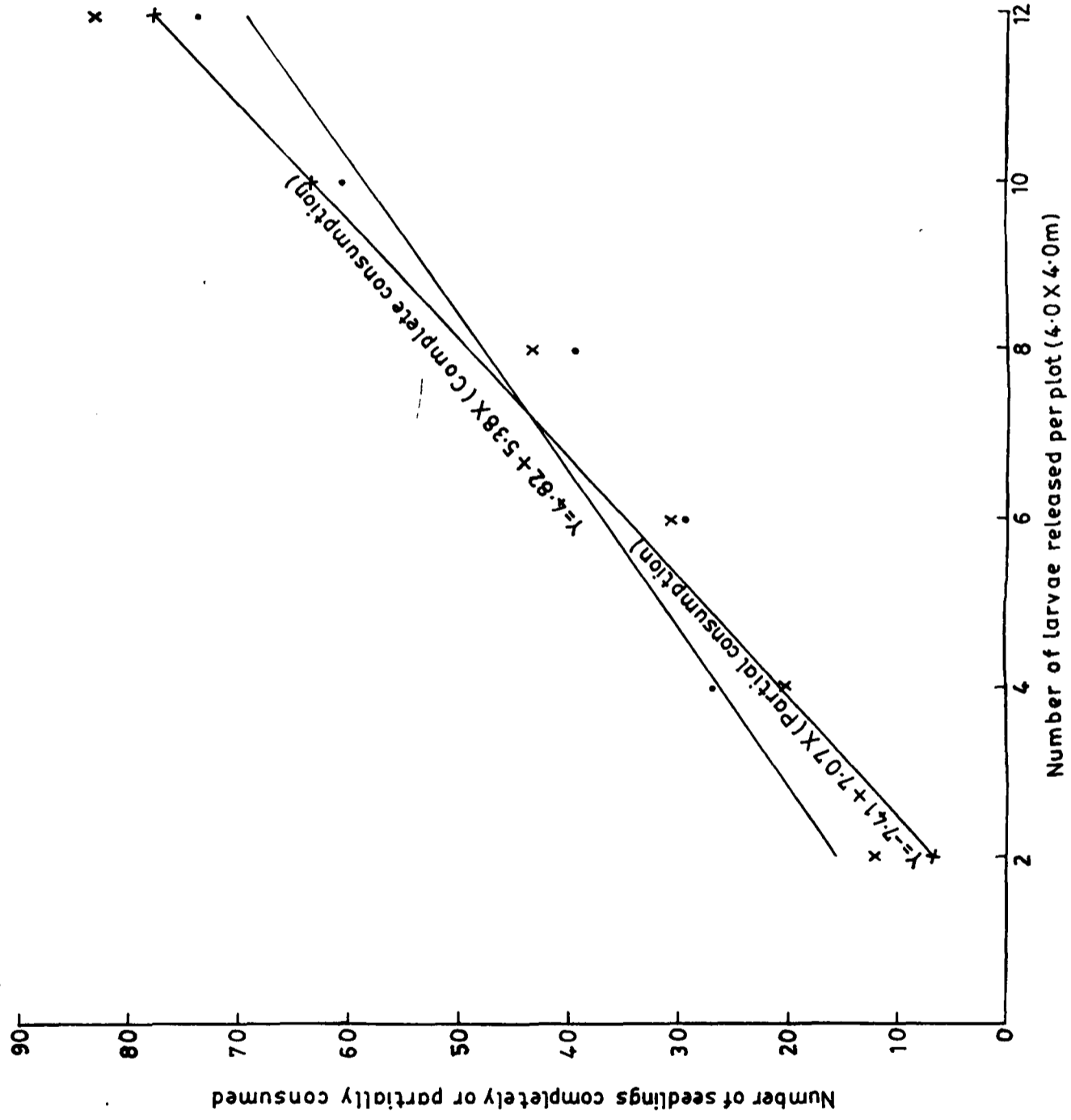


FIG. 11. RELATIONSHIP BETWEEN LARVAL NUMBER AND FEEDING PATTERN ON CUT SEEDLINGS.

them. In older seedlings, VI instar nibbled on the peripheral part of stem as a result the plant leans to the ground. These instars were designated as 'cutting instars'.

Third instar larvae exhibited feeding patterns intermediate to the above two groups. They cut the younger seedlings of about two days old, fed on the succulent part of stem on older seedlings. Interestingly larvae also made shot holes on leaves in two days old seedlings after inflicting cut.

From the foregoing description, it may be inferred that larvae get the cutting instinct from late III instar and it would be at peak in IV, V and VI instars. The mandibles of larvae become hard, sclerotized from III instar onwards and develop into sharp, scissor like incisors as the age advances. Druzhelyubova and Makarova (1971) observed that the magnitude of injury to cotton seedlings by A. segetum depended on the number of larvae that were in the III to VI instar group at the time of germination. Kim et al. (1982) reported IV, V and VI instars as cutting instars in different crops. These reports support the observations made in the study. In contrast, Cabello and Hernandez (1988) recorded only IV and V instars of A. segetum as cutting stages in corn.

## 5.9 Dispersal behaviour

### 5.9.1 Dispersal rate

In all the treatments from T<sub>2</sub> to T<sub>5</sub>, where the nearness of seedlings from the released spot varied from 0.5 to 2.0 m, the larva travelled to the point of seedling during the same period and cut the seedlings. The larva which was released in the centre of each plot at dusk on the previous day cut the seedlings before dawn. This clearly indicates that the rate of dispersal of larva is more related to the availability of food and the distance that they had to travel in search of seedlings has no relevance. Though such studies are totally lacking on cutworms, the findings of Burkett et al. (1983) on Heliothis zea indicate the behaviour of larvae to remain at the sites of release on tomato plant feeding leaflets for a week time and later dispersing to the fruits, pin point that the movement of larvae is related to the availability of food. Similarly, Blickenstaff (1983) observed that the Western bean cutworm larvae, Loxagrotis albicosta (Smith), did not disperse beyond 3.66 m from the release point of egg masses on the crop canopy and 72 per cent of the damage occurred within a smaller area. Therefore, it may be concluded that the dispersal of a larvae is guided by the availability of food. If food becomes scarce, the larvae are capable of moving longer distance.

### 5.9.2 Dispersal pattern

In general, the dispersal pattern of the larva was random (App. 1 to 5). In  $T_1$  where the plants were normally distributed, the damage was found more near the release points (App.1) and hence the distance travelled by the larva was less (111.0 cm/day). More or less same pattern was recorded in  $T_2$  also (App.2). As the distance between release point and availability of seedlings increased from 0.5 to 2.0 m, the larva moved further (169.3 to 234 cm/day). There was no any specific pattern either row wise or across the rows in treatments  $T_3$  to  $T_4$  and hence, movement was more a random (App. 3 & 4). In  $T_5$  with the gap area of 16 m<sup>2</sup>, where very few seedlings were available, the movement was quite erratic (App.5).

There is no much information on this aspect except the report of Blickenstaff (1983) who recorded the dispersal of L.albicosta upto 3.05 to 3.66 m in the release row and 2.45 to 3.05 m across the rows on the field bean (Phaseolus vulgaris L.) plants from the points of egg-mass infested to the foliage.

### 5.9.3 Extent of damage

As the number of hills in different treatments decreased, the extent of damage also decreased from 23.6 seedlings in  $T_1$  to 8.6

seedlings in T<sub>5</sub>. The reduction in damage was gradual from T<sub>1</sub> to T<sub>3</sub> (from 23.6 to 20.0 seedlings) while, in an increasing rate from T<sub>3</sub> to T<sub>5</sub> (20.0 to 8.6). This apparently was due to reduction in the number of seedlings available for feeding.

Blickenstaff (1983) observed that L.albicosta damaged to the tune of 72.3 per cent in three rows of 1.83 m wide and 3.66 m long and beyond these distances damage abruptly reduced but continued to decline with increase in distance from the release point on bean plants.

#### 5.10 Host plant interaction

Food is the major ecological component for the survival and build up of any insect pest and studies on the host preference and suitability are obviously of prime importance. This would help in understanding the various components of host plant resistance and may lead into development of effective strategy in the management of any insect pest. Thus, an effort was made to know the larval preference under free choice conditions and the effect of different host plants on the biology of the insect pest.

##### 5.10.1 Host preference

Two seasons study on the host preference by larvae indicated (Fig. 12) that cotton was the most preferred among

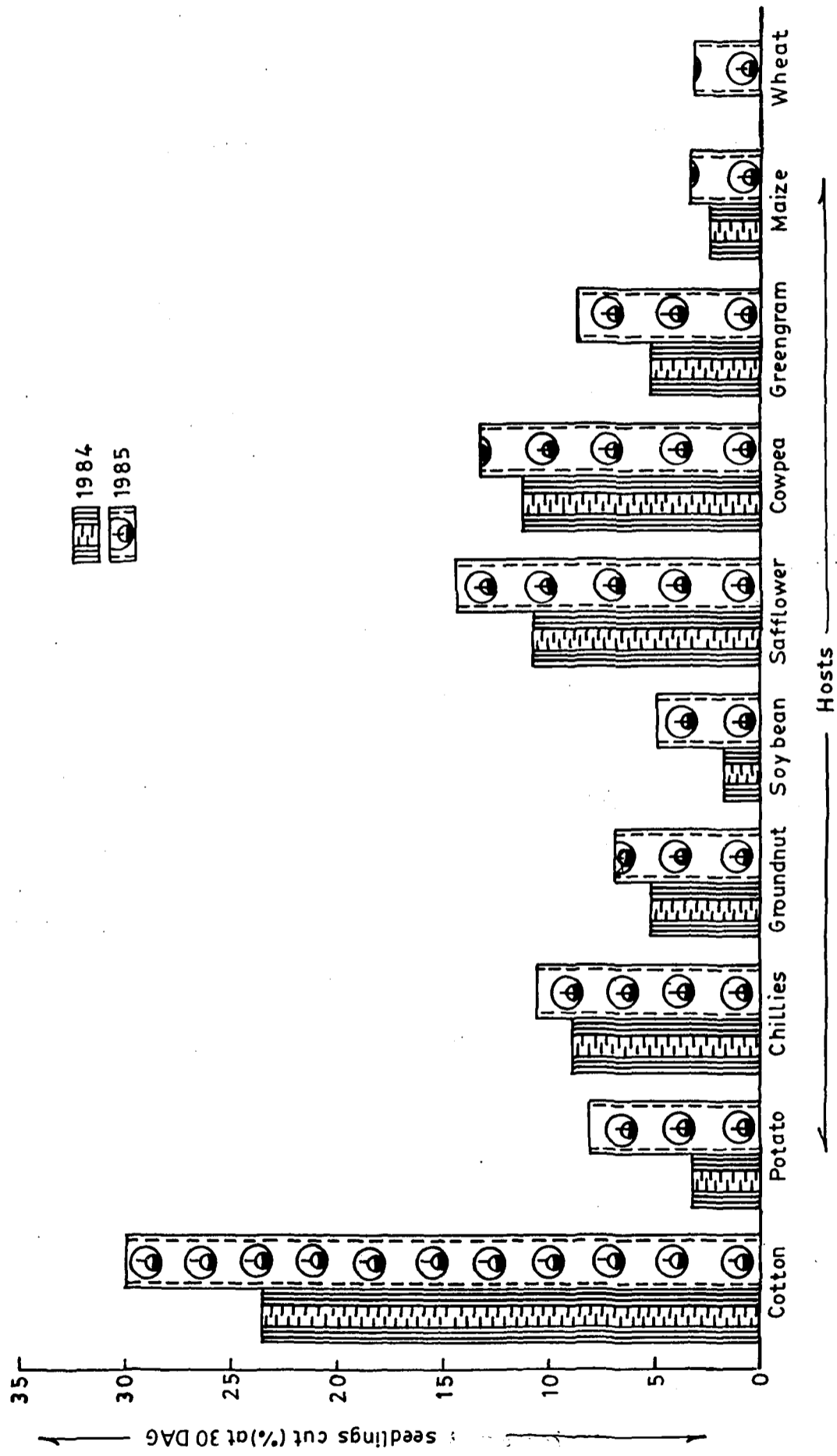


FIG.12.HOST PREFERENCE BY THE LARVAE UNDER FIELD CONDITIONS.

