BIOMETRICAL ANALYSIS AND BIO-ECOLOGY OF *Spodoptera litura* Fabricius ON DIFFERENT HOSTS ALONG WITH ITS MANAGEMENT IN CASTOR

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BY
AJAY B. MAGHODIA
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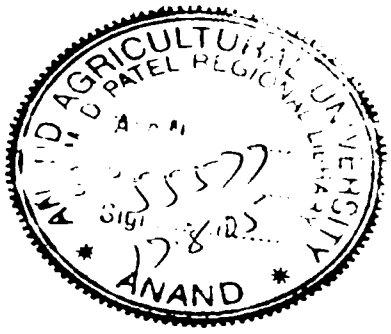

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
B. A. COLLEGE OF AGRICULTURE
ANAND AGRICULTURAL UNIVERSITY
ANAND – 388 110 GUJARAT (INDIA)

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TO MY

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PARENTS

&

DR. D. J. KOSHIYA SIR

Abstract

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NAME OF STUDENT
AJAY B. MAGHODIA

MAJOR ADVISOR
DR. D. J. KOSHIYA

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
B. A. COLLEGE OF AGRICULTURE
ANAND AGRICULTURAL UNIVERSITY
ANAND-388 110

ABSTRACT

Investigations were carried out on biometrical analysis, bio-ecology and management of *S. litura* at B.A. College of Agriculture, Anand Agricultural University, Anand during the year 2003-04 and 2004-05.

Studies on biometrical analysis were carried out to test the applicability of Dyar's Law to the larvae of *S. litura*, reared on five different hosts. The measurements of head capsule width (mm) of the larvae fall into six well defined groups, when the larvae were reared on castor, tobacco, groundnut, cotton and cabbage at a constant temperature of 27 $\pm$ 1 °C. These groups evidently characterized as an instar. The progression factor revealed that the increase in head width during successive instar follows the Dyar's Law, when the larvae were reared separately on different hosts under

study. The progression factors determined from the body length and body width indicated the great deviation to provide any support for the theory suggested by Prazibran and Megusar (1912).

Biological observations indicated that the incubation period ranged from 3.23 to 3.53 days on different hosts under study. Larval period varied from 18.00 (castor) to 23.63 (cotton) days. The mean percentage of survival on different hosts ranged from 80.00 to 86.67 per cent and were at par on these hosts. The longest prepupal period (2.33 days) was observed on cotton and the shortest (2.07 days) on castor. The results on per cent pupae formed on different hosts revealed that it was the highest (87.50 %) on castor and the lowest (72.50 %) on cotton. Considering the growth index values the hosts can be arranged as: castor > tobacco > groundnut > cabbage > cotton.

The pupal period varied from 9.10 (castor) to 9.47 (cotton) days and did not differ significantly, when the larvae were reared on groundnut, cotton and cabbage.

The maximum number of eggs was recorded on castor (2269.25) whereas it was the lowest on groundnut (1591.58).

A study on population dynamics of *S. litura* revealed that the pest first appeared on castor during first week of October and remained active throughout the crop season. The highest population was recorded

during first week of December. Correlation between the population and weather factors (WF) was worked out. The study indicated that among the different physical factors of environment, wind speed (WS) showed significant negative correlation indicating that population of this pest increased with decrease in WS. Among the other factors, minimum temperature (MinT), mean temperature (MT), morning and evening vapour pressures and evening relative humidity (RH_2) showed negative correlation with the pest.

Results on investigations on life fecundity tables of *S. litura* on castor, tobacco, groundnut, cotton and cabbage revealed that maximum expectancy of newly deposited eggs was on cabbage followed by castor, tobacco, cotton and groundnut. On the basis of reproductive potential (Ro), the host can be arranged in descending order as: castor > cotton > groundnut > cabbage > tobacco. The mean length of generation was maximum on cotton followed by cabbage, tobacco, groundnut and castor. The intrinsic rate of natural increase in number (rm) ranged from 0.148 to 0.174 females per female per day on respective host. Thus, considering the values of rm, the hosts can be arranged as: castor > groundnut > tobacco > cabbage > cotton. The finite rate of increase in number (λ) ranged from 1.161 to 1.192 females per female per day on different hosts. The

population on reaching a stable age distribution comprised of approximately 99 per cent of immature stages.

A study on field life tables on this crop clearly indicated that among the various mortality factors, a larval parasite, *Apanteles beneficus* Viereck and NPV were found to be effective in causing suppression in pest population.

A field study on evaluation of different newer insecticides for the control of *S. litura*, treatment with indoxacarb 0.015, alphamethrin 0.0075, quinalphos 0.05 and profenophos 0.05 per cent proved to be the most effective in controlling *S. litura*. It has been further observed that among the biopesticides, *Bt* was found to be the best treatment for managing this pest, whereas NSKS 2 per cent found least effective. Yield data clearly indicated that plots treated with indoxacarb 0.015 per cent registered the highest (2199.07 kg ha^{-1}) followed by alphamethrin 0.0075 (1907.58 kg ha^{-1}) and quinalphos 0.05 per cent (1620.37 kg ha^{-1}). Considering economics and efficacy of the treatments, alphamethrin 0.0075 (1:23.15) and quinalphos 0.05 per cent (1:16.37) gave appreciable incremental cost benefit ratio (ICBR). Thus, these insecticides can be recommended for the management of *S. litura* on castor crop.

Dr. D.J. Koshiya
Associate Director of Research
Anand Agricultural University
Anand-388 110
Gujarat, INDIA

CERTIFICATE

This is to certify that the thesis entitled **BIOMETRICAL ANALYSIS AND BIO-ECOLOGY OF *Spodoptera litura* Fabricius ON DIFFERENT HOSTS ALONG WITH ITS MANAGEMENT IN CASTOR** submitted by **Shri Ajaykumar Bhagvanjibhai Maghodia** in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** in **Agricultural Entomology** of the Anand Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision. The thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Anand
Date : July 18, 2005

(D.J. Koshiya)
Major Advisor

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ANAND *(AJAY B. MAGHODIA)*

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Introduction

I. INTRODUCTION

Castor, *Ricinus communis* L. belonging to family Euphorbiaceae is one of the most important and valuable oilseed crops. The crop is grown in tropical and sub-tropical regions of the world under varying soil types and eratic monsoon pattern due to its drought tolerance habit. The crop is cultivated in about 30 countries including India. The major castor growing countries are Brazil, India, China, Thailand, Russia and U.S.A. The world production of castor seed is about 1.1 million MT from 1.3 million hectares with an average yield of 0.9 MT/ha (Anonymous, 1998). In India, the crop is grown in about 585 thousand hectares, producing 428 thousand tonnes of seeds with productivity of 730 kg/ha (Anonymous, 2003). It plays a vital role in economy of Indian agriculture, industry and export trades. The crop is also important in earning substantial foreign exchange through export of castor oil. The oil is major product from seeds and is mainly used as a lubricant because of its property to remain liquid at very low temperature (-32 °C), high density and viscosity. It is also used in production of paints and varnishes, lacquers, sulfonated oil, artificial leathers, lubricants and greases, hydraulic fluids, cosmetics, soaps, printing ink, linoleum and oil cloth. It also serves as a row material

of various important chemicals. Further, its cake is excellent manure containing 6% N_2, 2.5% P_2O_5 and 1.5% K_2O (Anonymous, 1999).

Adoption of high yielding castor hybrids by farmers helped in boosting the yield from 470 kg per hectare (before release of hybrids in 1967-68) to 1580 kg per hectare (1995-96) in Gujarat (Anonymous, 1997). Thus, in Gujarat, the castor is grown in almost all the districts of the state in about 242.20 thousand hectares and producing 283.10 thousand tonnes castor seeds with a productivity of 1169 kg/ha (Anonymous, 2003).

The crop is found to be attacked by various insect pests during its different life stages resulting in yield loss of about 14.36 to 71.9% (Anonymous, 1999). According to Patel *et al.* (1970) the following major pests were observed to attack on castor crop in Gujarat.

Sr. No.	Name of the Pest	Damaging Stage	Nature damage
1.	Semi looper, *Achaea janata* Linnaeus	Larva	Defoliation
2.	Castor capsule borer, *Dichocrocis punctiferalis* Guenee	Larva	Bore the shoots and capsules
3.	Leaf eating caterpillar, *Spodoptera litura* Fabricius	Larva	Feed on leaves
4.	Leaf hoppers, *Empoasca flavascens* Fabricius	Nymphs and adults	Suck the sap from the leaves
5.	Thrips, *Scirtothrips dorsalis* Hood	Nymphs and adults	Suck the sap from the leaves
6.	White flies, *Trialeurodes ricini* Misra	Nymphs and adults	Suck the sap from the leaves
7.	American serpentine leaf miner, *Liriomyza trifolli* Bur	Maggots	Mines the leaf
8.	Red Spider mite, *Tetranychus telarius* Linnaeus	Nymphs and adults	Scarify foliage making webs under severe infestation
9.	Red hairy caterpillar, (i) *Amsacta albistriga* Walker (ii) *A. moorei* Boisd	Larva	Defoliation
10.	Castor hairy caterpillar, *Euproctis lunata* Walker	Larva	Defoliation

Sr. No.	Name of the Pest	Damaging Stage	Nature damage
11.	Hairy caterpillar, *Pericallia ricini* Fabricius	Larva	Defoliation
12.	Surface grass hopper, *Chrotogonus trachypterus* B.	Nymphs and adults	Cut young plants
13.	Termite, *Odontotermes obesus* Ramb	Adults	Cut roots and bore the stem
14.	White grub, *Holotrichia consanguinea* Blanch	Grub	Cut roots and bore the stem
15.	Bihar hairy caterpillar, *Diacrisia obligua* Walker	Larva	Defoliation
16.	Cutworm, (i) *Agrotis segetum* (D & S) (ii) *A. ipsilon* F.	Larva	Cut young plants
17.	American bollworm, *Helicoverpa armigera* Hubner	Larva	Feed on leaves

Of the various insect pests attacking the castor crop, leaf eating caterpillar, *Spodoptera litura* Fabricius is a serious pest causing economic damage. It being polyphagous in nature feeds on about 112 cultivated crops (Moussa *et al.*, 1960), of which 50 cultivated species were reported in India (Lefroy, 1908). It is reported as a severe pest of important crops including castor, cotton, groundnut, tobacco, chillies, coriander, cabbage, jute, cauliflower, gingelly, soybean, cowpea, onion, brinjal, banana, watermelon, okra, pigeonpea, lettuce, papaya, sweet potato, mulberry, maize and turmeric etc. (Pandey, 1977; Patel, 1977; Chari, 1980; Ramaprasad, 1997). The outbreak of this pest generally occurs with a good rainfall after a long dry spell (Chelliah, 1985 and Chari *et al.*, 1987). The newly hatched larvae feeds gregariously from lower surface of the leaves and causing heavy damage to the leaves, shoots, stems and capsules. The

grown up larvae consume almost whole castor leaf leaving behind only hard veins (Patel, 1977).

The development and survival of *S. litura* larvae have been found vary with the host plant species (Thobbi, 1962; Thobbi and Srihari, 1967). Since different species of host plants play an important role in maintaining continuity of the pest through out the year, the information regarding the growth and survival potential of *S. litura* on commonly cultivated crop plants is of practical significance.

The pest being nocturnal in habit, the moths are active during night and due to its high mobility, female ovipositing on a wide range of host plants which promotes and even ensure survival of *S. litura* individual. Adequate knowledge on biology of *S. litura* in relation to its various host plants and oviposition behaviour in particular crop ecosystem may provide basis for attacking on the weakest links in its population cycle.

Now, it has been realized that this insect pest is one of the most destructive and widely distributed species in North India (Tiwari and Bhattacharya, 1987). Deshmukh *et al.* (1976) reported that its menace is continuously increasing in the country since last few years, perhaps due to shift in planting and high yielding varieties under larger areas which are more prone to its attack.

Castor, tobacco, cotton, groundnut and cabbage occupy a unique position in the agricultural economy of the Gujarat State. It is a fact

that there is no detail information available on the biology of this pest on different host crops. It was very essential to study the effect of host plants on the growth, development and population dynamics of *S. litura* which may provide some information for devising its proper control measure programme.

Population of *S. litura* shows violent fluctuations in its natural environment. Life tables are the tools most useful for determining population dynamics, which recorded a series of sequential events that reveal population fluctuation throughout the life cycle of a given set of environmental conditions. It also provides an important clue on relationship of biotic and abiotic environmental factors and their role in fluctuation of the population. When these relationships are related to mortality, the life tables forms a budget of the successive processes that operate in a given population (Morris and Miller, 1954; Harcourt, 1969 and Singh *et al.*, 1977). The field life tables state a condition of an important and useful fact to understand the actual condition of seasonal abundance of an insect pest species for planning the successful pest management strategies.

Life fecundity tables (for females) are the useful tool in determining biotic potential and the stage in the life cycle of pest, which contributes to the trend of population. Birch (1948) developed the statistics to determine reproductive potential of a pest species. This statistics is the

innate capacity of increase (rm) in number, which signifies number of individuals added to the population per head per unit of time.

Earlier, several chemical pesticides as well as biopesticides were recommended for combating this pest, of which chlorpyriphos, leptophos, methamidophos and phoxim each at 0.05% proved effective (Grewal *et al.*, 1982). However, indiscriminate use of the chemical pesticides caused several concerns. Among biopesticides, commercial preparation of *Bt* (*Bacillus thuringiensis* Berliner) were proved effective for the management of this pest (Babu and Subramanian, 1973). Among the several avenues to overcome the insecticidal resistance problem, replacement with insecticides is one of the important considerations. Therefore, it is necessary to evaluate the efficacy of newer insecticides against *S. litura* for their effective control.

Considering above facts, attempt was, therefore, made to determine the effect of different host plants like castor (*Ricinus communis* L.) tobacco (*Nicotiana tabacum* L.), cotton (*Gossypium hirsutum* L.), groundnut (*Arachis hypogaea* L.) and cabbage (*Brassica oleracea* var. *capitata* L.) on the growth, development, intrinsic rate of natural increase and the role of key mortality factors in the fluctuation of population of *S. litura*. The present investigations on *S. litura* were carried out on the following broad areas, which will be helpful in devising pest management programme.

1. Biology of *S. litura* on different host crops.
2. Biometrical analysis on different host crops.
3. Population dynamics of *S. litura* on castor.
4. Fecundity life tables (for female) of *S. litura* on different host crops.
5. Ecological life tables of *S. litura* on castor.
6. Evaluation of newer insecticides against *S. litura* on castor.