10 economical host plants tested as evidenced from highest proportion of seedlings damaged (23.3 and 30.3 per cent) followed by safflower, cowpea and chillies. Wheat was least preferred with an average damage of 1.5 per cent. Such records of establishing preference for some hosts over others have been reported by few early workers. Nikolova (1971) reported that A.ipsilon larvae were injurious to over 50 cultivated and wild plants; amongst which tobacco, beet, maize and vegetable were most preferred. Similarly, Kim and Kim (1981) recorded higher proportion of damaged seedlings in Chinese cabbage and sesame and lowest damage on soybean and radish.

The relationship between an insect and its host plant is often extremely complicated since the factors regulating host selection by adult, and subsequent survival of its off-spring vary considerably throughout the season. The selection of a host plant by an insect is a finely tuned system based on the physiological state of both the insect and the plant (Finch, 1988). Based on the amount of damage and nature of plant, it appeared that the larvae generally preferred seedlings with succulent stems and leaves having more water content as encountered in safflower, cotton, cowpea. This explanation has been documented by Southwood (1975) who observed low water content in the leaf as a major evolutionary hurdle for phytophagous insects.

Jack (1918) observed that the cutworm, A.segetum can feed on any plant including grasses having succulent plant parts and this observation holds good in the present findings. However, potato seedlings which are fairly succulent are less preferred and this indicates involvement of other factors besides succulency.

Insect behaviour is one of the two components involved in the preference mechanism. Under the multiple cropping conditions, if the host plant has got undesirable plant properties, the insect tries to avoid the host and in the present studies wheat and maize received almost no damage and the possible reason might be antixenosis. Such of these findings might help as one of the tools in the management of an insect pest by using the most preferred hosts as trap crop in protecting the principle crop from the insect attack. Exploitation of such phenomenon in the pest management is well documented against number of destructive pests in the literature. Makarov (1916) recommended planting of susceptible rye as trap crop surrounding the main crop in the control of cutworms, A.segetum and is a sound proposition in this direction.

### 5.11 Effect of host plants on the biology of A.segetum

The host plants exerted significant effects on the biology of A.segetum. Incubation period varied from 3.9 days on potato to 4.5 days on wheat. Mean larval period was shortest (Fig. 13) on potato (27.2 days) and longest on wheat (39.4 days) and the number of instars remained at six on all the species of host plants tested. Nikolova (1961) reported that the larvae of A.ipsilon became fully fed in 35 days on lucerne and beet while in 40 days on maize. Similar reports were made by El-Kifl et al. (1973a) in A.ipsilon larvae with shortest (20.9 days) larval period on lucerne and longest (28.3 days) on castor. The larval development varied from 24.6 days on wheat to 47.0 days on annual morning glory (Busching and Turpin, 1977). Nikolova (1977) observed that quality of food plant determines the length of the larval period for A.ipsilon taking 19 days on beet and Chenopodium album and 29.4 days on maize. Longer larval duration on maize as reported by Nikolova (1961) and Nikolov (1977) are in agreement with the present findings of higher duration (39.2 days) on maize as compared to the lowest of 27.2 days on potato. Cotton and safflower were at par with potato with lower duration, while cowpea, groundnut, greengram, soybean and chillies were intermediate in their effect on the larval period.

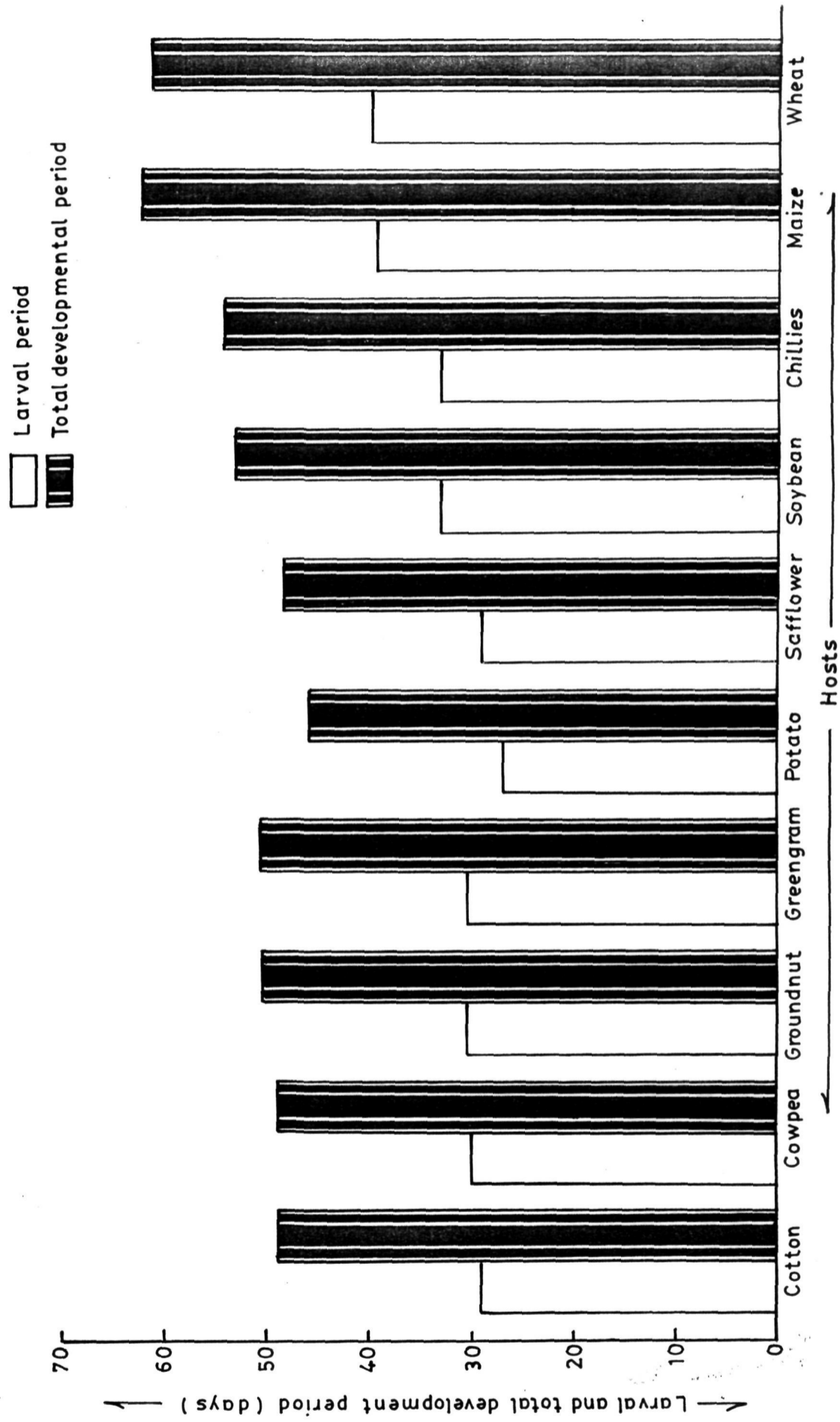


FIG.13. EFFECT OF HOST PLANTS ON THE DEVELOPMENTAL PERIOD OF A. segetum.

Significant difference in the larval weight on 10th, 20th day and of VI instar was noticed among different hosts. Weight of full fed VI instar larva, varied from 733.3 g in safflower to 391.6 g in chillies. Cotton recorded statistically same amount of weight as that on safflower; while maize, soybean and wheat were at par with chillies and suggested their adverse effects on nutrition of the insect. The gain in weight was enormous between 10th and 20th day after hatching in all the hosts excepting maize, wheat and chillies. The larvae of A.segetum generally feed voraciously from IV instar onwards. Increase in the feeding rate was highest on safflower between 10 and 20 days after hatching (393.9 per cent over 10th day). This was possibly due to the succulency of seedlings. Contrary to this, per cent gain was meagre (80-100) on wheat, maize and chillies implying less suitability of these hosts to support the insect growth. In contrast, the larvae gained substantial amount of weight at the end of VI instar on these hosts which could be due to prolonged larval durations. Highest weight gain at the end of larval growth on safflower and cotton reflected the host suitability. Such reports on the influence of host plant on the weight of cutworm larvae are not available, but the observations made by Thobbi (1961), Pandey and Srivastava (1967) & Parasuraman and Jayaraj (1985) in Spodoptera litura support the present findings.

Variation in the pre-pupal period between hosts observed in the study has been reported by Habib and Patel (1977) in Heliothis virescens and Parasuraman and Jayaraj (1985) in S.litura.

Every larva fed on cotton, potato and safflower transformed to pupa with no larval mortality (Fig. 14 ). While, survival<sup>Survival</sup> ability was reduced by half on maize and wheat. The pupal duration was shortest (12.7 days) on cowpea and longest on maize (16.0 days). Cotton, potato, groundnut, greengram, safflower, soybean and cowpea were at par. Absence of variation in pupal period due to larval food in the case of A.ipsilon, according to El-Kifl et al. (1973a), is contradictory to the above findings. However, the reports of Parasuraman and Jayaraj (1985) and Kulkarni (1989) indicating the influence on the pupal duration of S.litura corroborate the present investigations.

The weight of pupa varied from 228.3 g on cowpea to 326.6 g on safflower. Cotton and potato followed safflower in recording higher pupal weight. Pupal weight on the hosts in accordance with larval weight at the end of growth period on favourable hosts which might possibly be due to the favourable nutritional status of the hosts. These findings are supported by El-Kifl et al. (1973a) and Nikolov (1977) who stated that the pupal weight of A.ipsilon was dependent on the larval food.

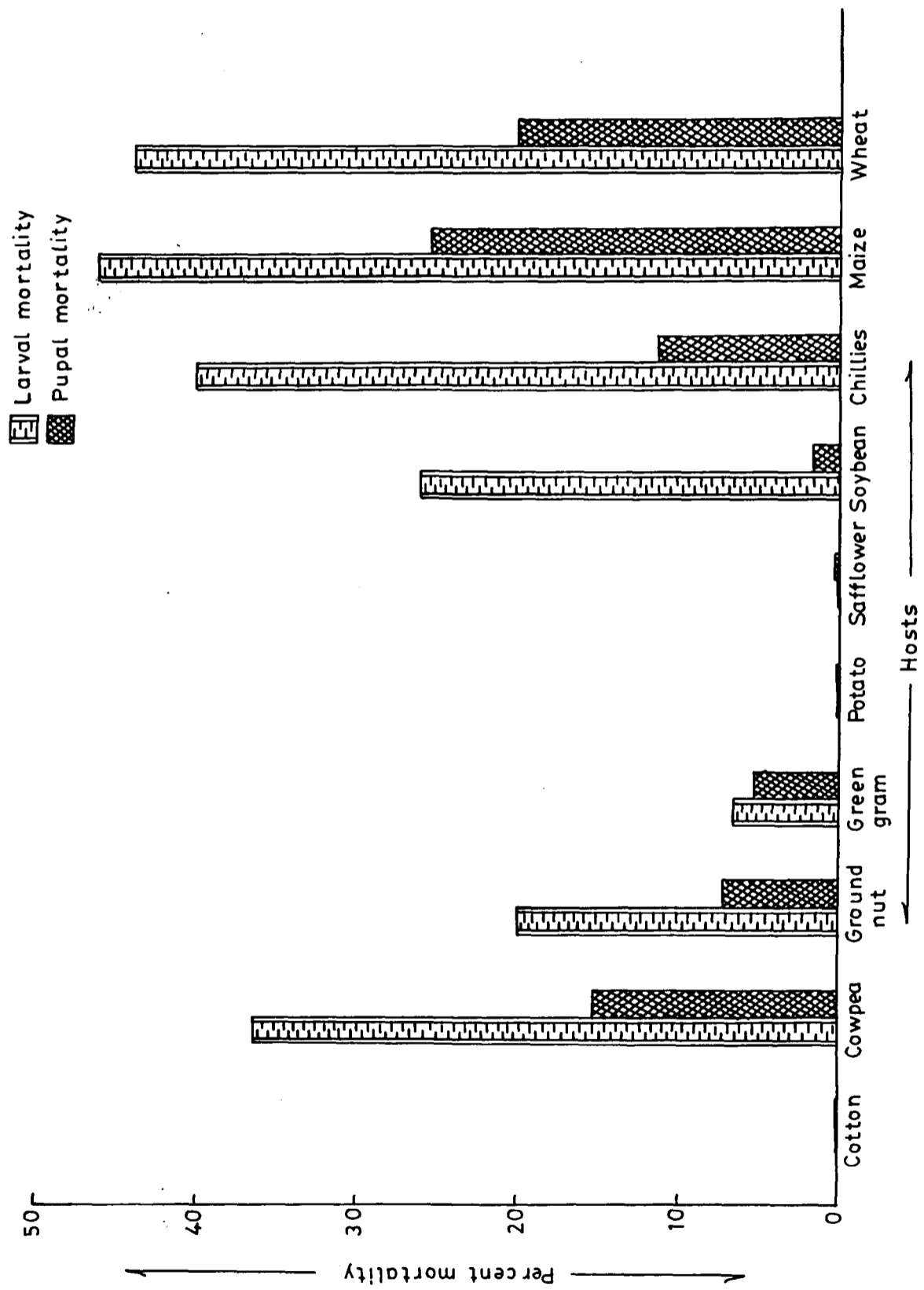


FIG.14.EFFECT OF HOST PLANTS ON THE MORTALITY OF A.segetum.