Review of Literature

II. REVIEW OF LITERATURE

The literature pertaining to the different aspects of the present investigations reviewed and presented under different headings.

2.1 Host range of *Spodoptera litura* Fabricius.

2.2 Biology and biometrical studies on different hosts.

2.3 Population dynamics of *S. litura* on castor.

2.4 Natural enemies of *S. litura*.

2.5 Life fecundity tables.

2.6 Life tables to determine key mortality factors.

2.7 Evaluation of newer insecticides and biopesticides against *S. litura*.

2.1 HOST RANGE OF *Spodoptera litura* FABRICIUS

S. litura is a polyphagous and reported to feed on many crop plants and weeds. Moussa *et al.* (1960) recorded 112 species of plants belonging to 44 families as food plants. The pest is most serious on cotton, berseem and maize. The important crop plants attacked are castor, tobacco, cotton, groundnut, tomato, lucerne, cabbage, cauliflower, sweet potato, potato, cowpea, onion, brinjal, banana, watermelon, okra, pigeonpea, Indianbean, lettuce, papaya, soybean, mulberry, maize, turmeric, til, clover, eucalyptus etc.. It has been recorded feeding on a number of weeds such as

Amaranthus spinosus, Portulaca quadrifida, Zinnia elegans, Chenopodium amaranticolor (Patel and Patel, 1969 and Patel, 1977). As many as 73 host plants of this insect have been recorded in Egypt, 16 of which serve as host for oviposition and 45 hosts for oviposition and feeding (Hafez, 1977). Patel (1977) recorded it's occurrence on 29 cultivated crops in Gujarat.

2.2 BIOLOGY AND BIOMETRICAL STUDIES ON DIFFERENT HOSTS

2.2.1 Egg

Earlier Thomas *et al.* (1969) studied the host biology relations of *S. litura* and reported the fecundity on tomato and castor, whereas, the lowest on banana (693.60 eggs/female) at temperature of 25-30 °C. The eggs are laid in cluster of 50 to 300 on the under surface of leaves and occasionally on the upper surface of the leaf by female moths. The eggs are laid in one or more layers. The egg masses are covered with scales from the body of the female moths. According to Nasr and Nassif (1971), the moth had the ability to choose the suitable site for oviposition and normally preferred the lower surface of leaves of cotton, mulberry, castor, okra and soybean. However, Lloyd *et al.* (1972) observed that the sex ratio had no effect on the percentage of eggs that hatched. Nakamura (1973) reported that more number of eggs were laid on first and second day after moth emergence. The average egg laying capacity was recorded to be 2518 eggs

per female of which above 90% of the eggs being laid between the second and the fifth day after emergence (Patel *et al.*, 1973).

Etman and Hooper (1979) reported that the fecundity of *S. litura* was increased (2673 eggs/female) when it was reared on artificial diet at 28 °C temperature.

Balasubramanian *et al.* (1984) studied the effect of host plants on the biology of *S. litura* at temperature range of 26 to 30 °C and observed the incubation period of 3.5 and 5.0 days on castor and cotton, respectively. The average incubation period was reported to be 4.80 days with a hatching percentage of 87% eggs, when the pest was reared on cotton (Patel *et al.*, 1986). Patel and Shah (1987) found the maximum number of eggs on castor (mean fecundity 3412 eggs/female) followed by tobacco (3365 eggs/female) and cotton (2990 eggs/female). They also observed that *Coccinia indica*, *Dolichos lablab* and *Vigna catjang* were the least preferred hosts with 1425, 1669 and 1531 eggs/female, respectively.

The average incubation period was observed to be 3-4 days on groundnut (cv. MH4 Spanish bunch) and cotton (var. F414) by Kharub *et al.* (1993) and Arora (1993).

Mann *et al.* (1995) studied the seasonal effect on incubation period and stated that eggs of *S. litura* hatched after 2 to 4.5 days during June-October, but the egg stage was prolonged to 27 days in December, when it was reared on cotton. According to Bae *et al.* (1999) the duration of

the egg stage could not differ significantly on different food sources, however, egg duration was shorter when it was reared at 32 °C as compared to 24 and 28 °C. Similar observations were also reported by Matholiya (1997). However, the maximum incubation period (3.47 days) was recorded on cotton and minimum (3.17 days) period on castor. Whereas, Soni *et al.* (2001) observed that the mean incubation period was significantly highest on cabbage (5.60 days) and the lowest on castor (3.40 days).

2.2.2 Larva

2.2.2.1 Larval Instars

Peterson and Haeussler (1928) stated that by applying Dyar's law the width of head capsule of Lepidopterous larva was more or less constant for any instar of a given species and successive larval instars of a given species exhibited a more or less geometrical progression in the growth of head capsules. They concluded that the number of larval instars of oriental peach moth, *Laspeyresia molesta* Busck was correlated with the rate of larval growth, as a rule rapid growth produced four instars and the slow growth produced five instars in the United States. Taylor (1931) analyzed the measurements in 46 species of sawflies and 28 species of Lepidoptera upheld Dyar's generalization. Metcalf (1932) could not determine the number of instars of *Sitoderpa banicea* (Z.) and concluded that the rate of development of sexes may yield different instars.

The study on biology of *S. litura* on different hosts under laboratory conditions indicated that there were 6 larval instars on cotton (Patel *et al.*, 1986), tobacco (Patel and Chari, 1987, Prapaipan, 1995) and groundnut (Kharub *et al.*, 1993). However, Mann *et al.* (1995) and Devinder *et al.* (1996) observed that larvae of *S. litura* passed through 5 larval instars, when they were reared on cotton and sunflower, respectively.

2.2.2.2 Head width and Instar duration

Shih and Shih (1995) reported that the mean head capsule widths of larvae of the tobacco cutworm (*S. litura*) when reared on artificial diet passed through six instars and the mean head capsule width was recorded 0.3, 0.5, 0.7, 1.2, 1.9 and 3.0 mm, respectively. Further, they stated that the developmental period of each stage decreased in increase with rearing the temperature.

Patel *et al.* (1986) studied the biology of *S. litura* on cotton under laboratory conditions and recorded six larval instars with average instar duration of 3.12, 2.60, 2.80, 3.56, 3.68 and 2.80 days, respectively. Almost similar observations were also reported by Kharub *et al.* (1993) when the pest was reared on groundnut.

2.2.2.3 Larval body length and width

According to Singh and Byas (1976) larval size and percentage survival of larvae of *S. litura* on different hosts in successive instars increase as the duration of the larval period decreased.

Venkateswarlu *et al.* (2001) investigated the growth and development of *S. litura* on 24 newly acquired germplasm lines of tobacco under laboratory conditions and observed that the length and weight of larvae varied from 24.8 to 32.3 cm and from 0.26 to 0.85 g, respectively.

Soni *et al.* (2001) evaluated the host preference of *S. litura* using castor, cabbage and cauliflower as host plants and found that the length and width of *S. litura* larvae were maximum on cauliflower (34.83 mm length and 5.45 mm width) and lowest on castor (32.62 mm length and 5.05 mm width).

Baloliya (2001) carried out the study on different hosts under laboratory conditions and observed that mean body length of *S. litura* larvae was maximum on castor (43.88 $\pm$ 0.614 mm) followed by tobacco (43.67 $\pm$ 0.593 mm), cotton (43.06 $\pm$ 0.681 mm) and cabbage (43.49 $\pm$ 0.642 mm). Similarly, mean body width was found maximum on castor (6.923 $\pm$ 0.161 mm) followed by tobacco (6.507 $\pm$ 0.184 mm), cotton (6.220 $\pm$ 0.140 mm) and cabbage (6.513 $\pm$ 0.120 mm).

2.2.2.4 Larval period

Singh and Hoi (1972) studied the duration of larval stage on different hosts and reported that the period varied with the host, which was the shortest on castor (15.4 days) and the longest on maize (20.6 days). Patel *et al.* (1973) stated that the larvae passed through six instars when reared on castor under laboratory conditions (28.6° C temperature) and

average larval period of male and female was found to be 12.8 and 13.1 days, respectively. A study has revealed that the larval period was the shortest (18.3 days) on castor, the longest (27.6 days) on cotton and could not completed the larval stage on sorghum at 27 °C temperature (Singh and Byas, 1976), whereas Balasubramanian *et al.* (1984) recorded it 15.5 days on castor and 18.9 days on cotton at 26 to 31 °C temperature. The growth index values were recorded 6.00 and 4.65 on castor and cotton, respectively.

Bhalani and Talati (1984) recorded the larval duration of 11.42, 12.37, 12.05 and 14.83 days on cabbage, groundnut, castor and brinjal respectively, whereas, Vora *et al.* (1984) observed 18 days larval period on castor at a constant temperature of 23 °C. Patel *et al.* (1986) recorded the mean larval period of 18.64 days on cotton. Patel and Chari (1987) observed six larval instars on tobacco and larval duration of 11 to 13 days.

Patel *et al.* (1987) reported the shortest larval duration on castor (17.4 days) followed by lucerne (22.5 days), cabbage (23.1 days), Wal, *Dolichos lablab* (25.0 days), wild tundi, *Coccinia indica* (29.4 days) with the highest growth index on castor (5.75) followed by cabbage (4.33), lucerne (4.08), *D. lablab* (3.76) and *C. indica* (2.79) when the pest was reared at constant temperature of 28 ± 1.56 °C. The total larval duration of

S. litura on cotton was 19.8 ± 1.04 days (Arora, 1993). Mann *et al.* (1995) observed that larval period varied from 17.53 to 25.75 days during June to October on cotton in Punjab. Devinder *et al.* (1996) observed that the larvae took the longest period (19.57 days) for its development on sunflower (cv. PSFH-67) and the shortest (15.08 days) on cultivar Jawalamukhi.

Matholiya (1997) observed the larval period of 14.35, 16.25 and 17.76 days on castor, tobacco and cotton at 29 ± 1.56 °C temperature, respectively. Soni *et al.* (2001) recorded the shortest larval period (16.30 days) on cauliflower, whereas it was 18.43 days on tobacco germplasm Tl-1123 (Venkateswarlu *et al.*, 2001).

Baloliya (2001) recorded the total larval period of *S. litura* and found that it was the shortest on castor (18.10 days) followed by tobacco (19.43 days), cotton (23.47 days) and cabbage (22.63 days). Similarly, larval duration was found shorter on castor and it was considered as the most suitable host plant for *S. litura* (Thomas *et al.*, 1969; Shin *et al.*, 1987; Patel *et al.*, 1987; Ahuja and Noor, 1991; Sudhakar *et al.*, 1995 and Dwivedi *et al.*, 1997).

2.2.3 Pre-pupa and pupa

Braune (1980) studied the life history of *S. litura* and recorded the pre-pupal stage of 2-3 days on taro (*Colocasia esculenta* (L.) Schott) in Western Samoa. Patel and Chari (1987) reported the average pre-

pupal period of 1 day on tobacco, whereas Prapaipan (1995) observed pre-pupal period 1.37 ± 0.48 days on the same crop.

Soni *et al.* (2001) recorded the shortest pre-pupal period on cauliflower (1.15 days) as against castor and cabbage.

Baloliya (2001) did not found any significant difference in prepupal period on four different hosts. However, it was comparatively shorter on castor (2.06 days) followed by tobacco (2.13 days), cotton (2.20 days) and cabbage (2.16 days).

Thomas *et al.* (1969) studied the relationship between host and biology of *S. litura* and they reported that pupal period on castor was 9 to 11 days with mean period 9.95 days when the larvae were reared at fluctuating temperature of 25 to 30 °C. The larvae of *S. litura* passed through six instars and pupated in earthen cells in the soil. The mean pupal period of male and female was found to be 7.3 and 6.1 days, respectively, when the larva were reared on leaves of castor (Patel *et al.*, 1973). Braune (1980) studied the life history of *S. litura* and the pupal period ranged from 9 to 13 days on taro (*Colocasia esculenta* (L.) Schott) in Western Samoa under laboratory conditions at 25-31 °C temperature.

Balasubramanian *et al.* (1984) reported the pupal period of 9.2 and 11.6 days on castor and cotton, respectively, when the pest was reared at 26 to 31 °C temperatures. According to Patel *et al.* (1986) the

pupal period was observed 7-11 days, averaging 8.12 days on cotton. The mean pupal period was observed 6.92 days, when the larvae were reared on tobacco (Patel and Chari, 1987). Kharub *et al.* (1993) reported the male and female pupal period of 8.6 and 8.4 days, respectively on groundnut (Spanish bunch), whereas it was 8.06 ± 0.63 days on cotton (Arora, 1993).

Prapaipan (1995) recorded the mean male and female pupal period of 11.49 ± 0.76 and 10.22 ± 0.59 days, respectively on tobacco. The duration of pupal stage on cotton was found 7.73 to 10.86 days during June to October and 22.66 days during October in Punjab (Mann *et al.*, 1995).

Devinder *et al.* (1996) studied the comparative development of *S. litura* on 4 different cultivars Jawalamukhi, Mega-363, MSFH-8 and PSFH-67 at Ludhiana and observed that the pupal period varied from 8.58 to 9.80 days on different hybrids. Matholiya (1997) studied the pupal period on different host plants at a constant temperature of 29 ± 1.56 °C and showed that the period was shorter (6.18 days) on castor compared to tobacco (7.15 days) and cotton (7.5 days).

Bae *et al.* (1999) evaluated the effect of temperature on pupal development of *S. litura* and observed that the mean pupal duration of 14, 10 and 7 days at 24 °C, 28 °C and 32 °C temperature, respectively.

Soni *et al.* (2001) found that the pupal period was shorter (10.40 days) on cauliflower as against cabbage and cotton, whereas it was varied from 4.20 to 6.75 days on tobacco (Venkateswarlu *et al.*, 2001).

Baloliya (2001) compared the pupal period during the pest was reared on different hosts. The pupal period was shorter (9.06 days) on castor followed by tobacco (9.20 days) cabbage (9.23 days) and cotton (9.50 days).

2.2.4 Adult

2.2.4.1 Pre-oviposition period

Balasubramanian *et al.* (1984) studied the effect of host plants on the biology of *S. litura* in the laboratory and observed that pre-oviposition period was shorter on castor as compared to other host plants. The pre-oviposition period for female on cotton was reported to be 1.60 days by Patel *et al.* (1986).

Bae *et al.* (1999) evaluated the effect of temperature on pupal development, longevity of adults and oviposition of tobacco caterpillar (*S. litura*) and observed the pre-oviposition duration of 3.2 days at 24 °C, 2.8 days at 28 °C and 2.5 days at 32 °C temperature.

Baloliya (2001) found that the pre-oviposition period of female was almost similar on the hosts under study, which was observed 1.33, 1.25, 1.58 and 1.50 days on castor, tobacco, cotton and cabbage, respectively.

2.2.4.2 Oviposition

Balasubramanian *et al.* (1984) recorded oviposition period of 5.6 and 5.0 days on castor and cotton, respectively at 26 to 30 °C

temperature. According to Patel *et al.* (1986) the mean pre-oviposition, oviposition and post-oviposition periods of female moths on cotton were found to be 1.60, 7.60 and 3.10 days, respectively.

Shin *et al.* (1987) investigated the effect of temperature and rearing density on the development of *S. litura* under the laboratory conditions and reported that the oviposition period of female moths was shorter at high densities than those reared individually or under field condition. Prapaipan (1995) recorded the average oviposition period of 6.40 $\pm$ 0.80 days on tobacco.

According to Matholiya (1997) while studying the biology of this pest on different host plants, the oviposition period was observed to be 7.58, 7.00 and 6.42 days on castor, tobacco and cotton, respectively.

Baloliya (2001) observed that the oviposition period was longer (7.60 days) when the pest was reared on castor as compared to tobacco (7.33 days), cotton (6.75 days) and cabbage (6.83 days).

2.2.4.3 Fecundity

The biology study of *S. litura* on cotton revealed that the number of eggs laid by a single female was 2507 to 3467, averaging 3032 and the number of egg masses were 10 to 16, averaging 12.80 (Patel *et al.*, 1986). In laboratory studies on the effect of temperature on the biology of *S. litura*, the highest fecundity and fertility of eggs were observed 1034 eggs and 100%, respectively at average temperature of 19.55 °C, while the

lowest fecundity and fertility (387.4 eggs and 45.2%) were observed at 34.9 °C (Sanjrani *et al.*, 1989). Kharub *et al.* (1993) recorded that the *S. litura* female laid on an average of 1618.8 eggs with 81.82% hatchability of 12 egg masses in a period of 4.0 days on groundnut cv. Spanish bunch, while it was 938 ± 12.2 eggs on cotton (Arora, 1993) and 5471.60 ± 230.30 eggs on tobacco leaves in the laboratory at 24.38 ± 2.84 °C temperature (Prapaipan, 1995). Devinder *et al.* (1996) studied the comparative development of *S. litura* on different cultivars of sunflower and observed that the maximum mean number of eggs (1600.7) was laid when the larvae were reared on the variety Mega-363 and the minimum (1223) on PSFH-67.

Soni *et al.* (2001) studied the host biology relationship of *S. litura* using castor, cabbage and cauliflower as host plants and the highest fecundity of female was recorded on cabbage (557.06 eggs) and lowest on cauliflower (397.63 eggs). Similarly, Baloliya (2001) recorded the highest fecundity of females on castor (2264.17 eggs/female) and lowest on cotton (1569.50 eggs/female), whereas it was found 1814.83 and 1648.75 eggs per female on tobacco and cabbage, respectively.

2.2.4.4 Longevity and sex ratio

Earlier, Etman and Hooper (1979) studied the longevity of male and female and it was recorded 10.4 and 8.3 days, respectively. Similarly, average life span of male and female moths on cotton was found 6.30 and 12.30 days, respectively (Patel *et al.*, 1986). According to Patel

and Chari (1987) the entire life span of male moths ranged from 49 to 53 days, and that of females from 50 to 56 days. Tiwari *et al.* (1988) recorded the longevity of male and female of 8.0 and 9.8 days, respectively on groundnut.

Kharub *et al.* (1993) reported that the females survived longer (9.7 days) compared to males (8.8 days) on groundnut, whereas the mean adult longevity of *S. litura* was recorded 5.66 ± 0.87 days on cotton (Arora, 1993). Prapaipan (1995) observed that the male and female longevities of *S. litura* were 13.00 ± 3.03 and 8.80 ± 2.23 days, respectively on tobacco leaves under laboratory conditions at 24.38 ± 2.84 °C temperature. Matholiya (1997) recorded the longevity of male and female of 8.33 and 11.25, 7.67 and 10.75 and 7.67 and 10.33 days, on castor, tobacco and cotton, respectively, when reared at constant temperature (29 ± 1.56 °C).

Singh and Prasad (2001) studied the entire lifecycle of *S. litura* which was completed within 50.57 ± 1.30 days during April to May and 40.02 ± 0.54 days during July to August on chilli under laboratory conditions. Soni *et al.* (2001) found that the longevity of male and female moths was maximum on cabbage (7.05 and 8.20 days, respectively) and minimum on castor (5.60 and 6.09 days, respectively). Similarly, Baloliya (2001) observed that the average life span of male was 37.53, 38.87, 43.33 and 42.27 days and of the female was 41.93, 43.20, 47.73 and 46.67 days on castor, tobacco, cotton and cabbage, respectively.

Patel and Chari (1987) reported that the sex ratio of moths reared from larvae collected in the field in India was 1:1.27 (male : female) on tobacco, whereas, it was 1:0.76 on groundnut in a normal population (Kharub *et al.*, 1993). Prapaipan (1995) reported that the sex ratio of tobacco leaf eating caterpillar moth was 1 male to 2.15 females. Rajesh *et al.* (1997) recorded the sex ratio (male : female) of 1:1.30 on wheat, as against 1:1.14 on lentil.

2.3 POPULATION DYNAMICS OF *S. litura*

Population of any insect species is influenced by various factors of environment. The population of *S. litura* shows violent fluctuation in its natural habitat. The environmental factors determine the occurrence of pest, its population growth and finally reach to a peak.

Zaz and Kushwaha (1983) studied the quantitative incidence of *S. litura* on cole crops and they observed that the population on cauliflower and cabbage was positively correlated with mean temperature and relative humidity. In Japan, Nakagawa *et al.* (1986) reported seasonal occurrence of adults of four major pests of sweet potato. Adults of *S. litura* were captured from August to November, the highest number of adult catches was observed during mid September.

Nandihalli *et al.* (1989) studied the population dynamics of *S. litura* in the field in Karnataka using light and pheromone traps and observed that the pest was active throughout the year but higher density

observed during July-January, however, there was a significant negative correlation between number of catches and average minimum and maximum temperatures for both traps, and a positive correlation with average morning relative humidity for light trap catches only.

According to Lee (1989) the highest number of *S. litura* moths were trapped during December to January and lowest numbers during March to June. The study clearly revealed that high temperature and humidity reduced adult activity between mid June and October. Senapati *et al.* (1990) worked out a correlation between temperature and occurrence of adults and found positive correlation with maximum temperature.

Mishra and Sontakke (1992) monitored the activity of adults through pheromone traps and reported three population peaks during August to October. The peaks were observed in late August, late November and mid December of 1987. Similarly, in 1989, the pest showed three peaks first during late June, second in early September and third in early October. However, during 1988 the pest attained a peak in early November but substantial population was recorded from early February to mid March. They further showed that among different meteorological factors, only relative humidity significantly influenced the trap catches.

Kharub *et al.* (1993) observed that the maximum and minimum temperature (33.8 and 18.6 °C, respectively) and 61% RH were conducive for the development of larvae of *S. litura* on groundnut in the

field. They further stated that abiotic factors *viz*., temperature, RH, rainfall and sunshine hours had a quantitative influence of 30.76% on the population dynamics of the pest. Malik and Parihar (1996) studied the effect of abiotic factors on the population dynamics of the pests of turnip in Uttar Pradesh and found positive correlation between maximum and minimum temperatures and population buildup, while relative humidity have negative effect.

Baloliya (2001) observed that the pest infestation in tobacco nursery was first appeared during first week of July, thereafter it increased gradually and attained a peak in first week of September and it gradually decreased during this month. He further stated that among the various physical factors of environment; mean vapour pressure had negative correlation with the pest population, whereas other physical factors showed no marked effect.

2.4 NATURAL ENEMIES

The major mortality factor for *S. litura* infesting castor was found *Cotesia (Apanteles) beneficus* (Chari *et al*., 1987).

Rai (1974) observed cent per cent parasitism of *S. litura* larvae with *Chelonus formosanus* during July to December in brinjal.

Thaontadarya and Nangia (1983) recorded 32.5 per cent parasitism of *S. litura* eggs with *Trichogramma chilonis* Ishii, 16.3 per cent larval parasitism with *Bracon brevicornis* Wesmeal and 3.4 per cent pupal

parasitism with *Brachymeria* sp. on soybean crop, whereas 14 per cent larval parasitism by *Cotesia ruficrus* on cabbage and cauliflower was observed Zaz and Kushwaha, (1983).

Krishnamoorthy and Mani (1985) recorded cent per cent egg parasitism by *Telenomus remus* and less than 5 per cent larval parasitism by *Cotesia marginivetris* of *S. litura* on cabbage crop.

Sathe (1987) obtained 60 per cent parasitism of *S. litura* larvae by *Campoletis chloridae*, 20 per cent by *Diadegma argenteopilosa*, *Apanteles prodeniae* and *A. colemani*, whereas that of less than 5 per cent by *Enicopilus* sp. and *Echthromorpha* sp.

Jalali *et al.* (1987) conducted the study to evaluate the parasitism of *C. marginiventris* against *S. litura* on various host plants and recorded that the parasitoid had a marked performance for castor (49.3% parasitism) followed by cowpea (24.0%) and tobacco (20.0%) in comparison to other host plants.

Patel (1997) reported the endo larval parasite of *S. litura*, *Apanteles beneficus* Viereck on castor followed by cauliflower, soybean, lucerne and tomato.

2.5 LIFE FECUNDITY TABLES

Birch (1948) defined the intrinsic rate of increase as the actual rate of increase of population under specified environmental

conditions in which space and food were unlimited. Th re no mortality factors other than physiological one.

Howe (1953) suggested that a life-table can be const by following the life history of a group of insects from the deposition to successful adult emergence, as all deaths occur together in adult s He also suggested that the food mainly affected the rate of increase and t effect was expressed through developmental stages of insects. Such studies were conducted on stored grain pests *viz.*, *Trogoderma granarium* Everts and *Callosobruchus analis* Fabricius by Atwal *et al.* (1968) under the conditions of ample space and adequate food supply in Punjab, India, on broken wheat grains and mung grains, respectively. The innate capacity of increase in numbers (rm) and finite rate of increase (λ) of *T. granarium* was observed to be 0.118 and 1.125 females per female per day, respectively, whereas values of 'rm' and 'λ' was obtained 0.152 and 1.164, respectively for *C. analis* at 30 °C temperature and 70 per cent relative humidity. It was also noted that their population multiplied (Ro) 30.819 and 27.993 times, respectively between two successive generations with the generation duration of 29.14 and 21.89 days.

Bilapate *et al.* (1980) reported the intrinsic rate of increase in numbers of *S. litura* on sunflower at constant temperature of 26 and 30 °C.

temperatures and the net reproductive rate was reported 799.82 and 966.88, respectively, with the mean generation time of 41.08 and 34.61 days.

Garad *et al.* (1984) observed the highest net reproductive rate (Ro) on okra, whereas it was the lowest on groundnut. Dhandapani *et al.* (1985 and 1986) constructed life tables of *S. litura* on banana and chilli and showed that the net reproductive rates (Ro) under laboratory conditions were 479.15 and 533.46, respectively. The population increased at an infinitesimal rate of 0.1525 (banana) and 0.1670 (chilli) with finite rate of 1.165 (banana) and 1.182 (chilli) females per female per day and a generation was completed in 45.4 days on banana and 37.61 days on chilli. On reaching a stable age distribution, the population comprised of about 99% immature stages on both the crops. Balasubramanian *et al.* (1988) reported the net reproductive rate of 547.18 on castor and 358.76 on cotton with the intrinsic rate of natural increase 0.1935 and 0.1465 females per female per day, respectively with the corresponding doubling times of 3.59 and 4.72 days, respectively. Reaching to a stable age, the egg, larva, pupae and adult of this pest contributed 54.82, 43.29, 1.64 and 0.25% on castor and 53.23, 45.23, 1.32 and 0.21% on cotton, respectively.

Dhandapani *et al.* (1989) studied the rate of multiplication of this Noctuid on cotton, *Gossypium hirsutum* and *G. arboreum*. The net reproductive rate (total female births) was worked out to the tune of 653.05 and 561.34, the rate of increase in numbers was 0.1750 and 0.1640 with the

finite rate of increase in numbers 1.191 and 1.179 females per female per day in a mean generation time of 37.05 and 38.61 days, respectively.

Kulkarni and Lingappa (1993) studied life fecundity table for females and stable age distribution of this pest on groundnut. The net reproductive rate (Ro), the innate capacity for increase (rm) and the daily finite rate of increase (λ) were worked out to the tune of 20, 2.4 and 1.14, respectively. On reaching the stable age distribution, the population of *S. litura* would comprise 50.0, 45.97, 2.82 and 0.41 per cent eggs, larvae, pupae and adults, respectively.

Ouyang and Ouyang (1994) recorded life history data for this Noctuid at 25 °C which was analyzed using 2 sex and traditional life table, using 2 sets of data in each case. Using traditional life table analysis, the intrinsic rates of increase (rm) was 0.2001 and 0.2140, respectively. The mean generation time (T) was found to be 36.17 and 34.86 days, the net reproductive rates (Ro) 1394 and 1737 and the finite rates of increase (λ) 1.2215 and 1.2386. Using 2-sex life table analysis, the corresponding values were 0.1869 and 0.1864; 37.36 and 37.12 days; 1078 and 1011 and 1.2055 and 1.2040.

Baloliya (2001) studied the life fecundity tables of *S. litura* on different varieties of tobacco and reported that the highest survival of immature stages was recorded on GTH-1 followed by GT-5 and GT-7. On

the basis of reproductive potential (Ro) the varieties can be arranged as: GTH-1 > GT-5 > GT-7. The mean length of generation was almost equal on all the three varieties, however, it was the lowest (43.62 days) on GT-7. The intrinsic rate of natural increase in numbers (rm) ranged from 0.1503 to 0.1594 females per female per day on different varieties. Similarly, the finite rate of increase in numbers (λ) ranged from 1.162 to 1.173 females per female per day on different varieties.