The total developmental period (Fig.13) of A.segetum, a measure of cumulative effect of growth period of immature stages, varied from 46.1 days on potato to 62.4 days on maize. The delay in completing development by about two weeks on maize was apparently due to prolonged egg, larval, pre-pupal and pupal durations thus indicating its unsuitability as favoured host. The other host plants exerted intermediate influence between the above two. The growth index (Fig.15) was maximum on potato (3.6 ) followed by cotton and safflower and this was due to shorter larval duration and higher pupation. In contrast, maize recorded lowest growth index (1.3 ) followed by wheat and chillies, wherein the larva took about 10 to 12 days more to complete larval growth. The information on this aspect is totally lacking. However, different growth indices due to the variation in larval food have been reported in S.litura by Parasuraman and Jayaraj (1985) and Kulkarni (1989).

Adult emergence (Fig.16 ) was cent per cent on cotton and potato followed by safflower and soybean. It was lowest on maize (74.7%) followed by wheat. The mortality in general, was less in pupal stage compared to the larval stage irrespective of larval food provided. The present findings of maize as poor host is in conformity with the findings of Nikolov (1977) in A.ipsilon, but contradict the report of Nikolova (1961) who observed lower mortality (8.0 to 9.5 %) on maize as compared to 97 per cent mortality

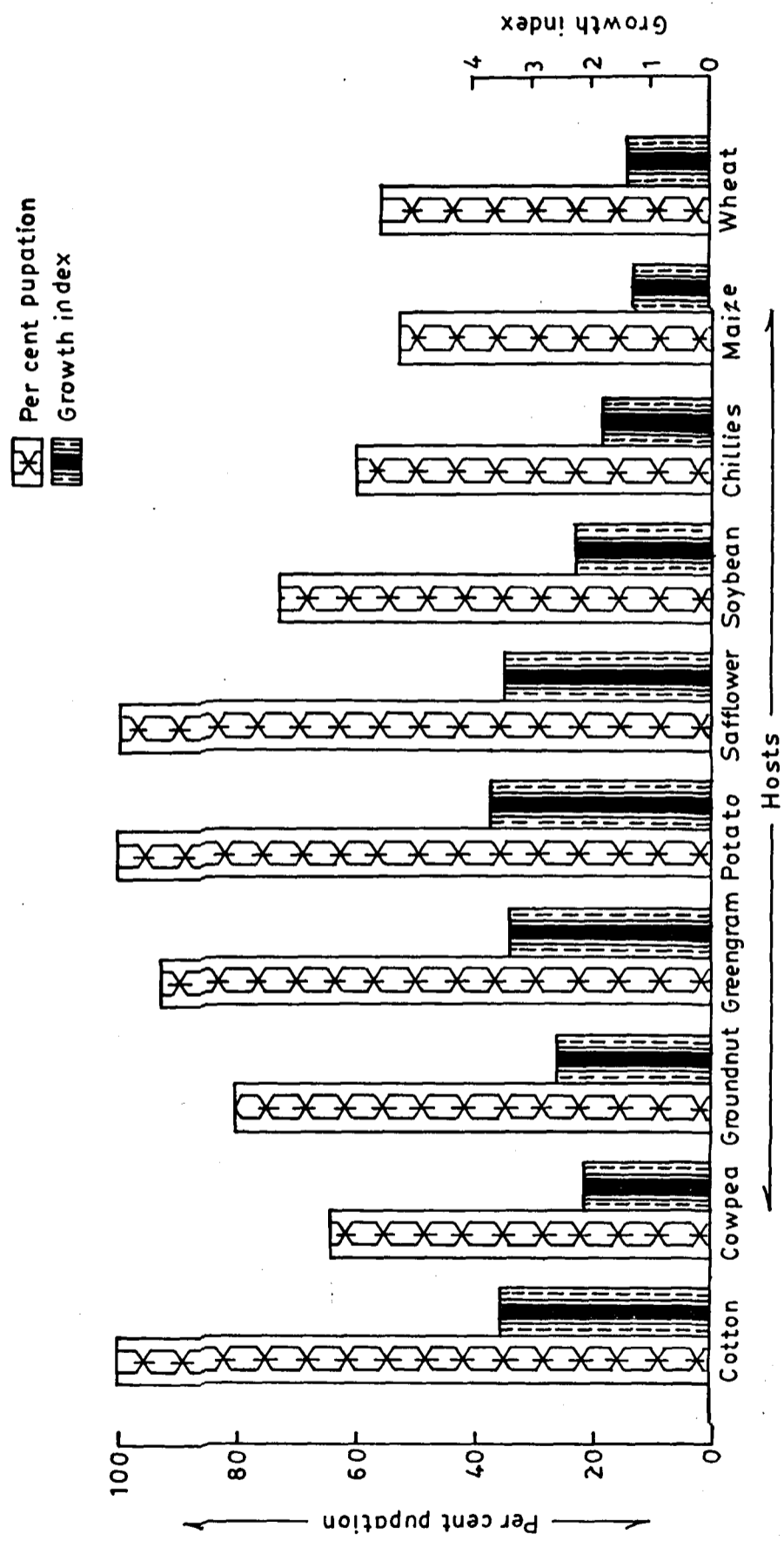


FIG.15. EFFECT OF HOST PLANTS ON GROWTH AND SURVIVAL OF A. segetum LARVA.

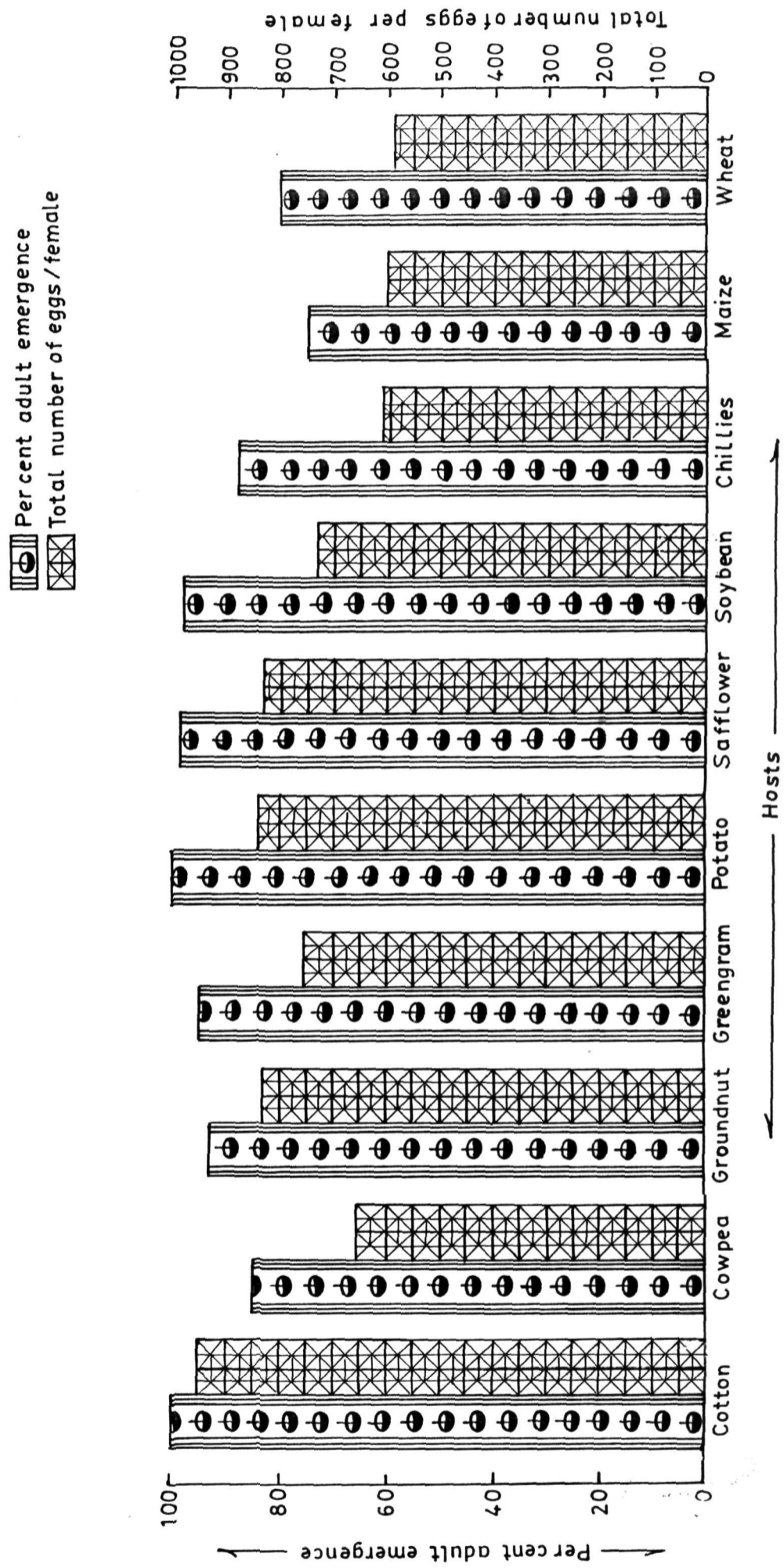


FIG.16. EFFECT OF HOST PLANTS ON FECUNDITY AND ADULT EMERGENCE OF *A. segetum*.

of neonate larvae of A.ipsilon on turkish tobacco. Similarly, Bushing and Turpin (1977) reported that the survival of A.ipsilon was highest on blue grass, curled dock and wheat while complete mortality on gaint fox tail or leaf debris.

Longevity of male moths was shortest on potato (5.2 days) and longest on cotton (9.4 days), while the female longevity varied from 6.8 days (safflower) to 10.8 days (cotton). Nikolova (1961) noticed the adults to survive longer and shorter when the larvae were fed on beet and maize, respectively. Contrary to his report and the present findings, Nikolov (1977) concluded that the larval food had an insignificant influence on the life-span of the A.ipsilon adults. While narrower sex ratio (male : female) was observed in safflower and potato, males prepondered (wider ratio) on wheat, chillies, maize, soybean and cowpea, which were found to be less suitable hosts from the point of nutritional requirements to the larvae.

The fecundity (Fig.16) varied from 950.0 on cotton to 591.6 eggs on wheat. The egg laying of the moth reared on cotton was significantly higher than on the remaining host plants. These numerical values are contrary to investigation of El-Kifl et al. (1973a) who recorded each A.ipsilon moth to lay 375 eggs on cotton and in full agreement with their observation on maize with 545 eggs as compared to 1000 eggs on sweet potato.

## 5.12 Management

### 5.12.1 Effect of diflubenzuron on A.segetum under laboratory conditions

#### 5.12.1.1 Effect on egg

Diflubenzuron at various concentrations exerted ovicidal action. Inhibition of egg hatching was more pronounced (2.0 to 64.0 %) in one day old eggs than in three days old (1.3 to 18.0%). Thus, the compound is highly effective when the chorion is freshly formed. Inhibition increased with increase in concentration and highest percentage (64.0) was encountered when one day old eggs were treated at 0.0125 per cent. Findings on the ovicidal action of diflubenzuron on cutworm are lacking. However, Rao and Reddy (1984) reported 30 to 100 per cent egg hatch inhibition in S.litura and 54 to 100 per cent in A.janata at test concentrations ranging from 10 to 1000 ppm. Positive association was noticed between the concentration and ovicidal action and this is in conformity with the present observations. Ovicidal action of diflubenzuron in Spodoptera littoralis (Boisd.) (Ascher & Nemny, 1974). Leucoptera scitella (Costa, 1836) (Grosscurt, 1978) S.litura (Natesan, 1979) has also been documented.

The dosage of the compound required to inhibit 50 per cent egg hatch was 125 ppm (0.0125%) which is comparable to the finding of Rao and Reddy (1984) who observed

about 75 per cent inhibition in A.janata and S.litura at 100 ppm.

#### 5.12.1.2 Effect on larva

The compound affected larval moult and caused morphological deformities in all the three instars tested. The product induced oozing of yellow fluid through anus and later prevented moulting. At higher concentrations (0.005 to 0.0125%), the mortality of III and V (Fig. 17) instar larvae was quick and they succumbed within 10 DAT. However, at lower concentrations, the mortality was extended beyond larval stage with ten to 15 per cent mortality from 10 DAT to pupal stage. In VI instar, inhibition of moulting was distinct at lower concentrations (0.00025 to 0.0025%) with the formation of larval-pupal intermediates in the treated larvae. While at higher concentrations (0.005 to 0.0125%) the death of the larvae was rapid, as all the treated larvae died during larval stage and about seven to 27 per cent mortality occurred during the pupal stage at lower concentrations (Fig.18).

As against 93 to 100 per cent normal adult emergence in the untreated control in three instars, emergence of deformed adults from the pupae at dosages from 0.00025 to 0.0025 per cent implied that the effects of the growth

- 1 10 DAT
- 2 10 DAT to pre-pupal stage
- 3 Pre-pupal stage to adult emergence
- 4 Normal adult emergence \*
- 5 Deformed adults

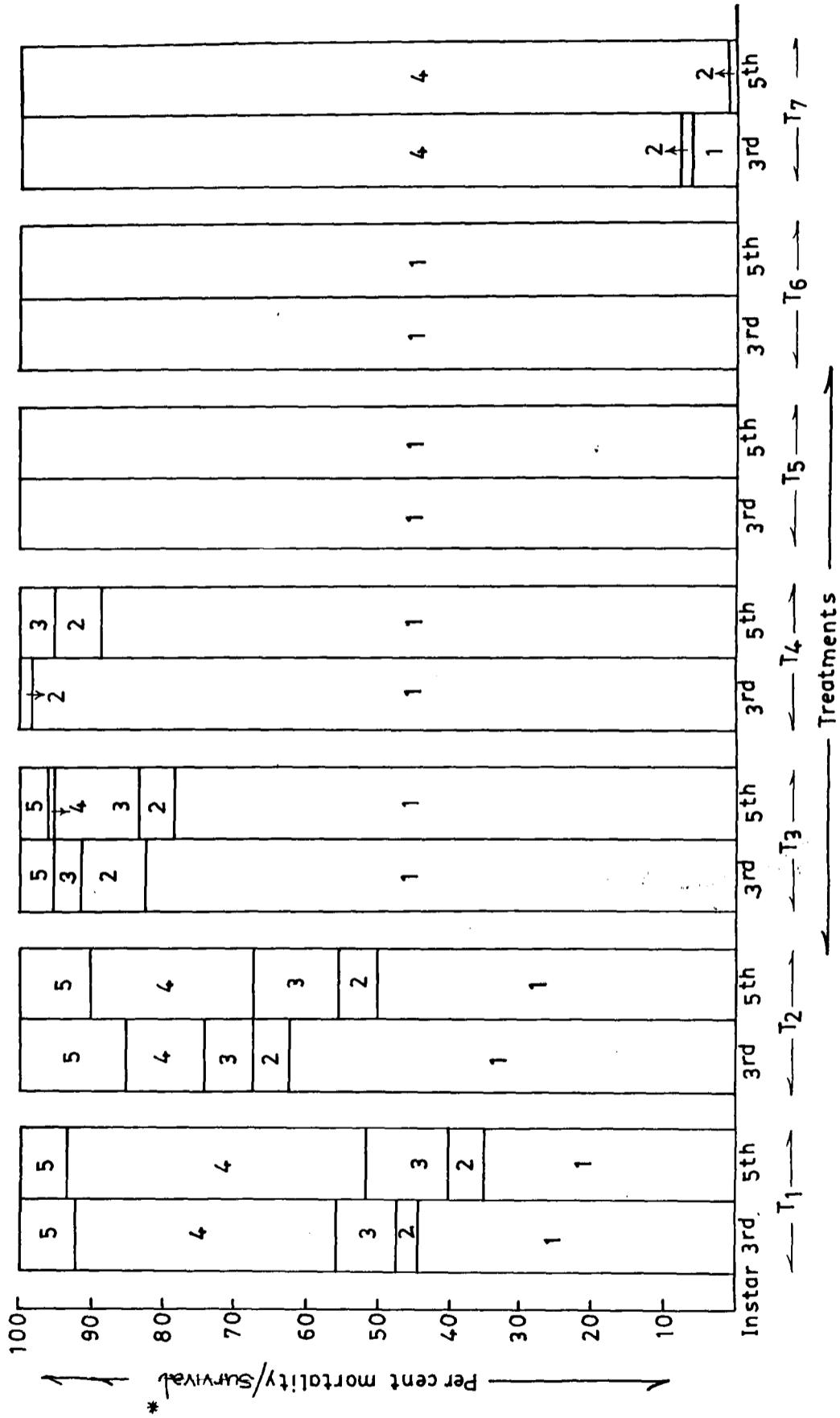


FIG.17.EFFECT OF DIFLUBENZURON ON THE DEVELOPMENT OF III AND V INSTAR LARVAE OF A.segetum.

- 1 Till pupation
- 2 Pupation to adult emergence
- 3 Normal adult emergence\*
- 4 Deformed adults

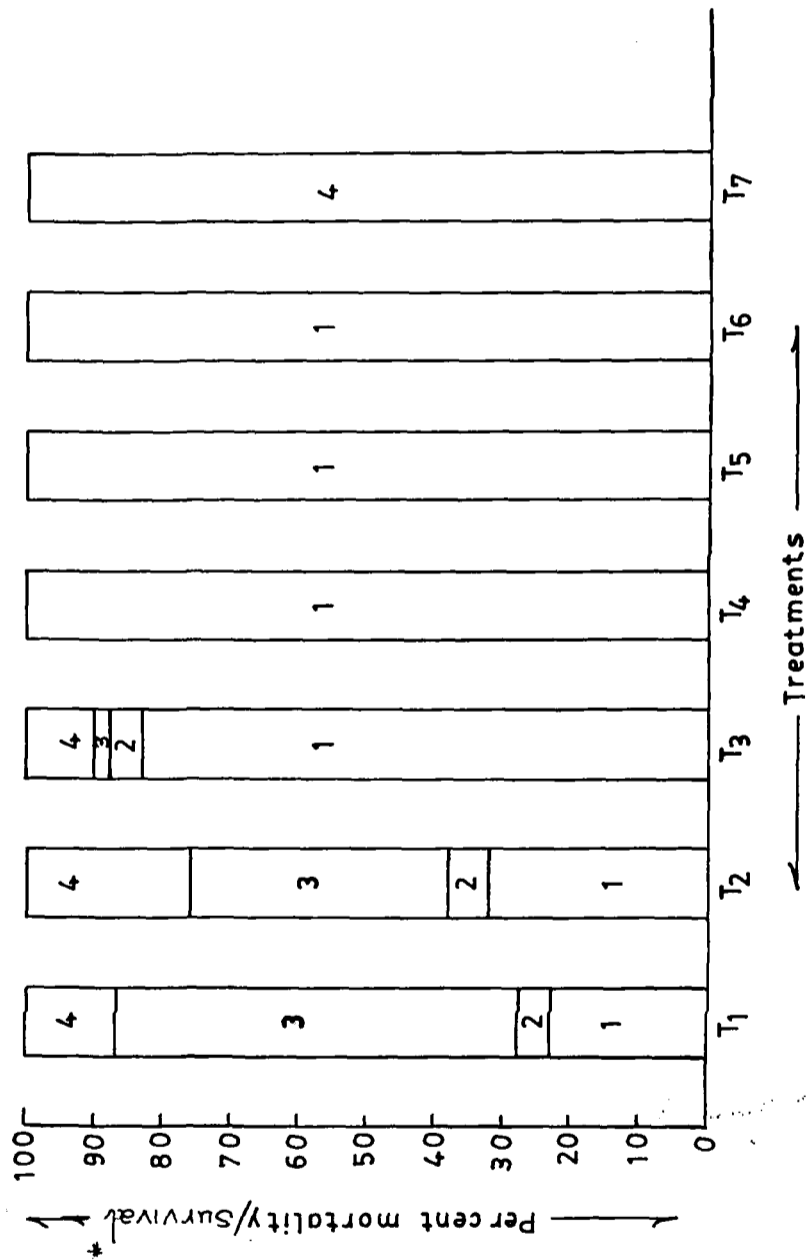


FIG. 18. EFFECT OF DIFLUBENZURON ON THE DEVELOPMENT OF VI INSTAR LARVAE OF A. segetum

regulator are progressive till the adult emergence. In contrast to 93.3 per cent normal adult emergence in the untreated check, only 35.6 and 11.0 per cent emergence was recorded when the III instar larvae were treated at 0.00025 and 0.00125 per cent. Conversely, deformed adults were higher at 0.00125 per cent than in the lower dosage. The same phenomenon was noticed in the other two instars too.

When susceptibility of the larvae to the compound among the three instars was compared, dosage required to cause 50 per cent mortality in VI instar was twice that on III and V instar. This infers that the amount of chemical required to cause death increases as larval age advances due to decreased susceptibility to the action of moulting inhibitors. Such observations have been documented by Rao and Reddy (1982 and 1984) in Dysdercus cingulatus Fabricius, Corcyra cephalonica Staint., S.litura and A.janata.

Lipa (1976) reported heavy mortality of A.segetum larvae due to Dimilin treatment at 2.5 to 25 ppm when the compound was orally administered with artificial diet. On the contrary, in the present study, to cause 50 per cent or more mortality in III and V instar, the dosage was to be increased by two to four times the highest dosage used by Lipa (1976). Apparent anomalies in the dosage could be due to the age of larvae, larval food and quantity of product

ingested. However, the reports of Balasubramanian et al. (1980) in H.armigera and Rao and Reddy (1984) in A.janata and S.litura indicate moderate to high mortality of the larvae at 2.5 to 250 ppm diflubenzuron. These results lend support to the current findings.

In the present study it was observed that in all the three instar groups of A.segetum there was no effect on the larvae until they entered apolytic stage, preceding actual shedding of the exuviae. At the time of shedding of old skin, the larvae were unable to undergo the normal ecdysis. The integument of affected larvae blackened just before death and during transformation from VI instar to pupa, morphological deformities in the form of larval-pupal intermediates were encountered. These observations are in full agreement with the findings of Suryasrinivas (1983) in groundnut leaf miner, Aproaerema modicella, (Deventer) Rao & Reddy (1984) in A.janata and S.litura, and Sundaramurthy (1980) in Opisina arenosella.