2.6 LIFE TABLES FOR FIELD POPULATION

The life tables were initially used for the study of insects like *Drosophila melanagaster* Strains (Pearl and Parker, 1921) and *Tribolium confusum* Jaca (Pearl *et al.*, 1941) and then it was extensively used for human beings (Harcourt, 1969). Deevey (1947) stated that the life tables for field population are a concise summary of certain statistics of a population. Probably he was the first to apply the technique to the natural population, however, format for the life table was adopted for the first time by Morris and Miller (1954) for insect populations. Price (1975) presented a detail example of life table for natural population of an insect. Southwood (1968) opined that the life table technique could be applied to the field populations, when generations are not much overlapping. Multifactor studies incorporating the field life table techniques have been undertaken for some 20 forest and agricultural pests (Harcourt, 1969).

Sridhar and Prasad (1996) studied the life table of *S. litura* on groundnut in Andhra Pradesh and reported the generation mortality to the tune of 1.0314 in the 1st generation, 0.9355 in the 2nd generation and 1.0094 during the overlapping generations. Among the four known mortality factors, a fungi species *Nomuraea rileyi* (Farlow) Samson caused maximum mortality (36.9%) followed by protozoan (13.8%), whereas among the larval parasites *Peribaea orbata* Wiedemann and *Apanteles ruficrus* (Haliday) caused 13.7 and 8.2% mortality, respectively. Similarly, Bhanukiran *et al.* (1998) reported that the *N. rileyi* (Farlow) Samson was the main larval mortality factor followed by the birds (*Acridotheres tristis* and *Dicrurus adsimilis*), *Vespa cincta* Fab., *Eumenes* sp. and spiders. They further observed that coccinellids *Verania vincta, Coccinella transversalis* Fab. and *Menochilus sexmaculata* Fab. played a major role in reducing the pest population. The survival rate was worked out to be 0.5745 and 0.3615, respectively indicating the effect of natural factors in reducing the *S. litura* population.

2.7 EVALUATION OF NEW INSECTICIDES AGAINST *S. litura*

Babu and Subramanian (1973) conducted the field study with *Bacillus thuringiensis* Berliner on *S. litura* in Tamil Nadu, India and found that commercial preparation of *B.t.* viz., Thuricide HP, Biotrol BTB 25 W, Bactospeine PM and Thuricide dust, were effective in controlling second

and third instar larvae of *S. litura* on castor. However, among the chemical insecticides, leptophos, methamidophos, chlorpyriphos and phoxim each at 0.05 per cent were found most effective (Grewal *et al.*, 1982). In another field study on castor, with sprays of fenitrothion 0.05, parathion 0.05 and DDT 0.1 per cent gave better control of *S. litura* larvae on castor (Saroja *et al.*, 1973).

Chlorpyriphos 0.06 per cent showed effective control of *S. litura* on groundnut in Tamil Nadu (Natesan and Balasubramanian, 1979). Neem Seed Kernel Suspension (0.5%), *Pongamia glabra* (0.3%) and neem leaf extracts (0.5%) effectively reduced infestation of the larvae in Junagadh, Gujarat (Koshiya and Ghelani, 1990).

The infestation of *S. litura* on cotton has been effectively managed by the spray using mixture of neem oil 0.5 per cent with Polytrin-C 44 (cypermethrin + profenophos) 0.088 per cent. The mixture of NSKS @ 5.0 and endosulfan 0.07 per cent found effective against *S. litura* on cotton (Anonymous, 1997) and black gram (Venkateswarlu *et al.*, 1992). Fang and Fang (1994) observed that bifenthrin 2.8% EC at 1000 fold dilution and cyromazin 75% WP at 5000 fold dilution applied once during 20 to 30 days after pea crop sowing found effective against *S. exigua*.

Gaffar and Kushwaha (1994) reported that a local field isolate of *B.t.* sprayed at 4.4×10^8 and 2.2×10^8 viable spores/ml against *S. litura* on cauliflower resulted in 58.3 and 38.2 per cent mortality, respectively.

Materials and Methods

III. MATERIALS AND METHODS

Present investigation was carried out at Department of Entomology, Bansilal Amritlal College of Agriculture, Anand Agricultural University, Anand during 2003-04 and 2004-05. Methodologies for the following aspects are described in this chapter:

3.1 Biometrical observations.

3.2 Biology of *S. litura* on different hosts.

3.3 Population dynamics of *S. litura* on castor.

3.4 Life fecundity tables.

3.5 Life tables to determine key mortality factors.

3.6 Evaluation of new insecticides and biopesticides against *S. litura*.

REARING TECHNIQUE

Initial culture of *Spodoptera litura* Fabricius was developed by collecting a large number of larvae from the castor field of the College Farm of B.A. College of Agriculture, G.A.U., Anand Campus, Anand. The field collected larvae were reared in a round galvanized iron cage (36 x 12 cm) under laboratory conditions and fresh castor leaves were provided as food. The cages were kept clean and fresh castor leaves were offered to the larvae everyday in the morning until pupation. Petiole of each leaf was wrapped with wet cotton wool to maintain the turgidity of the leaf. Top of

the cage was covered by using muslin cloth and the same was secured in position with the help of rubber bands. The full grown larvae which were about to pupate were transferred to other galvanized cages. Bottom of the cage was covered with 6 cm thick layer of moist soil to facilitate pupation. The pupae were collected three days after pupation and transferred to plastic containers for adult emergence. Plastic strips were hanged in the containers for resting of the adults. Freshly emerged moths were transferred into a wooden cage measuring 30 cm in length, 30 cm in width and 45 cm in height having a glass top. All the sides of the cage were covered with a fine muslin cloth. Urethane foam pieces, soaked in 5 per cent honey solution were placed in the cage as food for the moths which was replaced with fresh food everyday morning. Plastic strips were hanged in the cage for resting and oviposition of adults. The strips were observed daily for the eggs. The strips containing eggs were transferred and kept in a separate cage for hatching. Newly hatched larvae were carefully removed with the help of a wet camel hair brush and released on different hosts under study *viz.*, castor, tobacco, cotton, groundnut and cabbage leaves. All the larvae were reared individually on these hosts. The rearing was continued through two successive generations on respective hosts to acclimatize. Thus, the nucleus culture from third generation was used for the further investigation.

3.1 BIOMETRICAL OBSERVATIONS

3.1.1 Larval instars

Newly emerged larvae (350) were kept individually in plastic containers (5 cm diameter x 5.5 cm height) and were reared on castor, cotton, groundnut, cabbage and tobacco leaves. In order to determine the larval instars, the individual larva was observed daily for the exuva as well as head capsule. The moulting was confirmed by the presence of cast off head capsule. Freshly moulted 30 larvae were killed in hot water (60 °C temperature) and head width, body length and body width of each larva was measured with the help of ocular micrometer. The application of Dyar's (1890) law was tested for the larval instars. For the purpose of assigning single individuals to their respective instars, regression relationship between instar and the mean head capsule width of larva was calculated. The observations on the larval body length and width were tested for the applicability of Prazibran and Megusar's (1912) rule. The regression relationship between the instar, mean body length and body width was also calculated. The regression equation used was:

$$\log_{10} Y = a + bx$$

Where,

Y = body length/ width/ head capsule width

a = constant

b = logarithm of growth ratio

x = number of instars

Multiple correlation and partial regression studies on the variables *viz*., larval body length, larval width and head capsule width were calculated by using the following form of equation:

$$Y = a + b_1x_1 + b_2x_2$$

Where,

Y = mean width of head capsule

x_1 = mean larval length

x_2 = mean larval width

a = regression constant

b_1 and b_2 = coefficient of partial regression

The values of a, b_1 and b_2 were calculated by using the least square method.

3.2 BIOLOGY OF *S. litura*

Investigation on various aspects of biology were carried out at a constant temperature of 27 ± 1 °C using B.O.D. incubator. In order to study the biology, larvae were reared separately on the respective hosts upto adult stage and eggs were obtained with a view to determine the hatching percentage and incubation period, the eggs laid on leaves of castor, cotton, groundnut, tobacco and cabbage were counted and transferred into glass petridishes (15 cm diameter) with the help of a wet camel hair brush. The petridishes containing eggs were kept in B.O.D.

incubator till hatching. The egg duration and number of larvae hatched were recorded.

In order to determine the different larval instars, instar durations and total larval duration, the newly hatched larvae were collected and reared separately on leaves of respective hosts. The individual larva was transferred in a plastic vial (2.5 cm diameter and 7.5 cm length) (Plate-I) with the help of wet camel hair brush and was provided with fresh food. The food was changed everyday in the morning. In order to determine the larval instars, the individual larva was observed daily for the exuviae as well as head capsule. The moulting was confirmed by the presence of casted off head capsule. Observations on number of instars, instar duration and total larval period were recorded. When the larvae were about to pupate, sieved moist soil was provided at the bottom of the galvanized cages to facilitate the pupation.

To know the pre-pupal period, observations were taken everyday in the morning during the larval development. Full grown larvae stopped feeding, become sluggish and darker in colour before entering into the pupal stage. These characteristics were used to know the initiation of the pre-pupal stage. The period from the larva stopped the feeding to entered into the soil for pupation was considered as pre-pupal period. The pupae were collected three days after pupation. Pupal period was calculated from the date of entry inside the soil to the date of emergence of imago.

Plate-1 : Biology of *S. litura* on different hosts

A : Castor
B : Tobacco
C : Groundnut
D : Cotton
E : Cabbage

The male and female adults emerged from the respective hosts on the same day were paired by releasing them in oviposition cages. Fresh twigs of respective hosts were also kept in the cage for oviposition. A piece of urethane (1 x 1 cm) soaked in 5 per cent honey solution was placed in the oviposition cage as a food for adults. The pre-oviposition, oviposition and post oviposition periods were noted. To know the fecundity, number of eggs laid by a single female was counted daily until the death of the female.

The data obtained on different biological characters were subjected to statistical analysis by grouping the larvae into five replicates of 15 each.

3.3 POPULATION DYNAMICS OF *S. litura*

The study on population dynamics of *S.* litura was under taken at the College Farm of B.A. College of Agriculture, Anand Agricultural University, Anand during the year 2003-04 and 2004-05. Recommended agronomical practices were followed for raising the crop. The crop was kept unsprayed throughout the season. Population of *S. litura* was recorded at weekly interval. For this purpose, 20 quadrates (3m x 2m) were fixed in the crop. Population of *S. litura* was recorded from five randomly selected plants in each quadrate. Thus, the data obtained on population were correlated with weather parameters *viz.*, minimum and maximum temperatures, rainfall, morning and evening vapour pressure and humidity by using correlation regression study.

3.4 LIFE FECUNDITY TABLES

The investigation on life fecundity table was carried out on castor, cotton, groundnut, tobacco and cabbage at a constant temperature of 27 ± 1 °C. To construct life tables, adults of both the sexes were kept into 30 cm x 30 cm x 45 cm wooden oviposition cage. All the sides of the cage were covered with muslin cloth. Eggs laid on plastic strips were used for this study. In order to construct the life fecundity tables, freshly laid eggs were collected carefully from the cage with the help of wet camel hair brush and placed in ten plastic containers (5.0 cm diameter x 5.5 cm height) in batches of 10 each. The eggs were glued on black card paper stripe in one row to facilitate observations on hatching. Immediately after hatching, the larvae were transferred individually on respective hosts. Fresh food was provided daily in the morning. Subsequent observations on hatching, larval development, formation of pupae, successful emergence of adults and fecundity of females were recorded daily. Age specific mortality in different developmental stages such as eggs, larvae, pupae and adults was also recorded. With a view to determine the age specific fecundity, total number of adults emerged on the same day were caged for oviposition. Healthy twigs with fresh leaves of the specific host were kept into the cage for oviposition. The twigs were replaced daily and number of eggs laid on subsequent days on the twigs and muslin cloth were recorded. Observations on fecundity were continued till all the females died. As the sex ratio was

1:1 (based on 1725 adults), the total number of eggs obtained per female was divided by two to get the number of female birth (mx).

The column headings for construction of the life fecundity tables proposed by Howe (1953) and Atwal and Bains (1974) were used in this study. The same are as under:

x = pivotal age in days

lx = survival of female at age 'x'

mx = age schedule for female births at age 'x'

3.4.1 Net reproductive rate

The values of 'x', 'lx' and 'mx' were calculated from the data given in life tables. The sum total of products 'lxmx' is the net reproductive rate (Ro) (Lotka, 1925). The 'Ro' is the rate of multiplication of population in generation measured in terms of number of females produced per generation. The number of times a population would multiply per generation was calculated by using the following formula:

$$Ro = \sum lxmx$$

3.4.2 Mean duration of generation (Tc)

The approximate rate of generation time (Tc) (the mean age of the mothers in a cohort at the birth of female off spring) was calculated with the help of following formula:

$$Tc = \frac{\sum x\ lx\ mx}{Ro}$$

3.4.3 Innate capacity for increase in numbers (rm)

Total number of individuals survived and mean number of female off-springs birth was recorded at each age interval. From these data the arbitrary values of 'rm (rc)' was derived by using the following formula:

$$rc = \frac{Log_e{}^{Ro}}{Tc}$$

Where,

e = 2.71828

Tc = Mean generation time

The intrinsic rate of increase (rm) was subsequently calculated from the arbitrary 'rm' by taking two trial values arbitrarily selected on either side of it differing in the second decimal place by establishing the following relationship (Atwal and Bains, 1974).

$$e^{7 - rmx \cdot lxmx} = e^{7} = 1097$$

Such tables were constructed separately for each host with the help of 'x' and 'lxmx' for each trial of 'rm' (Appendices I to V). The value of $e^{7 - rmx \cdot lxmx}$ obtained from the two trials were plotted against their respective arbitrary 'rm' which gave a straight line (Fig. 7). The straight line was intersected by a vertical line drawn from the described values of $e^{7 - rmx \cdot lxmx} = 1097$. The points of the intersection gave a value of true 'rm' accurate to four decimal points. The precise generation time (T) was then calculated by using following formula :

$$T = \frac{Log_e{}^{Ro}}{rm}$$

3.4.4 The finite rate of natural increase (λ):

The number of females per female per day i.e. finite rate of increase was determined as :

$\lambda = \text{antilog } e^{rm}$

From this data the weekly multiplication of the population was calculated. Hypothetical F_2 females were also worked out with the formula $(Ro)^2$.

3.4.5 Stable age distribution

The stable age distribution (per cent distribution of variou age groups) of *S. litura* on different hosts was worked out with th knowledge of 'rm' and the age specific mortality of the immature a mature stages. The stable age distribution table was constructed following the method of Andrewartha and Birch (1954) and Atwal Bains (1974). The 'Lx' (life table age distribution) was calculated fro 'lx' table by using the following formula:

$$Lx = \frac{lx + (lx + 1)}{2}$$

Per cent distribution of each age group (x) was cal d by multiplying the Lx with $e^{-rm\,(x+1)}$. By putting together the percen nder each stage *viz.*, egg, larval, pupal and adult stages, the expect r cent distribution was worked out.

3.4.6 Life table for computing life expectancy of *S. litura*

Life expectancy on different hosts was worked out by using columns x, lx, dx, 100qx, Lx, Tx and ex.

Where,

x = pivotal age (days)

lx = number of surviving at the beginning of age interval out of 100

dx = number dying during 'x'

$$100qx = \frac{dx \cdot 100}{lx}$$, mortality rate per hundred alive at beginning of age interval

$$Lx = \frac{lx + (lx+1)}{2}$$ Alive between x and x+1

Tx = Number of individual's life days beyond 'x'

$$ex = \frac{Tx}{lx} \cdot 2$$, Expectation of further life

3.5 LIFE TABLES FOR DETERMINING KEY MORTALITY FACTORS

3.5.1 Sampling procedure

The investigation was carried out under the field conditions. The number of *S. litura* in the available stage (s) was counted with the

appearance of the insect on the crop. The sampling was carried out from the beginning till the harvesting of the crop at seven days interval.

3.5.1.1 Eggs

Egg population was recorded from 25 randomly selected plants. More than 20 eggs were collected from experimental plot. These eggs were reared singly in glass tubes till hatching of larvae / emergence of the parasitoid adults. Number of eggs hatched into larvae, the ones giving rise to parasitoid adults and those remained unhatched was recorded separately.

3.5.1.2 Larvae

Since the generations were overlapping, the larvae belonging to low age groups 1st and 2nd instars and grown up were recorded separately from 25 plants at 7 days interval through out crop season. More than 20 larvae were collected in the above mentioned two age groups separately from the field and kept them individually in glass tubes in laboratory till pupation. Number of larvae died during the period to ascertain the cause of death and number of dead larvae from the various causes of mortality was recorded separately.

3.5.1.3 Pupae

S. litura pupates in the soil and hence 50 mature larvae were collected from the plants and were released in 10 quadrants @ 5 larvae per quadrate (0.5 x 0.5 m^2). After 3-4 days of releasing the larvae, the soil in

each of the quadrates were dugout gently upto 10-15 cm depth to collect pupae. Number of such pupae formed was recorded. The pupae collected were reared in laboratory till the adult emergence. Number of pupae died due to parasitoids and unknown causes as well as emergence of adult from the pupae were recorded.

3.5.1.4 Adults

The adults emerged from the field collected pupae and larvae were sort out into males and females and sex ratio was determined. A pair of male and female moths was enclosed into a glass jar for oviposition. Number of eggs per female was recorded till death of the female.

3.5.2 Construction of life table

The column headings used for the construction of life tables in the present study were those proposed by Morris and Miller (1954) and Harcourt (1969) are as under:

x = The age interval, egg, larva, pupa or adult

lx = The number surviving at the beginning of stage noted in the 'x' column

dx = The number of dying within age interval stated in the 'x' column

dxf = The mortality factor responsible for 'dx'

100qx = per cent mortality

sx = Survival rate within the age mentioned in the 'x' column

3.5.3 Analysis of causes for fluctuation of population and identification of key mortality factors

As the mortality factors cause population fluctuation, budgets were worked out to determine the key mortality factor (K) that influences the population trend in castor crop. The method suggested by Varley and Gradewell (1963 and 1965) was followed to find out density relationship of mortality factors. Similarly, the value of killing power (k) of each mortality factor/(s) in different age groups was worked out by taking the difference between the logarithms of population density before and after its action. The total killing power (K) was computed by taking the sum of killing power of K's.

3.6 EFFICACY OF NEWER INSECTICIDES AGAINST *S. litura*

Field experiment was conducted at College Farm, B.A. College of Agriculture, Anand Agricultural University, Anand to test efficacy of different insecticides against *S. litura* on castor during the year 2003-04 and 2004-05. Details of insecticidal treatments are as under. Nine treatments excluding a control were tried in randomized block design with three replications.

Insecticides used for evaluation of their efficacy against S. litura

Sr. No.	Common Name	Trade Name	Formulation	Conc. (%)	Manufacture Agencies
1.	Quinalphos	Ekalux	25 EC	0.05	Novartis India Ltd., Mumbai
2.	Alphamethrin	Farsa	10 EC	0.0075	BASF India Ltd., Mumbai
3.	Lufenuron	Match	5 EC	0.005	Novartis India Ltd., Mumbai
4.	Acephate	Astaf	75 SP	0.075	Rallis (India) Ltd., Mumbai
5.	Profenophos	Curacron	50 EC	0.05	Novartis India Ltd., Mumbai
6.	Indoxacarb	Avaunt	14.5 SC	0.015	El Dupont India Ltd., Mumbai
7.	*Bacillus thuringiensis* var. *kurstaki*	Biolep	WP	1 kg/ha	Biotech International Ltd., New Delhi
8.	Azadirachtin	-	w/w	0.03	Osho Worship Centre
9.	NSKS	-	-	2	-

Castor variety GCH-6 was sown at 90 x 60 cm apart having gross and net plot size of 5.4m x 3.6 m and 4.2m x 1.8m, respectively. All the recommended agronomical practices were followed for raising the crop. The first spray was carried out at Economic Threshold Level (1 larval mass of 1st instar/ 2 plants) and second 15 days after first spray. The insecticidal treatments were applied with the help of Knapsack Sprayer and quantity of

spray solution was used @ 600 litre per hectare. Observations on number of larvae were recorded from each plot 24 hours before and 3rd, 5th and 7th days after spray. The methodology of observations on pest population was same as described under population dynamics (Section 3.3). The data thus obtained were converted to percentage mortality by using the formula of Henderson and Tilton (1953) as under:

$$100 \left(1 - \frac{Ta \,.\, Cb}{Tb \,.\, Ca} \right)$$

Where,

Tb = number of larvae observed before treatment

Ta = number of larvae observed after treatment

Cb = number of larvae observed from untreated check plot before treatment

Ca = number of larvae observed from untreated plot after treatment

Experimental Results

IV. EXPERIMENTAL RESULTS

Present investigations on different aspects of *S. litura* were carried out under laboratory as well as field conditions during the year 2003–04 and 2004–05 at Anand Agricultural University, Anand. The results obtained are presented under the following heads.

4.1 Biometrical analysis of *S. litura* on different host crops.

4.2 Biology of *S. litura* on different hosts.

4.3 Population dynamics of *S. litura* on castor.

4.4 Fecundity life tables of *S. litura* on castor, tobacco, groundnut, cabbage and cotton.

4.5 Ecological life tables of *S. litura* on castor.

4.6 Evaluation of newer insecticides against *S. litura* on castor.

4.1 BIOMETRICAL ANALYSIS

Biometrical studies were carried out under laboratory conditions at a constant temperature of 27 ± 1 °C. Biometrical parameters *viz.*, head capsule width, larval body length and body width in successive instars were recorded by rearing *Spodoptera* larvae separately on castor (*Ricinus communis* L.), tobacco (*Nicotiana tabacum* L.), groundnut (*Arachis hypogaea* L.), cabbage (*Brassica oleracea* var. *capitata* L.) and cotton (*Gossypium hirsutum* L.). Results obtained are reported for the respective hosts.

4.1.1 Castor

4.1.1.1 Head capsule width

Larvae of *S. litura* were reared on castor leaves and the data on observed and estimated head width in different larval instars are presented in Table 1.

Table 1 : Comparison of observed and estimated values (mm) of mean measurements of head capsule width of *S. litura* on castor

Details	Mean values of head capsule width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.29 ± 0.02	0.52 ± 0.03	0.79 ± 0.02	1.28 ± 0.02	1.97 ± 0.03	2.99 ± 0.03	
Growth ratio	-	1.79	1.52	1.62	1.54	1.52	1.598
Estimated	0.31	0.49	0.78	1.24	1.96	3.12	1.588
Difference	-0.02	0.03	0.01	0.05	0.01	-0.13	
Difference per cent	-6.65	6.12	0.91	3.91	0.31	-4.02	

Perusal of data on mean values (Table 1 and Fig. 1) of larval head capsule width revealed that the larvae, when reared on castor leaves passed through six distinct instars. The observed and estimated mean head width for first to sixth instars was recorded 0.29 and 0.31, 0.52 and 0.49, 0.79 and 0.78, 1.28 and 1.24, 1.97 and 1.96 and 2.99 and 3.12 mm, respectively. These measurements fall into six well-defined groups, each characterized as an instar. The mean progression factor of observed and calculated (estimated) head width was worked out to the tune of 1.598 and 1.588, respectively for the six instars. It is evident from the data that

estimated head width as well as progression factors are in close approximity to the observed head width and progression factor.

When log head capsule widths were plotted against number of instars, almost straight regression line (Fig. 1) was obtained and the following regression equation was fitted between the mean head width and instars.

$$\log_{10} Y = -0.7116 + 0.2009X$$

4.1.1.2 Larval body length and width

The observations on mean measurements (mm) of larval body length and width of *S. litura* larvae, when they were reared on this host, are summarized in Tables 2 and 3.

Table 2 : Comparison of observed and estimated values (mm) of mean measurements of larval body length of *S. litura* on castor

Details	Mean values of larval body length (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	1.86 ± 0.02	3.89 ± 0.03	10.32 ± 0.09	19.59 ± 0.03	27.88 ± 0.03	37.80 ± 0.55	
Growth ratio	-	2.09	2.65	1.90	1.42	1.36	1.884
Estimated	2.30	4.26	7.90	14.64	27.15	50.35	1.854
Difference	-0.44	-0.37	2.42	4.95	0.73	-12.55	
Difference per cent	-18.99	-8.64	30.70	33.79	2.68	-24.93	

Table 3 : Comparison of observed and estimated values (mm) of mean measurements of larval body width of *S. litura* on castor

Details	Mean values of larval body width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.39 ± 0.02	0.79 ± 0.02	1.38 ± 0.03	2.01 ± 0.12	3.02 ± 0.13	6.51 ± 0.27	
Growth ratio	-	2.03	1.75	1.46	1.50	2.16	1.78
Estimated	0.43	0.73	1.23	2.08	3.53	5.98	1.695
Difference	-0.04	0.06	0.15	-0.07	-0.51	0.53	
Difference per cent	-8.93	8.87	12.25	-3.51	-14.43	8.86	

The results indicated that the average body length for first to sixth instar larvae ranged from 1.86 to 37.80 mm. The mean observed and estimated progression factor obtained from the mean of growth ratios for different instars was 1.884 and 1.854, respectively. Further, the values of 'a' and 'b' were computed by least square method and following regression equation was fitted.

$$\log_{10} Y = 0.0929 + 0.2681X$$

The observed and estimated geometrical progression factor was worked out as 1.780 and 1.695, respectivcly. Data on mean body width ranged from 0.39 to 6.51 mm with the calculated values 0.43 to 5.98 mm. The regression equation for the six larval instars was :

$$\log_{10} Y = -0.5981 + 0.2292X$$

4.1.1.3 Multiple correlation and partial regression study

The multiple correlation and partial regression analysis was carried out to study the strength of association among three characters *viz.*, larval head width, body length and body width by using the following form of regression equation :

$$Y = a + b_1X_1 + b_2X_2$$

High value of R^2 (0.9967) (Table 4) for the fitted equation indicated that the body length (X_1) and body width (X_2) determine head width (Y) quite satisfactory. The multiple regression equation was fitted:

$$Y = 0.1389 + 0.0419\ X_1 + 0.1958\ X_2$$

The duration for all the six instar (Table 4) was also recorded and the data revealed that the larva has spent maximum time in sixth instar (3.77 $\pm$ 0.43 days), whereas minimum was observed during the second instar (2.27 $\pm$ 0.45 days).

Table 4: Multiple correlation and partial regression study of *S. litura* on castor

Instar	Mean body length ± S. D. (mm) (X_1)	Mean body width ± S. D. (mm) (X_2)	Mean head width ± S. D. (mm) (Y)	Coefficient of determination (R^2)	Mean instar duration (days)
First	1.86 ± 0.02	0.39 ± 0.02	0.29 ± 0.02	0.9967	3.13 ± 0.35
Second	3.89 ± 0.03	0.79 ± 0.02	0.52 ± 0.03		2.27 ± 0.45
Third	10.32 ± 0.09	1.38 ± 0.03	0.79 ± 0.02		2.83 ± 0.91
Fourth	19.59 ± 0.03	2.01 ± 0.12	1.28 ± 0.02		2.73 ± 0.45
Fifth	27.88 ± 0.03	3.02 ± 0.13	1.97 ± 0.03		3.17 ± 0.38
Sixth	37.80 ± 0.55	6.51 ± 0.27	2.99 ± 0.03		3.77 ± 0.43

4.1.2 Tobacco

4.1.2.1 Head capsule width

Data in Table 5 and Fig. 1 represent mean values of head capsule width (mm) of different larval instars. The mean head width for first, second, third, fourth, fifth and sixth instar was recorded 0.27, 0.49, 0.78, 1.28, 1.95 and 2.88 mm, respectively. The difference in the measurements between the two succeeding groups was sufficient enough to assign reliable single individuals to their proper instar. The observed and estimated values for mean progression factors were obtained 1.608 and 1.601, respectively. The equation obtained for the straight line best fitting the observed head width was :

$$\log_{10} Y = - 0.7358 + 0.2043 X$$

Table 5 : Comparison of observed and estimated values (mm) of mean measurements of head capsule width of *S. litura* on tobacco

Details	Mean values of head capsule width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.27 ± 0.02	0.49 ± 0.03	0.78 ± 0.02	1.28 ± 0.02	1.95 ± 0.03	2.88 ± 0.03	
Growth ratio	-	1.83	1.58	1.64	1.52	1.47	1.608
Estimated	0.29	0.47	0.75	1.21	1.93	3.09	1.601
Difference	-0.02	0.02	0.03	0.08	0.02	-0.21	
Difference per cent	-8.08	5.04	3.88	6.27	1.24	-6.85	

4.1.2.2 Larval body length and width

Observations on the mean body length and body width are given in Tables 6 and 7.