#### 5.12.1.3 Effect on pupae

Adult emergence was normal and cent per cent (Fig.19) in the untreated check and at lowest concentration (0.00025 % of diflubenzuron). From 0.00125 to 0.0075 per cent concentration, pupal development was affected resulting in

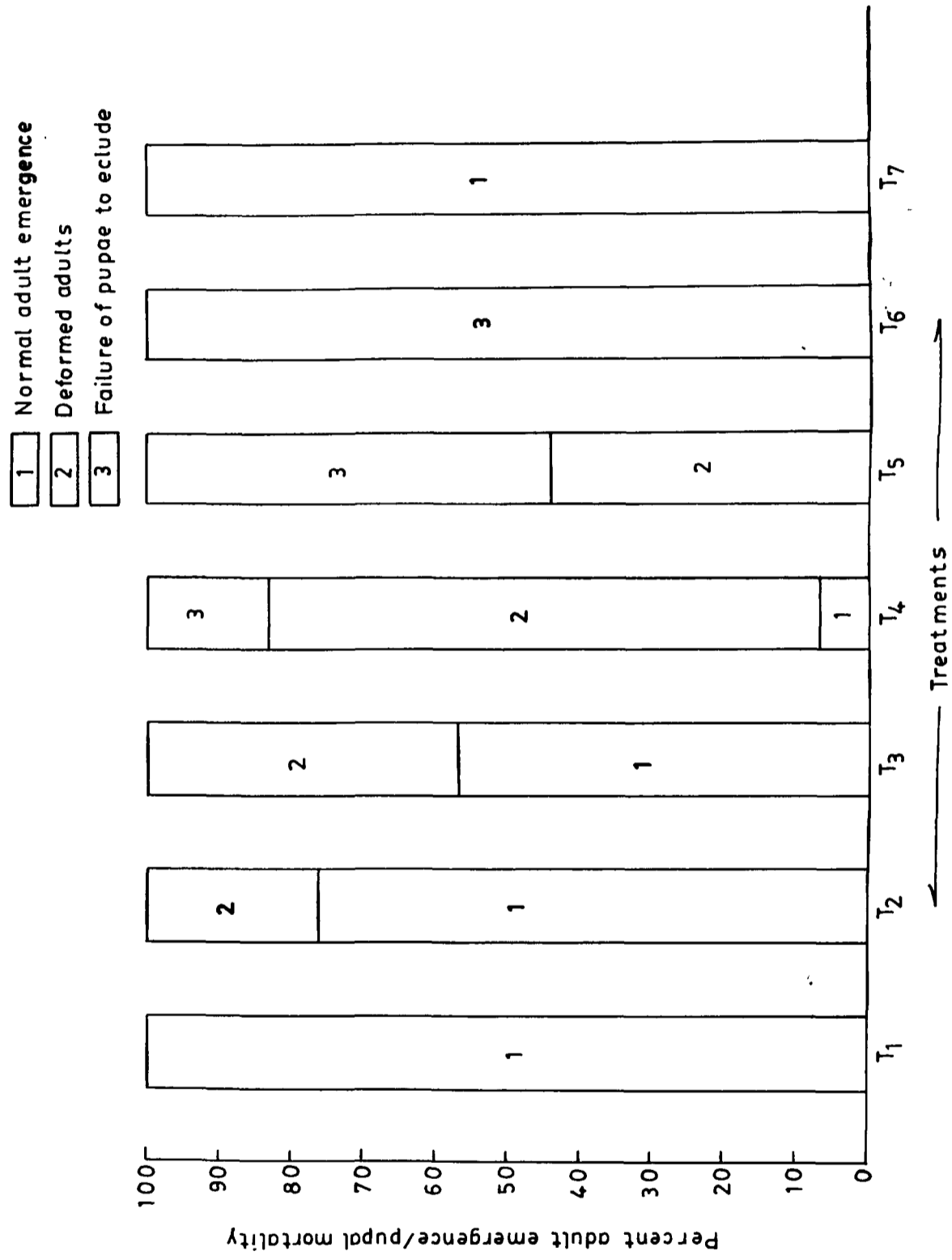


FIG.19. EFFECT OF DIFLUBENZURON ON THE PUPAE OF A. segetum

production of 23.3 to 76.6 per cent deformed adults which died subsequently. Conversely, with the increase in concentration beyond 0.0025 per cent, the pupal mortality increased without any emergence of adults. These findings are corroborated by Rao and Reddy (1984) who reported 23.3 to 100 per cent reduction in adult emergence of A.janata and S.litura from the topically treated pupae with Dimilin.

#### 5.12.2 Evaluation of insecticides

##### 5.12.2.1 Seedling damage

Yield reduction due to cutworms is attributed to the extent of damage to seedlings. The observation on seedling damage during 1983 and 1984 revealed significant difference among different chemical toxicants tested. All the toxicants tested were significantly superior to untreated control and similar observations have been made by several earlier workers (Chaudhary, 1953; Nirula, 1961; Thimmaiah et al., 1972; Babu et al., 1980; Thippeswamy et al., 1981b; Borah et al., 1982; Chavan, 1985 and Rajendran and Verma, 1989 etc.).

The seedling damage during 1983 (Fig.20) varied from 10.9 per cent to 39.3 per cent with highest damage recorded in control. Drenching endosulfan to soil around plants caused the cutworms to spare more of seedlings undamaged

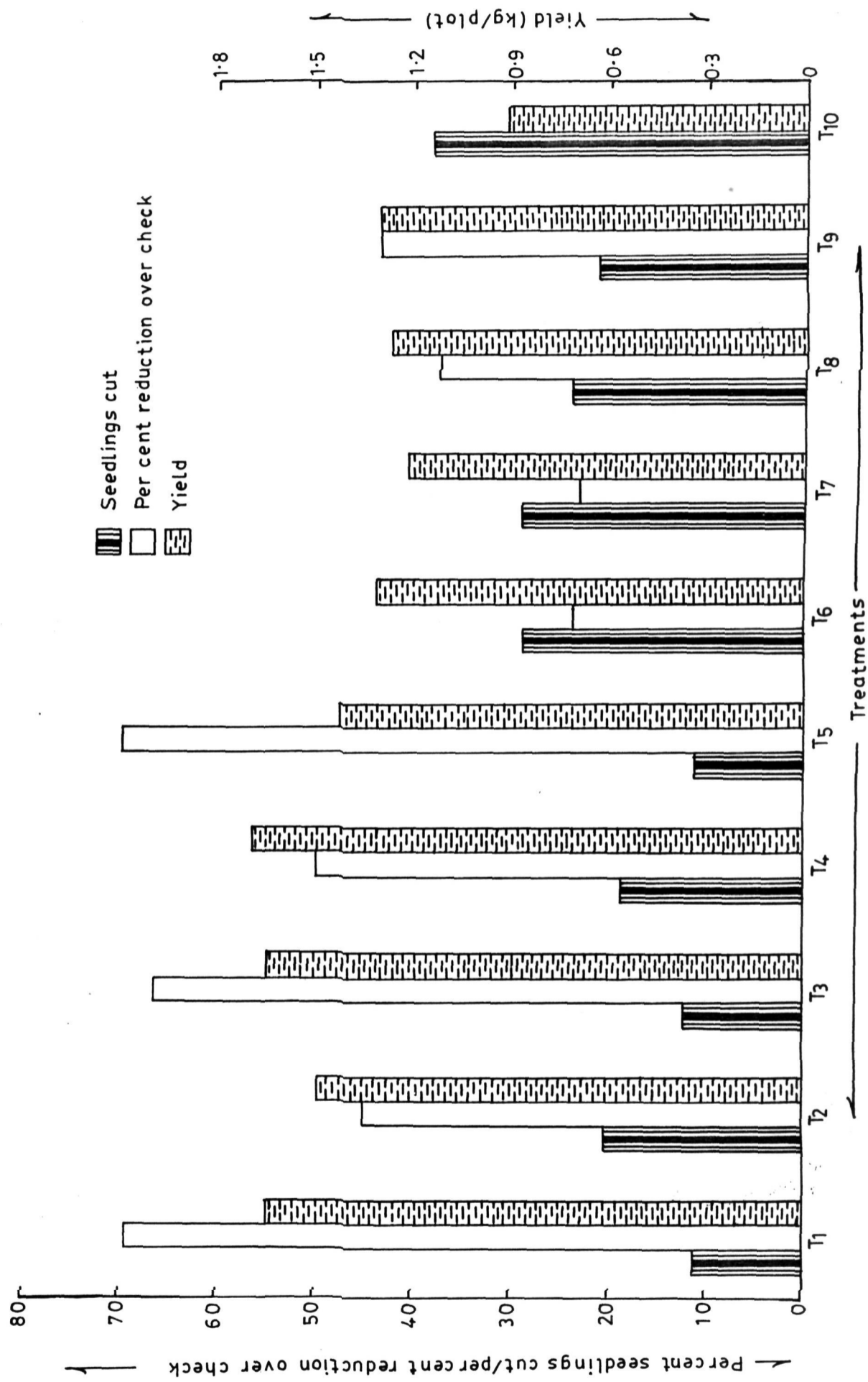


FIG.20.EFFECT OF INSECTICIDES IN THE SUPPRESSION OF CUTWORMS AND ON YIELD ( POOLED DATA FOR 1983 AND 1984 )

followed by quinalphos. In the order of decreasing effectiveness was monocrotophos, sevimol and phosalone which however, being at par, were significantly inferior to endosulfan. Neither the granular application of carbofuran and phorate on one hand, nor dusting with malathion or BHC afforded better protection to cotton seedlings from cutworms. The treatment efficacy was again confirmed in 1984 trial with minor variation (Fig.20).

The superiority of endosulfan drench over carbaryl in reducing the seedling damage in tobacco (Thimmaiah et al., 1972) over quinalphos, carbaryl and phosalone in potato (Rajendran and Verma, 1989) are in full agreement with the present results. However, at par effect of endosulfan and carbaryl in potato, according to Chandla et al. (1977) contradicts the present report.

Carbofuran and phorate granules, performing statistically better than dusts, were moderately effective in reducing the seedling damage in the present work. But, ineffectiveness of phorate granules in maize as observed by Rathore and Young (1975) is contrary to the present results. Similarly, Kumar et al. (1983) reported that dusts are more effective than all EC formulations tested except endosulfan. Superiority of endosulfan EC over dusts in the present study contradicts with the above where all dusts

tried were superior. Perhaps, low persistence of BHC, and Malathion dusts compared to cyclodiene dusts tested by the author may account for differential efficacy of dust formulation.

#### 5.12.2.2 Kapas yield

Analysis of pooled data from 1983 and 1984 experiments highlighted significant differences among the treatments. All the soil drench treatments recorded yield at par and significantly more than granules and dusts. The yield difference between untreated and treated plots (Fig.20) ranged from 0.28 kg to 0.74 kg per plot.

Endosulfan drenching which gave best protection registering 4.1 quintal more yield per hectare over untreated control is in close conformity with the report of Vaishampayan and Veda (1981) who harvested 7.9 q/ha seed yield of bengalgram, as compared to 1.6 q/ha in untreated control. Similarly, higher kapas yield recorded due to sevimol, quinalphos and monocrotophos drenching is in close agreement with the reports of Chandla et al. (1977), Rajendran and Verma (1989) and Chavan (1985) in potato and tobacco.

Kapas yield from plots receiving dusts and granular treatment did not differ; however, per cent increase over

control ranged from 29.1 in BHC dust to 36.5 in phorate granule as compared to the highest increase of 77.1 per cent in sevimol treated plots. About 17.4 per cent increase in potato yield due to phorate application, recorded by Alam and Ahmad (1975), is slightly less than the increase registered in the present work.

### 5.12.3 Evaluation of diflubenzuron as poison-bait (1985 kharif)

#### 5.12.3.1 Seedling damage

All the five chemicals including diflubenzuron in the form of bait were significantly superior to untreated control in lowering the seedling damage (Fig. 21). The diflubenzuron based baits at two dosages were intermediate in the efficacy with about 20 per cent damage, but were quite inferior to monocrotophos and endosulfan drenching and significantly superior over the rest of the toxicants. However, the baits performed statistically better than carbofuran granular application to soil.

The information available on the use of diflubenzuron bait in the control of cutworms is totally lacking, but the bait tried in the control of S.litura on sesbania by Gunashekar (1986) recorded 62.8 to 89.2 per cent reduction in larval population at dosage ranging from five to 50g a.i./ha.