It is evident from the Table 6 that observed and estimated geometrical progression factors for body length were 1.824 and 1.775, respectively. The value is greater than 1.26 and therefore, the larvae did not follow the Prazibran's and Megusar rule. The fitted linear regression equation was :

$$\log_{10} Y = 0.0689 + 0.2493 X$$

Table 6 : Comparison of observed and estimated values (mm) of mean measurements of larval body length of *S. litura* on tobacco

Details	Mean values of larval body length (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	2.46 ± 0.02	3.96 ± 0.03	5.35 ± 0.02	8.64 ± 0.02	22.74 ± 0.03	43.56 ± 0.03	
Growth ratio	-	1.61	1.35	1.61	2.63	1.92	1.824
Estimated	2.08	3.69	6.56	11.64	20.66	36.69	1.775
Difference	0.38	0.27	-1.21	-3.00	2.07	6.88	
Difference per cent	18.42	7.22	-18.45	-25.77	10.03	18.75	

Table 7 : Comparison of observed and estimated values (mm) of mean measurements of larval body width of *S. litura* on tobacco

Details	Mean values of larval body width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.48 ± 0.02	0.75 ± 0.03	1.26 ± 0.02	1.75 ± 0.02	3.15 ± 0.03	6.52 ± 0.03	
Growth ratio	-	1.55	1.68	1.39	1.80	2.07	1.698
Estimated	0.45	0.74	1.23	2.05	3.39	5.63	1.660
Difference	0.03	0.00	0.02	-0.30	-0.24	0.88	
Difference per cent	7.46	0.42	1.86	-14.48	-7.19	15.67	

A close perusal of data (Table 7 and Fig 3) indicated that body width of larvae, when moulted six times, attained 6.52 mm width with the observed and calculated progression factors 1.698 and 1.660, respectively. The regression equation fitted was:

$$\log_{10} Y = -0.5693 + 0.22\ X$$

4.1.2.3 Multiple correlation and partial regression studies

The impact of body length and body width on head capsule width was worked out using multiple correlation and partial regression studies. The following multiple regression equation was fitted as :

$$Y = 0.3205 + 0.0152\ X_1 + 0.3179\ X_2$$

The value of coefficient of determination (R^2) was estimated to the extent of 0.9478 which indicated a good fit.

Table 8: Multiple correlation and partial regression study of *S. litura* on tobacco

Instar	Mean body length ± S. D. (mm) (X_1)	Mean body width ± S. D. (mm) (X_2)	Mean head width ± S. D. (mm) (Y)	Coefficient of determination (R^2)	Mean instar duration (days)
First	2.46 ± 0.02	0.48 ± 0.02	0.27 ± 0.02	0.9478	3.23 ± 0.43
Second	3.96 ± 0.03	0.74 ± 0.03	0.50 ± 0.03		2.63 ± 0.49
Third	5.35 ± 0.02	1.26 ± 0.02	0.78 ± 0.02		2.87 ± 0.73
Fourth	8.64 ± 0.02	1.75 ± 0.02	1.28 ± 0.02		3.10 ± 0.80
Fifth	22.74 ± 0.03	3.15 ± 0.03	1.95 ± 0.03		3.37 ± 0.49
Sixth	43.56 ± 0.03	6.51 ± 0.03	2.88 ± 0.03		4.30 ± 0.47

It is evident from the data (Table 8) that the minimum instar duration of 2.63 ± 0.49 days was observed in second instar, whereas the longest duration (4.30 ± 0.47 days) was recorded in the last instar.

4.1.3 Groundnut

The head width of larvae in successive instars, when they were reared on groundnut, increased in a geometrical progression (Fig. 1) (Table 9).

Table 9 : Comparison of observed and estimated values (mm) of mean measurements of head capsule width of *S. litura* on groundnut

Details	Mean values of head capsule width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.27 ± 0.02	0.47 ± 0.03	0.77 ± 0.02	1.27 ± 0.02	1.96 ± 0.03	2.87 ± 0.03	
Growth ratio	-	1.73	1.63	1.66	1.54	1.46	1.604
Estimated	0.29	0.46	0.74	1.19	1.92	3.08	1.606
Difference	-0.02	0.01	0.02	0.08	0.04	-0.21	
Difference per cent	-5.44	1.45	3.14	6.46	2.23	-6.80	

The average observed and estimated values of progression factor which was computed by taking the mean of growth ratios which were observed to be 1.604 and 1.606, respectively for six instars. The observed head width of first to six instars was 0.27, 0.47, 0.77, 1.27, 1.96 and 2.87 mm, respectively. Thus, the measurements fall into six well defined groups each indicated as an instar. It is evident from the Table 9 that the estimated

head width was found in close approximity with the observed head width. The approximation of the data on the observed and estimated head width as well as progression factor is evidence that no moult has been accidentally missed through out the life cycle of this pest. The equation obtained for the straight line best fitting the observed head width was:

$$\log_{10} Y = -0.7462 + 0.2057X$$

4.1.3.2 Larval body length and width

The mean values (mm) of body length are summarized in Table 10 and graphically presented in Fig. 2.

It is evident from the data (Table 10) that the body length increased from 2.23 ± 0.02 to 34.30 ± 0.03 mm during six instars. The observed and calculated mean progression factor was worked out to the tune of 1.774 and 1.769, respectively. The regression equation with least square methods was fitted as :

$$\log_{10} Y = 0.0283 + 0.2478\ X$$

The mean body width (Table 11) for the first instar was 0.42 ± 0.02 mm and it increased up to 6.51 ± 0.03 mm in the sixth instar. The geometrical progression factor was calculated 1.748 for all the six instars and regression equation obtained was :

$$\log_{10} Y = -0.6222 + 0.2296\ X$$

Table 10 : Comparison of observed and estimated values (mm) of mean measurements of larval body length of *S. litura* on groundnut

Details	Mean values of larval body length (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	2.23 ± 0.02	3.19 ± 0.03	5.19 ± 0.02	8.38 ± 0.02	22.30 ± 0.03	34.30 ± 0.03	
Growth ratio	-	1.43	1.63	1.61	2.66	1.54	1.774
Estimated	1.89	3.34	5.91	10.46	18.51	32.74	1.769
Difference	0.34	-0.15	-0.72	-2.08	3.80	1.57	
Difference per cent	18.00	-4.47	-12.12	-19.93	20.55	4.80	

Table 11 : Comparison of observed and estimated values (mm) of mean measurements of larval body width of *S. litura* on groundnut

Details	Mean values of larval body width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.42 ± 0.02	0.69 ± 0.03	1.26 ± 0.02	1.69 ± 0.02	3.08 ± 0.03	6.51 ± 0.03	
Growth ratio	-	1.63	1.84	1.34	1.82	2.11	1.748
Estimated	0.40	0.69	1.17	1.98	3.36	5.69	1.697
Difference	0.02	0.00	0.10	-0.29	-0.27	0.81	
Difference per cent	4.07	-0.10	8.22	-14.57	-8.04	14.24	

4.1.3.3 Multiple correlation and partial regression study

Association between different variables *viz.*, larval body length, body width and head capsule width was estimated by using the multiple correlation and partial regression studies. The following regression equation was fitted.

$$Y = 0.3078 + 0.0613\ X_1 + 0.0825\ X_2$$

The value of coefficient of determination (R^2) was estimated to the extent of 0.9683 (Table 12) which indicated a good fit.

Data on instar duration (Table 12) revealed that the longest stadium was observed for the sixth instar (5.23 days) and the shortest (2.73 days) for the third instar.

Table 12 : Multiple correlation and partial regression study of *S. litura* on groundnut

Instar	Mean body length ± S. D. (mm) (X_1)	Mean body width ± S. D. (mm) (X_2)	Mean head width ± S. D. (mm) (Y)	Coefficient of determination (R^2)	Mean instar duration (days)
First	2.23 ± 0.02	0.42 ± 0.02	0.27 ± 0.02	0.9683	3.37 ± 0.49
Second	3.19 ± 0.03	0.69 ± 0.03	0.47 ± 0.03		3.27 ± 0.45
Third	5.19 ± 0.02	1.26 ± 0.02	0.77 ± 0.02		2.73 ± 0.78
Fourth	8.38 ± 0.02	1.69 ± 0.02	1.27 ± 0.02		3.43 ± 0.50
Fifth	22.30 ± 0.03	3.08 ± 0.03	1.96 ± 0.03		3.43 ± 0.50
Sixth	34.30 ± 0.03	6.51 ± 0.03	2.87 ± 0.03		5.23 ± 0.43

4.1.4 Cotton

4.1.4.1 Head capsule width

Table 13 and Fig 1 represent the data on mean measurement of head width (mm) of successive larval instars on cotton.

The larvae when reared on cotton leaves passed through six distinct instars. The observed mean head width was recorded as 0.23, 0.42, 0.73, 1.22, 1.93 and 2.83 mm with the estimated width 0.25, 0.41, 0.68,

1.13, 1.88 and 3.12 for the first to sixth instars, respectively. These measurements fall into six groups, which evidently indicated as an instar. The growth ratios of successive instars were worked out and the mean observed and estimated progression factor was obtained 1.66 and 1.658, respectively. The estimated and observed values of progression factor were very much closed to each other indicating that growth of larvae was in a definite progression factor. A perfect geometrical progression of head width was presented by a straight line by plotting the logarithms of the head measurements against the larval instars (Fig. 1) and the linear regression equation fitted as under :

$$\log_{10} Y = -0.8247 + 0.2197 X$$

Table 13 : Comparison of observed and estimated values (mm) of mean measurements of head capsule width of *S. litura* on cotton

Details	Mean values of head capsule width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.23 ± 0.02	0.42 ± 0.03	0.73 ± 0.02	1.22 ± 0.02	1.93 ± 0.03	2.83 ± 0.03	
Growth ratio	-	1.81	1.75	1.69	1.58	1.47	1.66
Estimated	0.25	0.41	0.68	1.13	1.88	3.12	1.658
Difference	-0.02	0.00	0.04	0.09	0.05	-0.28	
Difference per cent	-7.51	0.90	6.23	8.08	2.84	-9.10	

1.1.4.2 Larval body length and width

Data in Table 14 indicated that the larvae of *S. litura*, when reared on cotton leaves attained the body length from 1.93 to 43.29 mm

during the six instars with the mean observed and calculated progression factor 1.912 and 1.854, respectively. The values of 'a' and 'b' were estimated by using the least square method, and the following regression equation was fitted between mean body length and the instars (Fig. 2).

$$\log_{10} Y = -0.0379 + 0.268 X$$

Table 14 : Comparison of observed and estimated values (mm) of mean measurements of larval body length of *S. litura* on cotton

Details	Mean values of larval body length (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	1.93 ± 0.02	3.43 ± 0.03	4.99 ± 0.02	8.02 ± 0.02	22.02 ± 0.03	43.29 ± 0.03	
Growth ratio	-	1.78	1.45	1.61	2.75	1.97	1.912
Estimated	1.70	3.15	5.84	10.82	20.05	37.16	1.854
Difference	0.23	0.28	-0.85	-2.80	1.97	6.12	
Difference per cent	13.82	9.01	-14.55	-25.86	9.82	16.48	

The results (Table 15) also indicated that mean measurement values of body width (mm) fall into six different groups. The mean geometrical progression factor for the six larval instars was calculated 1.712 (observed) and 1.680 (estimated). The regression equation derived was a under :

$$\log_{10} Y = -0.6162 + 0.2252 X$$

Table 15 : Comparison of observed and estimated values (mm) of mean measurements of larval body width of *S. litura* on cotton

Details	Mean values of larval body width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.44 ± 0.02	0.65 ± 0.03	1.21 ± 0.02	1.65 ± 0.02	3.09 ± 0.03	6.14 ± 0.03	
Growth ratio	-	1.48	1.86	1.36	1.87	1.99	1.712
Estimated	0.41	0.68	1.15	1.93	3.23	5.43	1.680
Difference	0.03	-0.03	0.06	-0.27	-0.15	0.71	
Difference per cent	8.37	-4.46	5.63	-14.21	-4.59	12.99	

4.1.4.3 Multiple correlation and partial regression study

In order to examine strength of association among three characters, *viz.*, larval body length (X_1), body width (X_2) and head capsule width (Y), the multiple correlation and partial regression analysis was carried out and following equation was fitted :

$$Y = 0.1758 - 0.0233\ X_1 + 0.6274\ X_2$$

The value of coefficient of determination (R^2) was estimated to the extent of 0.9535, which indicated a good fit. Observations on mean duration for different instars (Table 16) indicated that the longest stadium was observed during the sixth instar, whereas the minimum was in the first instar.

Table 16 : Multiple correlation and partial regression study of *S. litura* on cotton

Instar	Mean body length ± S. D. (mm) (X_1)	Mean body width ± S. D. (mm) (X_2)	Mean head width ± S. D. (mm) (Y)	Coefficient of determination (R^2)	Mean instar duration (days)
First	1.93 ± 0.02	0.44 ± 0.02	0.23 ± 0.02	0.9535	3.40 ± 0.50
Second	3.43 ± 0.03	0.65 ± 0.03	0.42 ± 0.03		3.53 ± 0.51
Third	4.98 ± 0.02	1.21 ± 0.02	0.73 ± 0.02		3.77 ± 0.43
Fourth	8.02 ± 0.02	1.65 ± 0.02	1.22 ± 0.02		3.67 ± 0.66
Fifth	22.01 ± 0.03	3.08 ± 0.03	1.93 ± 0.03		4.13 ± 0.35
Sixth	43.27 ± 0.03	6.13 ± 0.03	2.83 ± 0.03		5.17 ± 0.18

4.1.5 Cabbage

4.1.5.1 Head capsule width

The mean head capsule width of larvae, when reared on cabbage (Table 17) were measured 0.27, 0.45, 0.75, 1.26, 1.94 and 2.85 mm with the estimated width 0.28, 0.45, 0.73, 1.17, 1.89 and 3.06 mm in first, second, third, fourth, fifth and sixth instar, respectively.

It becomes evident that the measurements fall into six different groups, each characterized as an instar. Further, the estimated width is almost close to the actual width indicated that the width of successive instar of *S. litura* follows more or less a geometrical progression. The growth ratio in successive instar was also computed and the mean observed and estimated progression factor was obtained to the tune of 1.61 and 1.615, respectively for all the six instar. When log head

capsule width were plotted against different larval instars (Fig. 1) gave a straight line relationship best fitting the observed head width which gave the following regression equation :

$$\log_{10} Y = -0.7629 + 0.2081 X$$

Table 17 : Comparison of observed and estimated values (mm) of mean measurements of head capsule width of *S. litura* on cabbage

Details	Mean values of head capsule width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.27 ± 0.02	0.45 ± 0.03	0.75 ± 0.02	1.26 ± 0.02	1.94 ± 0.03	2.85 ± 0.03	
Growth ratio	-	1.67	1.69	1.68	1.54	1.47	1.61
Estimated	0.28	0.45	0.73	1.17	1.89	3.06	1.615
Difference	-0.01	0.00	0.02	0.09	0.04	-0.21	
Difference per cent	-3.88	-1.02	3.34	7.28	2.30	-6.86	

4.1.5.2 Larval body length and width

The data on larval body length and width are included in Tables 18 and 19. The body length of larvae ranged from 2.35 ± 0.02 to 43.58 ± 0.03 mm for first to sixth instar. The mean geometrical progression factor was computed from the mean of growth ratios of successive instar. The observed and calculated progression factors were computed to the tune of 1.838 and 1.790, respectively. The values of 'a' and 'b' were estimated by following the method of least square which gave the regression equation as under :

$$\log_{10} Y = 0.0459 + 0.2528 X$$

The close perusal of data in Table 19 showed that the mean values of body width (mm) fall into six different groups each representing an instar. The observed and estimated geometrical progression factors were found 1.726 and 1.674, respectively with the regression equation :

$$\log_{10} Y = -0.5969 + 0.2237 X$$

Table 18 : Comparison of observed and estimated values (mm) of mean measurements of larval body length of *S. litura* on cabbage

Details	Mean values of larval body length (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	2.35 ± 0.02	3.84 ± 0.03	5.14 ± 0.02	8.55 ± 0.02	22.19 ± 0.03	43.58 ± 0.03	
Growth ratio	-	1.63	1.34	1.66	2.60	1.96	1.838
Estimated	1.99	3.56	6.37	11.41	20.41	36.53	1.790
Difference	0.36	0.28	-1.24	-2.85	1.78	7.05	
Difference per cent	18.34	7.89	-19.39	-25.02	8.73	19.29	

Table 19 : Comparison of observed and estimated values (mm) of mean measurements of larval body width of *S. litura* on cabbage

Details	Mean values of larval body width (mm) in different instars						Progression factor
	First	Second	Third	Fourth	Fifth	Sixth	
Observed	0.44 ± 0.02	0.76 ± 0.03	1.15 ± 0.02	1.68 ± 0.02	3.12 ± 0.03	6.47 ± 0.03	
Growth ratio	-	1.71	1.52	1.46	1.86	2.08	1.726
Estimated	0.42	0.71	1.19	1.99	3.32	5.56	1.674
Difference	0.02	0.05	-0.04	-0.31	-0.20	0.91	
Difference per cent	4.80	7.12	-3.04	-15.38	-6.16	16.28	

4.1.5.3 Multiple correlation and partial regression study

The studies were carried out to understand the association among the different variables, *viz.*, larval body length, body width and head capsule width. Following equation was fitted:

$$Y = 0.3055 + 0.0087\ X_1 + 0.3626\ X_2$$

The value of R^2 was estimated and presented in Table 20. The high value of R^2 (0.9435) revealed that the regression is good fit.

Duration of different instars was recorded (Table 20) and the shortest period (3.10 days) was observed in the second instar, where as it was the longest in the sixth instar (5.17 days).

Table 20 : Multiple correlation and partial regression study of *S. litura* on cabbage

Instar	Mean body length ± S. D. (mm) (X_1)	Mean body width ± S. D. (mm) (X_2)	Mean head width ± S. D. (mm) (Y)	Coefficient of determination (R^2)	Mean instar duration (days)
First	2.35 ± 0.02	0.44 ± 0.02	0.27 ± 0.02	0.9435	3.33 ± 0.48
Second	3.84 ± 0.03	0.76 ± 0.03	0.45 ± 0.03		3.10 ± 0.31
Third	5.14 ± 0.02	1.15 ± 0.02	0.75 ± 0.02		3.43 ± 0.50
Fourth	8.55 ± 0.02	1.68 ± 0.02	1.26 ± 0.02		3.73 ± 0.74
Fifth	22.18 ± 0.03	3.12 ± 0.03	1.94 ± 0.03		3.83 ± 0.79
Sixth	43.58 ± 0.03	6.47 ± 0.03	2.85 ± 0.03		5.17 ± 0.38

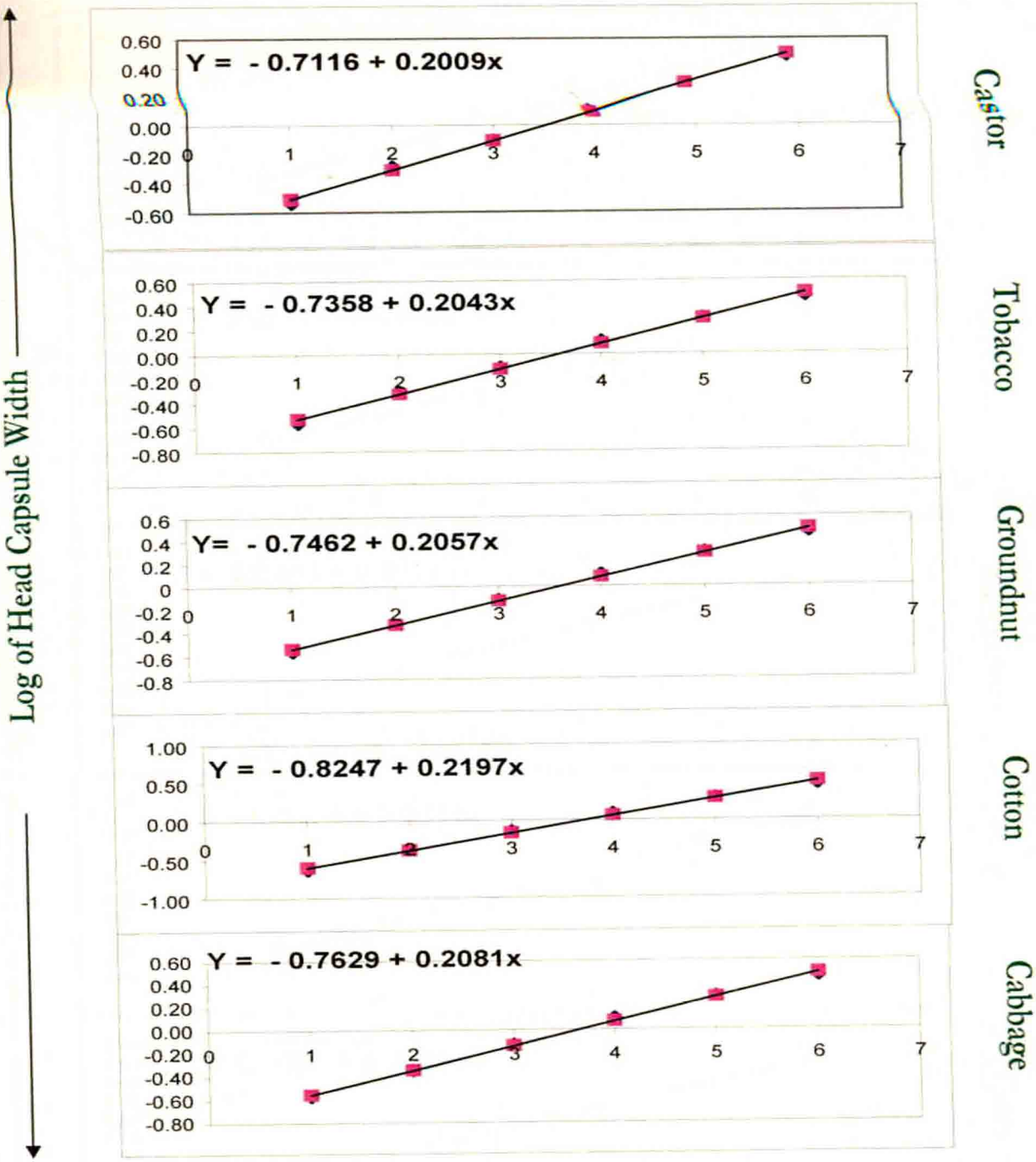


Fig. 1 : Regression of instars on mean head capsule width of *S. litura* on different hosts

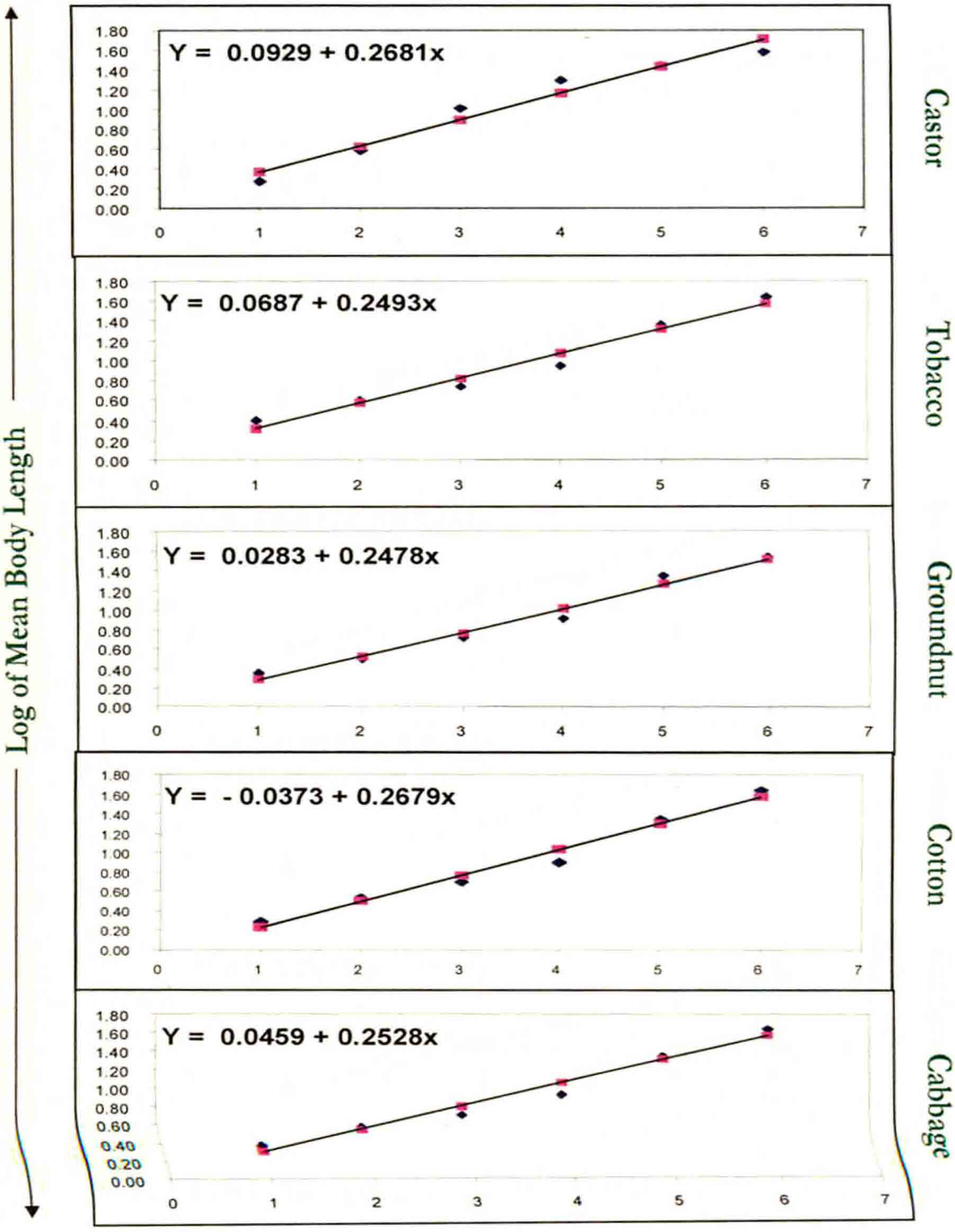


Fig. 2 : Relative growth in length of larvae of *S. litura* on different hosts

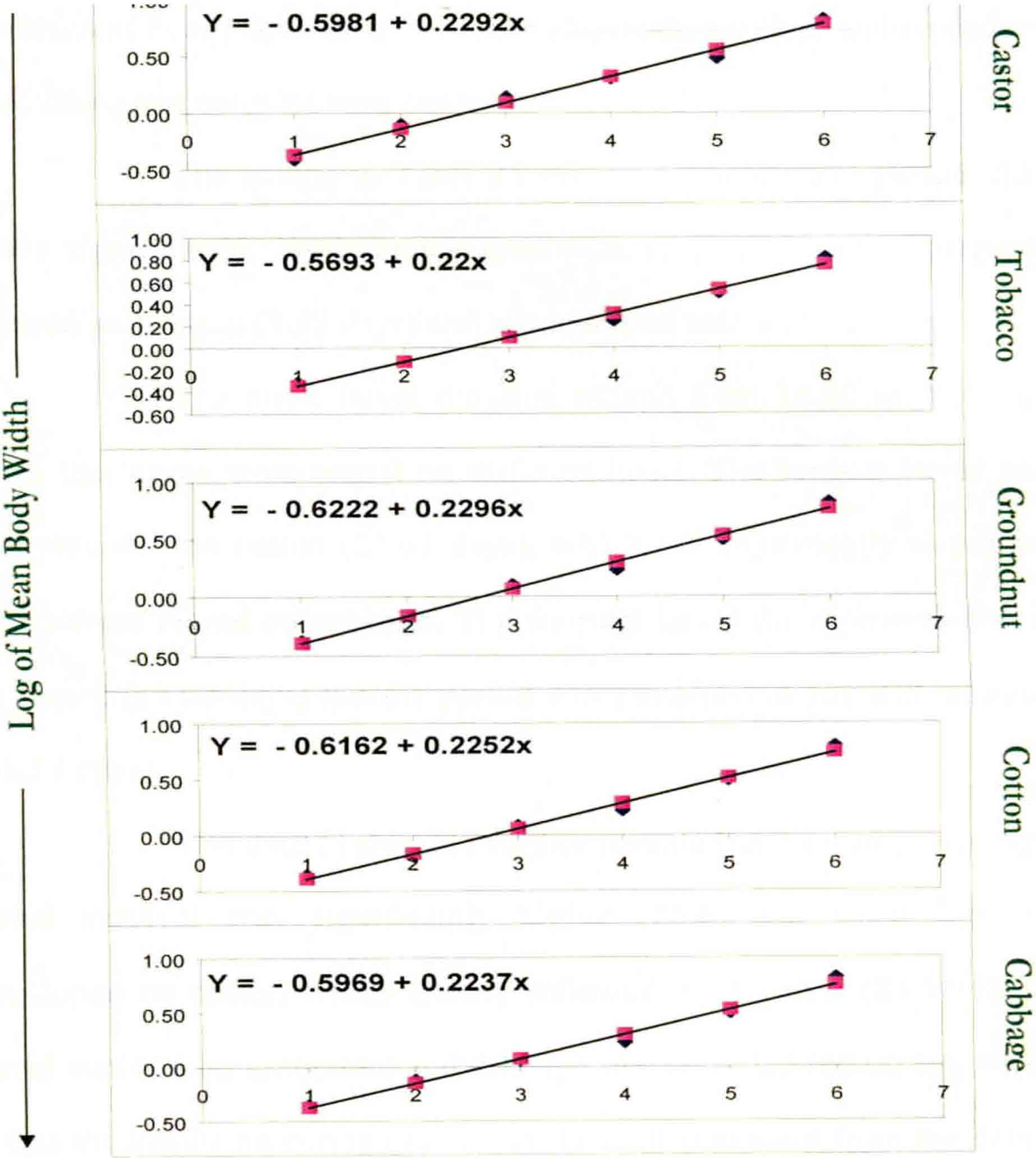


Fig. 3 : Relative growth in width of larvae of *S. litura* on different hosts

4.2 BIOLOGY ON DIFFERENT HOSTS

Present investigations were carried out to determine the effect of different host plants on growth, development, survival and reproduction of *S. litura* at a constant temperature of 27 ± 1 °C.