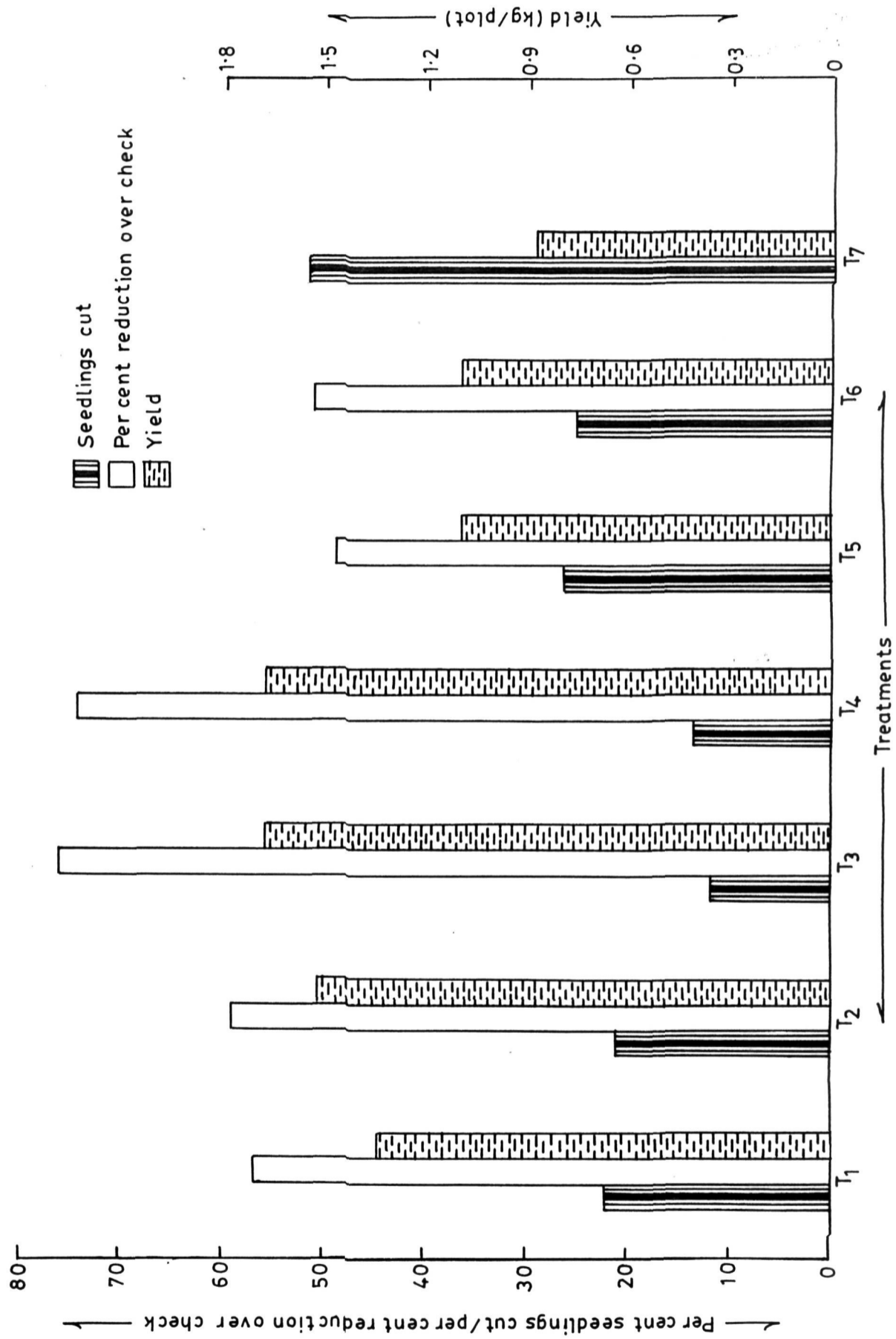


FIG.21.EFFECT OF IGR AND INSECTICIDES IN THE CONTROL OF CUTWORM AND YIELD.

However, in the present study, the bait was tested at 75.0 and 112.5 g a.i./ha. Based on this comparison, it may be said that the growth regulator can effectively be used as bait for spot application in the management of cutworms.

During 1985, undoubtedly drenching by endosulfan and monocrotophos was significantly effective in maximising the yield (Fig.21) followed by bait treatment which, however, was superior over carbofuran and phorate granules.

Shabolt (1983) recorded increased kapas yield with four to six sprays of diflubenzuron at 0.067 kg a.i./ha against the cotton boll weevil and Heliothis spp. Similarly, Balasubramanian et al. (1987) recorded an increase in kapas yield from 1310 kg to 1710 kg/ha due to the scheduled spraying of diflubenzuron against three species of bollworms. Biradar (1991) reported superiority of teflubenzuron in increasing the kapas yield over diflubenzuron.

#### 5.12.4 Diflubenzuron as soil drench

##### 5.12.4.1 Seedling damage

During kharif 1991, drenching diflubenzuron to soil at 100 and 150 g a.i./ha did not prove to be highly effective as reduction in seedling damage (Fig.22) was around 43 per cent. Similarly, diflubenzuron through bait was no better than

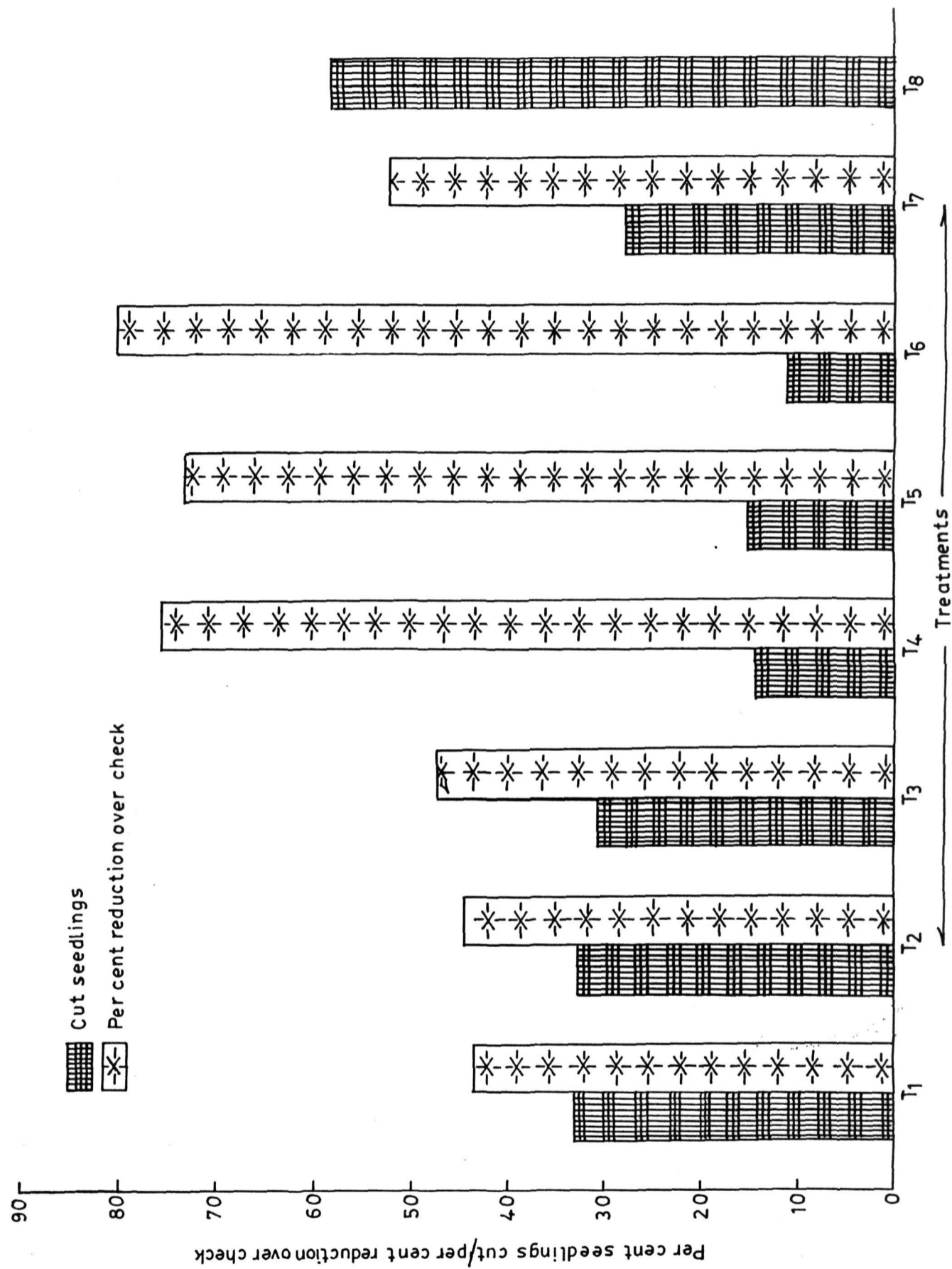


FIG.22.COMPARITIVE PERFORMANCE OF DIFLUBENZURON AND INSECTICIDAL TOXICANTS IN THE CONTROL OF CUTWORM.

drenching. Therefore, the method of treatment had no impact on the effectiveness of diflubenzuron. While, all the other insecticides viz., monocrotophos, endosulfan and methomyl were superior to diflubenzuron, BHC dust yielded as much as in diflubenzuron based poison-bait.

The information on efficacy of diflubenzuron in field scale in the control of cutworms is very scanty. Mokrousova (1977) recorded 30 to 40 per cent mortality of larvae of A.ipsilon and A.segetum on different host plants when sprayed with diflubenzuron at 0.1 to 0.01 per cent concentration under field conditions. Szatmari et al. (1978) tested the relative efficacy of the compound in the control of A.ipsilon on maize. The moult inhibitor has been used considerably in the control of other pests. While, Radwan and Rizk (1975) recorded 62.6 per cent reduction in boll damage by spotted and pink bollworms, cent per cent mortality of larvae of O.arenosella was recorded on coconut by Sundaramurthy (1980). Rabindra and Balasubramanian (1981) obtained 96 to 100 per cent control of A.janata on castor through spray at 1.0 g per litre of water. Similarly, spraying diflubenzuron significantly reduced the larval population and damage by H.armigera on chickpea (Sinha and Mehrotra, 1988).

Poor control of Pectinophora gossypiella (Saund.) (Flint et al., 1977) and cotton sucking pest complex (El-Nawawy et al., 1981) are

also on record but these findings are not comparable, since the site of application and feeding habits of pests under study are entirely different.

#### 5.12.5 Cost : Benefit ratio

The ratio was worked out for the commercial products available during the test period. The monetary return derived for every rupee spent in the control operation is the ultimate factor in choosing a particular toxicant in the control operation. Despite the poor efficacy in reducing the damage, BHC and malathion dusts were the most economical with a ratio of 1:5.16 and 1:5.5, respectively. This was obviously due to the low chemical and operational costs. Sevimol (1:2.65), endosulfan (1:2.61) and phosalone (1:1.91) were the next from the point of economics. Saxena and Rawat (1968) recommended BHC dust in the control of cutworms on wheat crop owing to its relative efficacy, persistent effect and low cost of control operation and this recommendation is in conformity with the present observation based on C B ratio.

The soil drenches, which gave an excellent control of the pest by reducing the seedling damage and increasing the yield significantly, proved to be expensive (Rs.921.85 to Rs.1681.25 per ha) compared to BHC (Rs.195/ha) and malathion

(Rs.255/ha). For maximization of yield though endosulfan was best, BHC dust appeared to be most acceptable for reducing the cost of plant protection and aiming higher returns for investments made.

From the foregoing discussion, the following findings have been brought out for the first time which are new to science :

1. Agrotis segetum (Dennis & Schiffermuller) has been recorded on cotton for the first time and as a principal species of cutworm from the transitional zone of North western Karnatak. The study also revealed that A.segetum is the dominant species of cutworm in different crop ecosystems of the region which is contrary to the previous reports, where in A.ipsilon (Hufnagel) was reported to be the only concerned species. Competitive displacement of A.ipsilon by A.segetum in different crop ecosystem has been a possible reason.
2. Evening relative humidity, minimum temperature and wind velocity influence the mothflight greatly.
3. Relationship between pest density and crop loss was estimated through regression models which help decide in imposing control measures.
4. Larval preference under free-choice condition and host suitability studies have opened new vistas in evolving an effective strategy in the management of pest, for e.g., use of safflower and cowpea which were favoured hosts next to cotton as trap-crops in protecting cotton.

**CHAPTER - VI**

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**SUMMARY**

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## VI. SUMMARY

Investigations on the species dynamics, biology and behaviour, crop loss, host plant interaction and control of cutworms, Agrotis segetum and A.ipsilon on cotton were undertaken at the Main Research Station and in the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad from 1983 to 1986 and in 1990-91.

Both A.segetum and A.ipsilon co-occur on a variety of field and horticultural crops in north-western region of Karnataka comprising Dharwad, North Kanara and Belgaum districts. Of the two, A.segetum was the principal species with 88.4 per cent (mean of five localities) of the field collected larvae belonging to it. While A.segetum was the most predominant species (96.8% of larvae) on cotton, it was the only species on groundnut, onion, cowpea, greengram and bengalgram. It was most dominant in cabbage (96.2%), safflower (93.8%), chillies (87.4%) and potato (75.8%). On the contrary, A.segetum and A.ipsilon infested amaranthus almost equally, while the proportion of these species on soybean was 2 : 1.

The life history of the pest species, A.segetum and A.ipsilon was studied on cotton. Moth laid eggs singly and often in small groups on soil, seedlings and the larval

exuviae. Eggs were incubated for 4.3 and 3.3 days in A.segetum and A.ipsilon, respectively. Larvae moulted five times in A.segetum and both five and six times in A.ipsilon from the same batch of eggs. Larval growth was completed in 28.9 days in A.segetum as against 32.3 days in pentamoulter and 38.2 days in hexamoulter of A.ipsilon. The pre-pupa was characterised by shrunk body with shortened length and deeply constricted intersegmental area and it lasted for 2.3 and 2.5 days in A.segetum and A.ipsilon, respectively. Pupation took place in earthen cell but seldom was naked and the stage occupied from 13.2 to 14.1 days in A.ipsilon and A.segetum, respectively. The total life cycle of the latter occupied 49.6 days (40 to 59 days) as compared to 51.3 days (41 to 64 days) in pentamoulter and 57.2 days (47 to 70 days) in hexamoulter of former species.

Moth emergence was restricted to night hours. The moths of two species could be distinguished based on spots on the wings. Survival period of adults in the presence of food was 10.1 and 11.9 days in A.segetum and 9.8 and 10.3 days in A.ipsilon male and female, respectively. The longevity was reduced in the absence of food. Female to male ratio was 1 : 1.5 and 1 : 2.0 in A.segetum and A.ipsilon, respectively. After a pre-oviposition period of 3.1 and 3.6 days, moths laid eggs over a period of 4.6 and 5.0 days in

A.segetum and A.ipsilon, respectively. The average fecundity per female was 987.4 (A.segetum) and 937.8 (A.ipsilon). The rate of egg laying was high during first half of oviposition period. Sexual dimorphism is distinct in both the species in the pupal and adult stages.

In the laboratory both the species of cutworms could be reared throughout the year. The mean development period ranged from 45.9 days in February-April to 51.5 days in November-December and 47.0 days in February-April to 50.7 days in September-November in A.segetum and A.ipsilon, respectively. A continuous observation on occurrence of larvae of different stages in the field coupled with rearing of field collected larvae at different times indicated completion of four overlapping generations from June to January and there onwards the pest activity declined in nature.

List of natural enemies included three species of parasitoids, a predator and a NPV virus apart from three fungi. Among these, Apanteles ruficrus (Braconidae) was the dominant parasitoid encountered on the larvae.

Both the species of cutworms exhibited cannibalistic behaviour. The rate of cannibalism was quite high (72.0 and 29.0%) in the absence of food. Agrotis ipsilon was more

cannibalistic than A.segetum and rate of cannibalism in the former was significantly higher (44.7%) than in latter (17.4%).

Light trap catches revealed high moth activity during kharif and early part of rabi seasons. Activity of moth was stretched from July to October reaching peak during September followed by August. Minimum temperature ( $r=0.18$ ), morning relative humidity ( $r=0.31$ ) and evening relative humidity ( $r=0.37$ ) exhibited significant and positive influence on moth catches, whereas the effect of maximum temperature was significantly negative ( $r=-0.23$ ). Multiple regression analysis of data indicated that evening relative humidity, minimum temperature and wind velocity had a greater influence on moth flight.

On the basis of yield obtained from differentially infested plots due to imposition of different treatments, the avoidable kapas yield loss computed over untreated control in the mechanically controlled, carbofuran applied and endosulfan drenched plots was 24.3, 29.3 and 49.7 per cent respectively. The correlation between number of cut seedlings and kapas yield was negative and significant ( $r=-0.84$ ) and predicted that yield is reduced by 15.6kg/ha(0.025kg/plot) for every unit per cent increase in cut seedlings.

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There was a progressive increase in the extent of damage (number of seedlings cut) with the increase in larval number. The extent of damage varied from 33.7 to 156.7 seedlings for two and 12 larvae per plot, respectively during 15 days destructive period by IV instar larva. The correlation between the number of larvae and cut seedlings was positive and significant ( $r=0.97$ ) and the number of cut seedlings per plot increased by 12.37 times for every increase in one larva. The estimated correlation between the larval number and yield was negative and significant ( $r=-0.98$ ). The yield was reduced by 52.65 kg per ha (0.09 kg/plot) for every increase in one larva.

Where there is choice, larvae showed preference for younger seedlings and percentage of 1 to 7 days old seedlings cut (72.2 to 80.8%) was significantly higher than in 8 to 15 days old seedlings (19.2 to 27.8%). The studies on the pattern of feeding revealed both complete and partial consumption of the cut seedlings. About 50 per cent of the cut seedlings were consumed partially and the relation between larval number and consumption pattern was positive and significant. Regression analysis of data indicated increase in the complete and partial consumption by 5.38 and 7.07 times for every increase in one larva.

Fourth, V and VI behaved as true cutting instars and I and II instars as scraping instars, while III instar was intermediate.

Irrespective of the nearness of food from the release point (0 to 2 m), the larvae reached the seedlings and damaged them within 12 hours. Thus the movement was influenced by the availability of food than distance. However, the dispersal pattern in general was random. The mean distance travelled increased with the increase in the distance between release point and availability of seedlings. Similarly, the extent of damage decreased with decrease in the number of hills in different treatments.

Among the 10 hosts studied, cotton was most preferred (26.8% cut seedlings) followed by safflower (12.5%), cowpea (12.2%) and chillies (9.6%). Maize (2.9%), soybean (3.6%) and wheat (1.5%) were least preferred.

In the laboratory, A.segetum passed through six instars on all the hosts. Potato permitted the insect to complete life-cycle in a shortest period (46.1 days) and maize in longest period (62.4 days). The developmental period from egg to adult emergence was 48.1 days on cotton but the growth index was maximum on potato (3.6) followed by cotton (3.4) and minimum on maize (1.3). All the larvae reached adult stage on cotton, potato, safflower as against

only 40.0 per cent on maize. On maize, least suitable host, proportion of mortality in the larval stage (46.7%) was higher than in pupal stage (25.3%). Moths reared on cotton laid highest number of eggs (950) vis-a-vis on wheat (591).

Diflubenzuron tested for its moult inhibiting effects on different stages of A.segetum elicited ovicidal, larvicidal and pupicidal effects inducing various morphological deformities. The compound inhibited egg hatch from 2.0 at 0.00025 per cent concentration to 64.0 per cent (0.0125%) in one day old eggs. At higher concentrations (0.005 to 0.0125%), mortality of larvae was noticed within 10 days after treatment, while at lower concentrations it was extended beyond the pupal stage. The mortality of the larvae was cent per cent from 0.005 per cent concentration onwards and it occurred just before actual shedding of the exuviae. In the treated pupae, the adult emergence was almost normal at lower concentrations and from 0.00125 per cent concentration onwards deformed adults (23.3 to 76.6%) emerged, while the pupae failed to eclose into adults from 0.005 per cent concentration onwards.

In the field trial, soil drenching was superior to dust and granular formulations in reducing the cutworm damage and increased the kapas yield. Diflubenzuron as poison-bait gave moderate control of the cutworms, and as

soil drench its performance was poor. The pooled data (1983 and 1984) of chemical toxicants indicated the increase in kapas yield from 50.0 to 77.2 per cent with endosulfan, sevimol, monocrotophos, quinalphos and phosalone soil drench, 33.3 to 36.5 per cent in two granular insecticides and 29.2 to 36.5 per cent in dusts over the untreated check.

BHC and malathion dusts proved to be most economical with a return of Rs.5.2 and Rs.5.5, respectively, for every rupee spent. Cost benefit ratio for sevimol, endosulfan and phosalone was 1:2.7, 1:2.6 and 1:1.9, respectively.

FUTURE LINE OF WORK

1. Survey work has to be intensified to include more locations and increase frequency of visits to confirm the competitive displacement of A.ipsilon by A.segetum. If the displacement phenomenon is confirmed, identification of limiting resource factors for occurrence of such phenomenon would be a great contribution to science. Study over a longer duration needs to be taken up to ascertain the role of abiotic components, specially climate in causing the swing in the species composition.
2. Use of highly preferred hosts of low commercial value as intercrops/trap crops in order to save the main crop of high commercial value.
3. Using dispersal behaviour of larva as a key, formulating different modified strategies of soil drenching such as drenching of alternate rows, alternate plants, random spots, so that cost of control is reduced.
4. Investigations on low cost control strategies viz., poison-baits, fermented baits for adult trapping, and field scale utilization of natural enemies such as Apanteles ruficrus and NPV.

**CHAPTER - VII**

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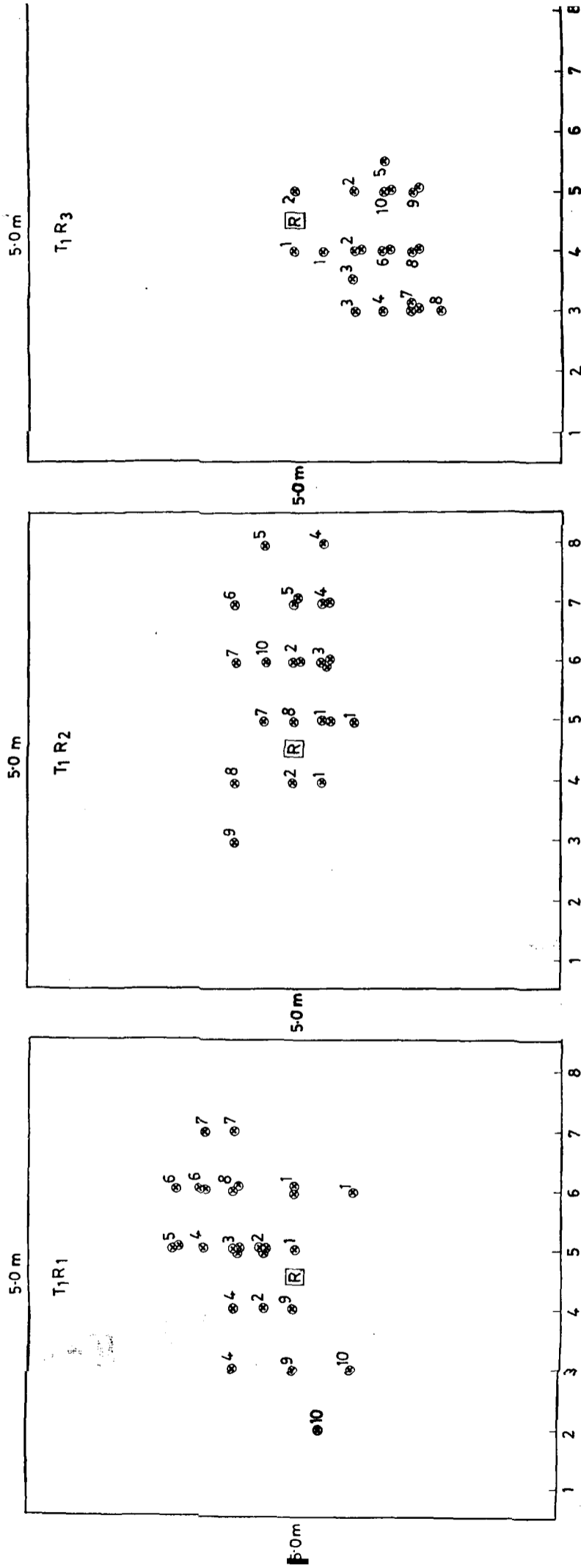
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## APPENDICES

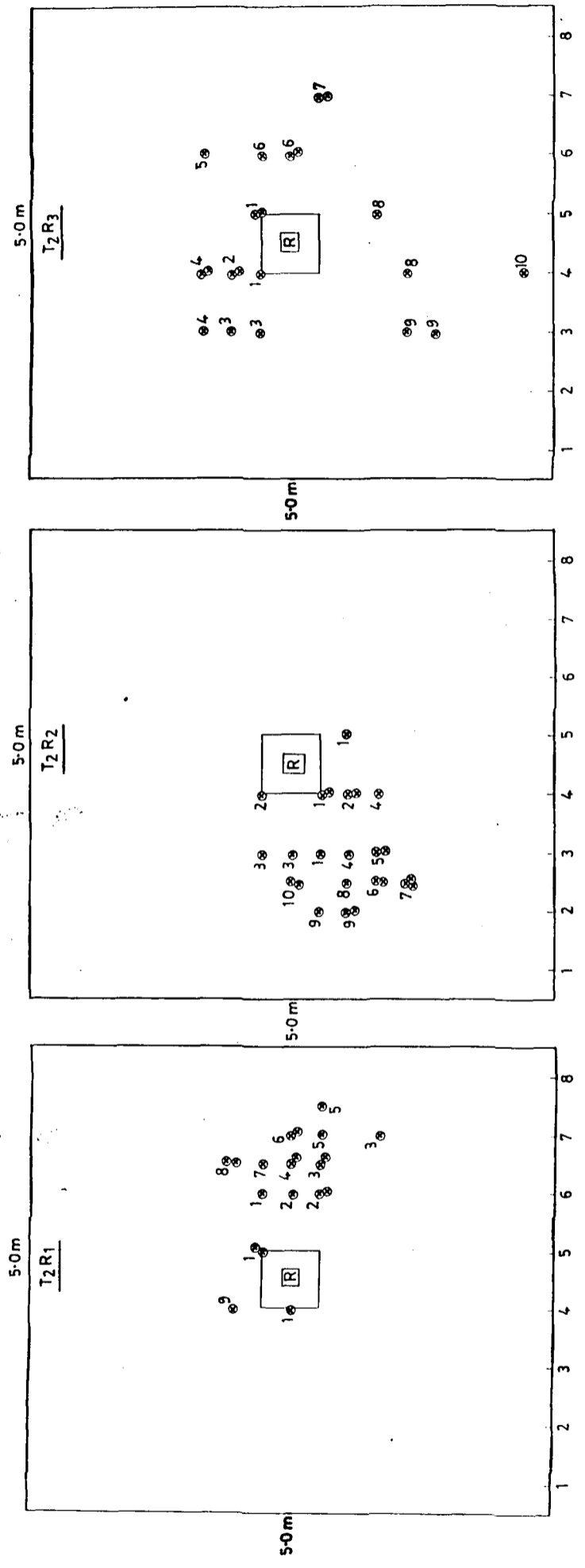
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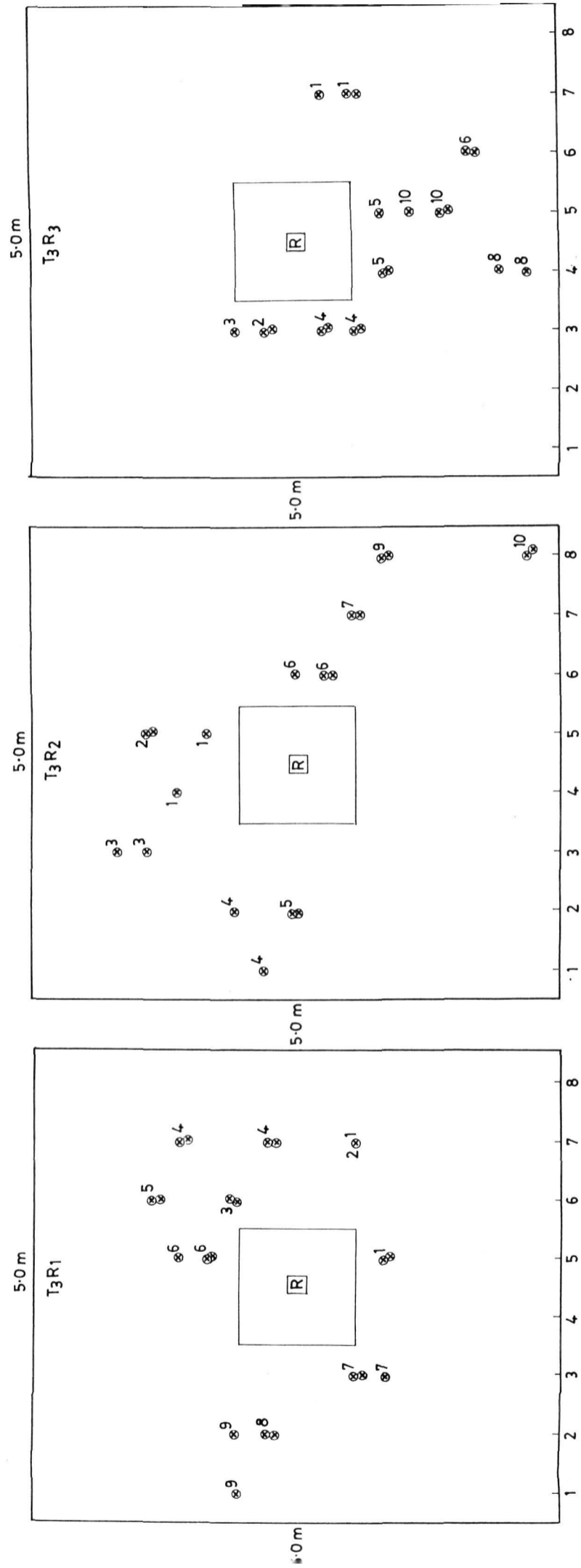
(Numbers within each block with 'e' sign refer to the seedling/(s) cut on that day after the release)



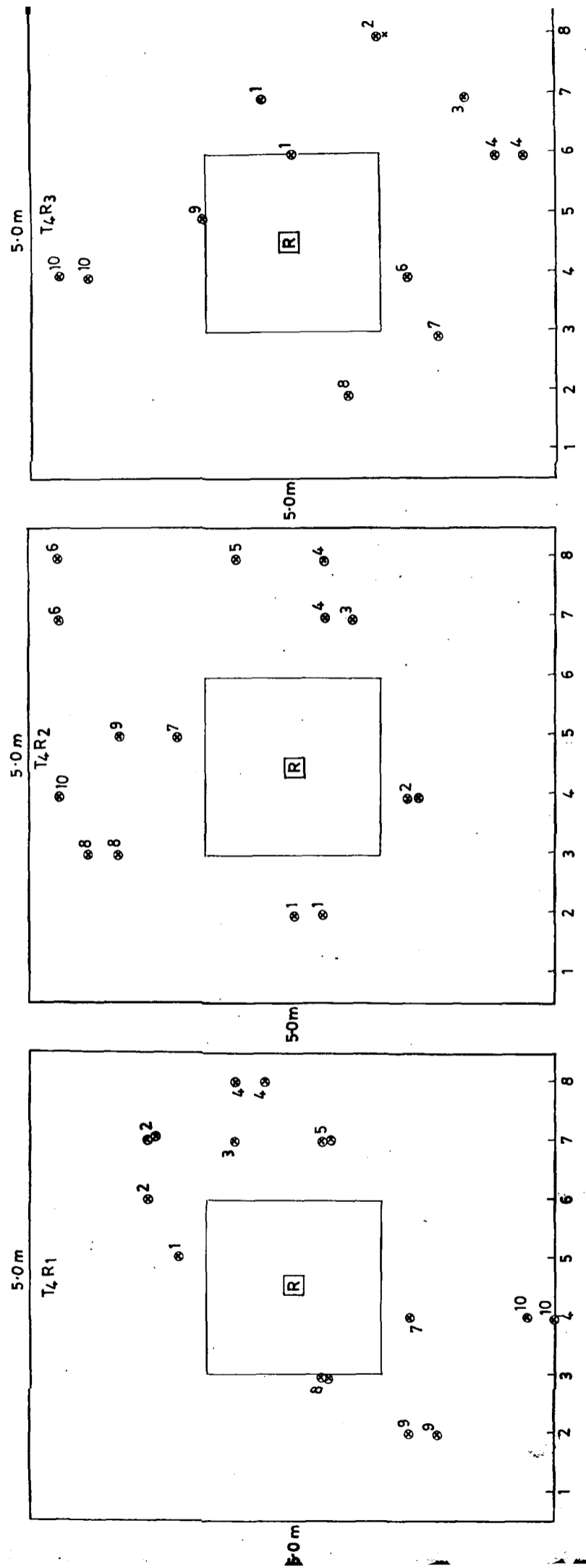
APPENDIX 1. DISPERSAL BEHAVIOUR OF A. segetum LARVA IN COTTON(T<sub>1</sub>).



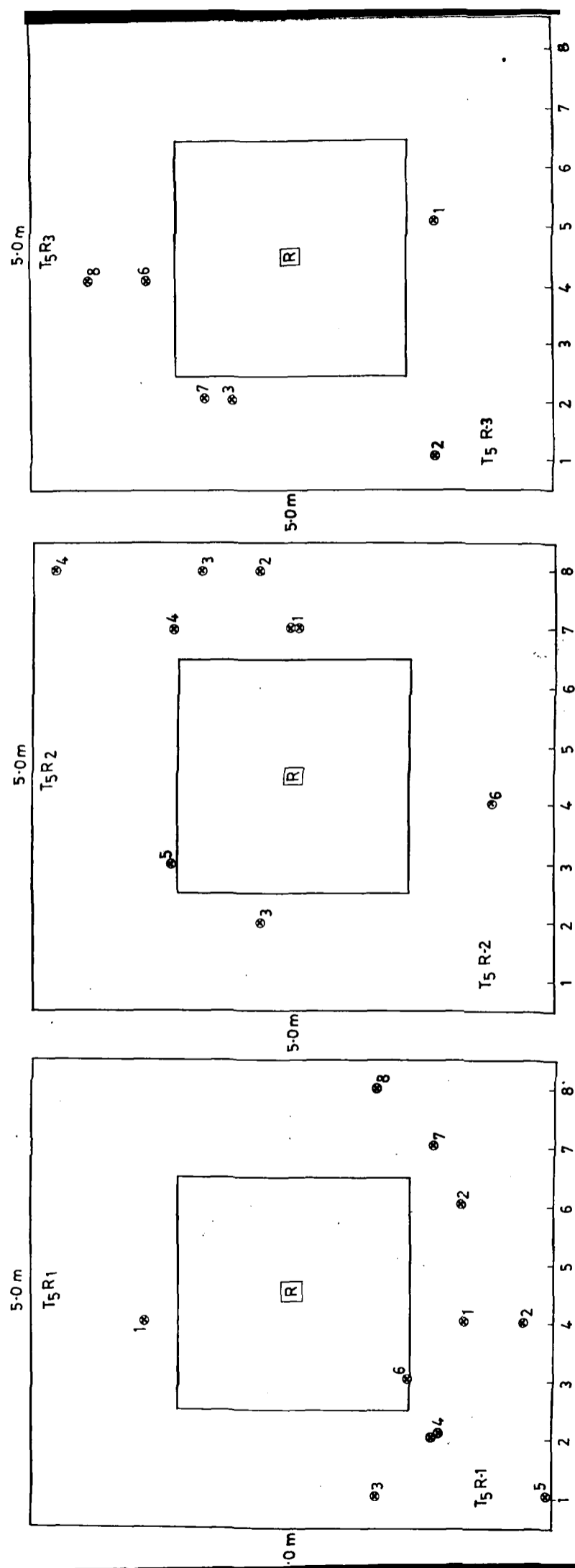
APPENDIX 2. DISPERSAL BEHAVIOUR OF A. segetum LARVA IN COTTON (T<sub>2</sub>).



APPENDIX 3. DISPERSAL BEHAVIOUR OF A. segetum LARVA IN COTTON (T<sub>3</sub>).



APPENDIX 4. DISPERSAL BEHAVIOUR OF A-segetum LARVA IN COTTON (T4).



APPENDIX 5. DISPERSAL BEHAVIOUR OF *A. segetum* LARVA IN COTTON (T5).

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ಗಾ.ಕ.ನಿ.ಕೆ, ಬೆಂಗಳೂರು-65  
- 5 JAN 1996  
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