The results in Table 21 revealed that the egg period did not differ significantly, however the maximum egg period was observed on tobacco and cotton (3.53 days) and minimum on castor (3.23 days).

The mean larval duration ranged from 18.00 to 23.63 days, when the larvae were reared on different hosts. The longest larval period was recorded on cotton (23.63 days), which was statistically at par when larvae were reared on cabbage. The shortest larval duration was observed on castor (18.00 days) but the period was remained at par with groundnut (18.17 days).

The data (Table 21) further revealed that mean percentage of larval survival was significantly higher (86.67 %) when they were developed on castor, which closely followed, by tobacco (83.33 %). The larval survival on groundnut and cabbage was recorded (80.00 %), whereas it was the lowest on cotton (73.33 %). Thus, it is evident from the data that castor proved to be the most suitable host for the growth of the larvae.

Table 21: Life cycle of *S. litura* on different host plants

Host	Mean incubation period (days)	Mean larval duration (days) (N_2)	Mean pre-pupal period (days)	Mean pupal period (days)	Total life-span		Mean per cent larvae survived	Growth index (N_1/N_2)	Mean per cent pupae formed (N_1)
					Male	Female			
Castor	3.23	18.00	2.07	9.10	37.42	41.92	86.67	4.86	87.50
Tobacco	3.53	19.53	2.23	9.27	38.25	42.67	83.33	4.35	85.00
Groundnut	3.27	18.17	2.20	9.37	42.42	47.33	80.00	4.26	77.50
Cotton	3.53	23.63	2.33	9.47	43.42	47.92	73.33	3.07	72.50
Cabbage	3.43	22.53	2.23	9.43	42.75	46.83	80.00	3.33	75.00
S.Em. ±	0.10	0.17	0.07	0.10	0.38	0.36	0.46	-	2.38
C.D. at 5%	NS	0.47	NS	NS	1.09	1.01	1.33	-	5.98
C.V. %	15.74	4.58	18.41	5.93	3.26	2.74	5.08	-	7.40

Similarly, the prepupal period ranged from 2.07 to 2.33 days on different hosts, but there were no significant difference observed on five different hosts. However, the longest period (2.33 days) was recorded on cotton and the shorted on (2.07 days) on castor.

The results on percentage pupae formed, when the larvae reared on different hosts revealed that the highest percentage of pupae (87.50 %) were obtained, when larvae were fed on castor, which remained stastically at par with tobacco (85.00 %). However, the least percent pupae (72.50 %) were recorded on cotton, which was at par with groundnut (77.50 %) and cabbage (75.00 %).

Results on growth index (Table 21) indicated that the value of growth index was the highest (4.86) on castor followed by tobacco (4.35) and groundnut (4.26). These values were almost similar on the other remaining hosts under study.

The longest pupal period (9.47 days) was recorded on cotton whereas it was the shortest on castor (9.10 days). However, no significant difference was observed for pupal period when the larvae were reared on different hosts.

The life span of male moth ranged from 37.42 to 43.42 days on different hosts under study. The maximum period was observed on

cotton (43.42 days), which was at par with cabbage (42.75 days) and groundnut (42.42 days) followed by on tobacco (38.25 days) and on castor (37.42 days). The life span of female was the highest on cotton (47.92 days) and was at par on groundnut and cabbage followed by castor and tobacco.

The data presented in Table 22 indicated that the preoviposition period varied from 1.25 to 1.58 days on different hosts. This period was the highest (1.58 days) on cotton and the lowest (1.25 days) on tobacco. However, no significant difference was observed on this duration when the pest was reared on the five different hosts under study.

The oviposition period was significantly affected by different hosts. The highest period was observed on castor (7.58 days) followed by on tobacco (7.33 days), whereas it was the lowest on groundnut (6.42 days) and it was at par on cotton and cabbage.

Data on fecundity of female moths showed that the egg laying capacity of the female ranged from 2269 to 1591 on five different hosts. Significantly the highest number of eggs were recorded when the females obtained from the larvae reared on castor. Groundnut was not the suitable host as the fecundity was low (1591.58) on this crop. The fecundity differs significantly, when the adults were obtained from the larvae reared on tobacco followed by cabbage and cotton.

Table 22 : Mean preoviposition, oviposition, post oviposition periods, longevity and fecundity of *S. litura* reared on different hosts

Host	Mean pre-oviposition period (days)	Mean oviposition period (days)	Mean post-oviposition period (days)	Mean longevity		Mean fecundity
				Male	Female	
Castor	1.42	7.58	2.17	7.17	11.50	2269.25
Tobacco	1.25	7.33	2.33	6.58	10.75	1819.58
Groundnut	1.42	6.42	2.42	6.25	10.42	1591.58
Cotton	1.58	6.75	2.67	6.33	10.17	1592.67
Cabbage	1.42	6.50	2.58	6.42	10.67	1669.25
S.Em. ±	0.14	0.16	0.14	0.16	0.24	14.11
C.D. at 5%	NS	0.46	NS	0.45	0.68	39.92
C.V. %	35.51	8.21	19.85	8.34	7.82	2.73

4.3 POPULATION DYNAMICS OF *S. litura*

Investigation on the population dynamics of *S. litura* was carried out for two consecutive years (2003-04 and 2004-05) at Anand under middle Gujarat conditions.

4.3.1 Larval population

4.3.1.1 Population trend

Pooled data of larval population (Table 23 and Fig. 4) revealed that the pest infestation commenced from first week of October (40th standard week). The population showed increasing trend up to second week of November (46th standard week) (18.09 larvae per 3 leaves) and attained a peak. During 2nd week of November to first week of December (46th to 49th standard week) the population remained static but then it gradually decreased up to second week of January (1st standard week) and then disappeared.

Thus, the data clearly indicated that the pest was active from October to January and was at peak during the month of November to December on castor.

4.3.1.2 Effect of weather parameters

In order to determine the effect of physical factors of environment responsible for causing such fluctuation in the pest activity, a correlation study was attempted. Results of the study (Table 24 and Fig. 5) revealed that WS (-0.55) had significant negative correlation with the larval

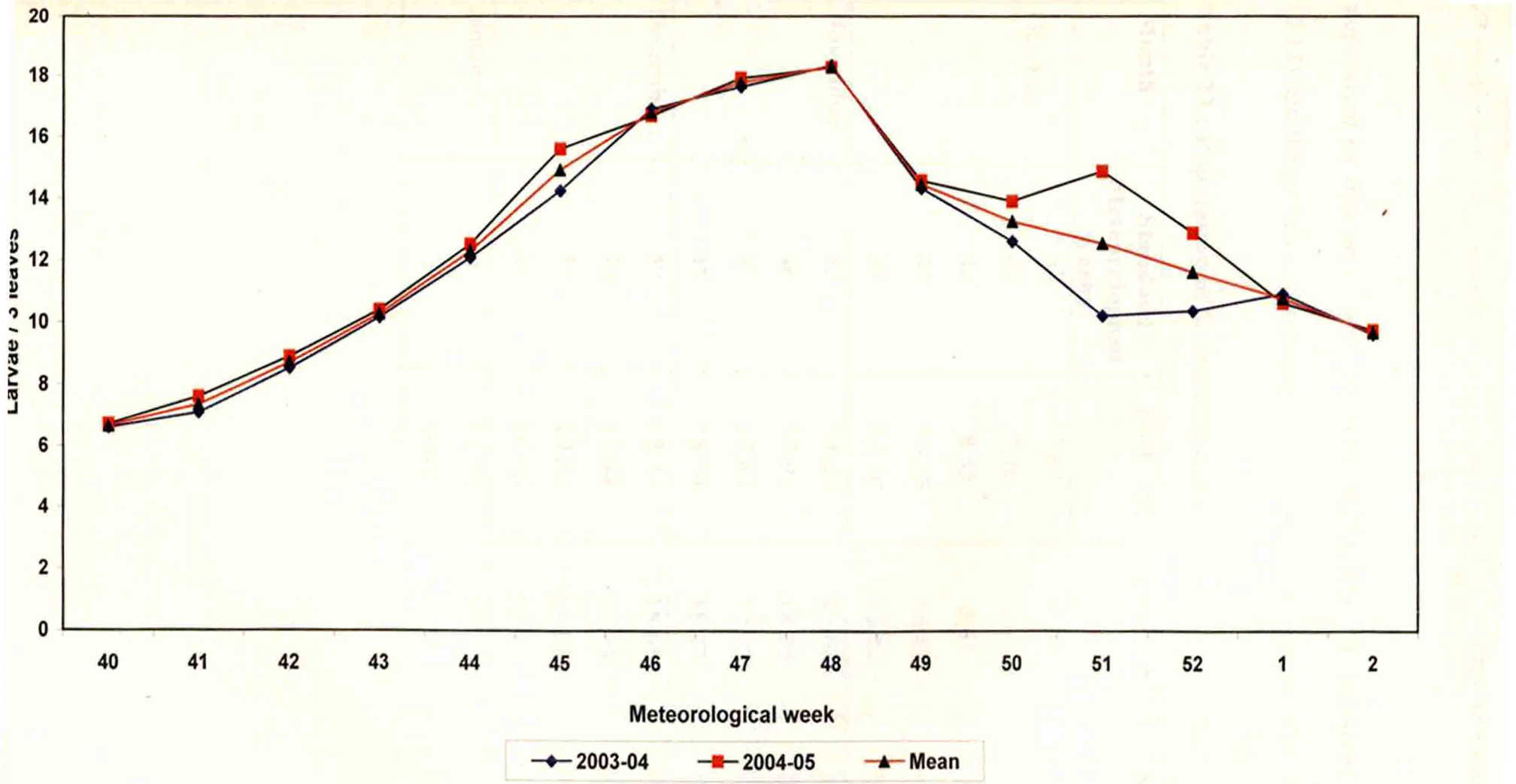
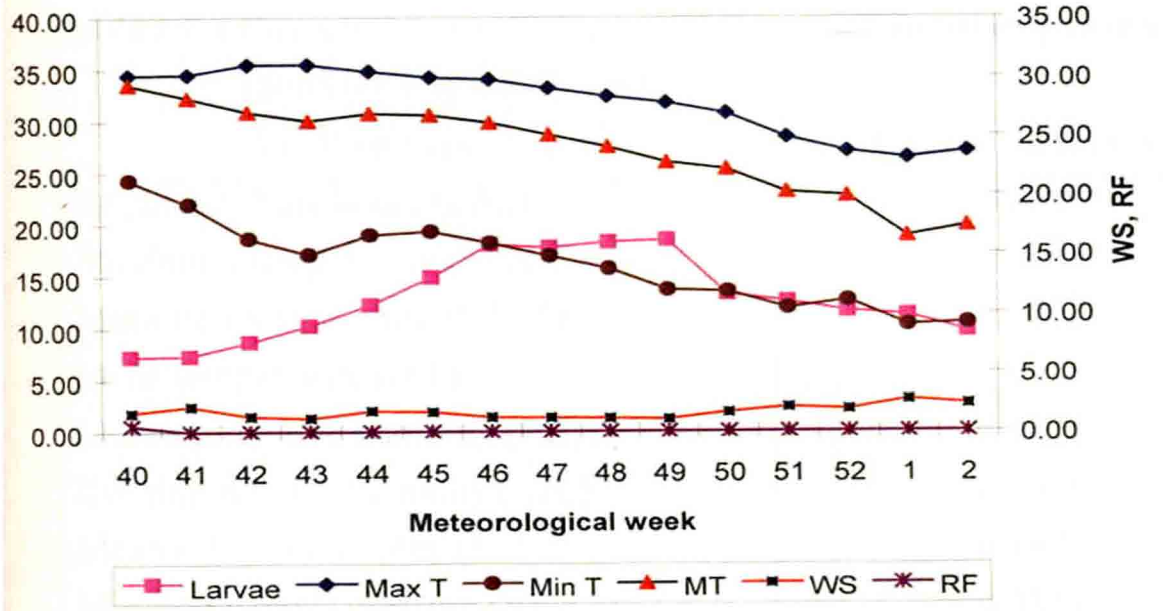


Fig. 4 : Population of *S. litura*

population of this pest, whereas BSS (0.26), Max. T. (0.0049) and RH_1 (0.18) had the positive correlation.

Table 23 : Population of *S. litura* on castor

Month	Standard Meteorological weeks	2003 – 04	2004 – 05	Mean
October	40	7.61	6.98	7.30
	41	7.10	7.62	7.36
	42	8.55	8.91	8.73
	43	10.18	10.42	10.30
	44	12.10	12.53	12.31
November	45	14.26	15.62	14.94
	46	17.92	18.25	18.09
	47	17.64	17.92	17.78
	48	18.34	18.27	18.31
December	49	18.35	18.65	18.50
	50	12.64	13.94	13.29
	51	10.25	14.91	12.58
	52	10.40	12.91	11.66
January	1	11.65	10.90	11.28
	2	9.64	9.77	9.70



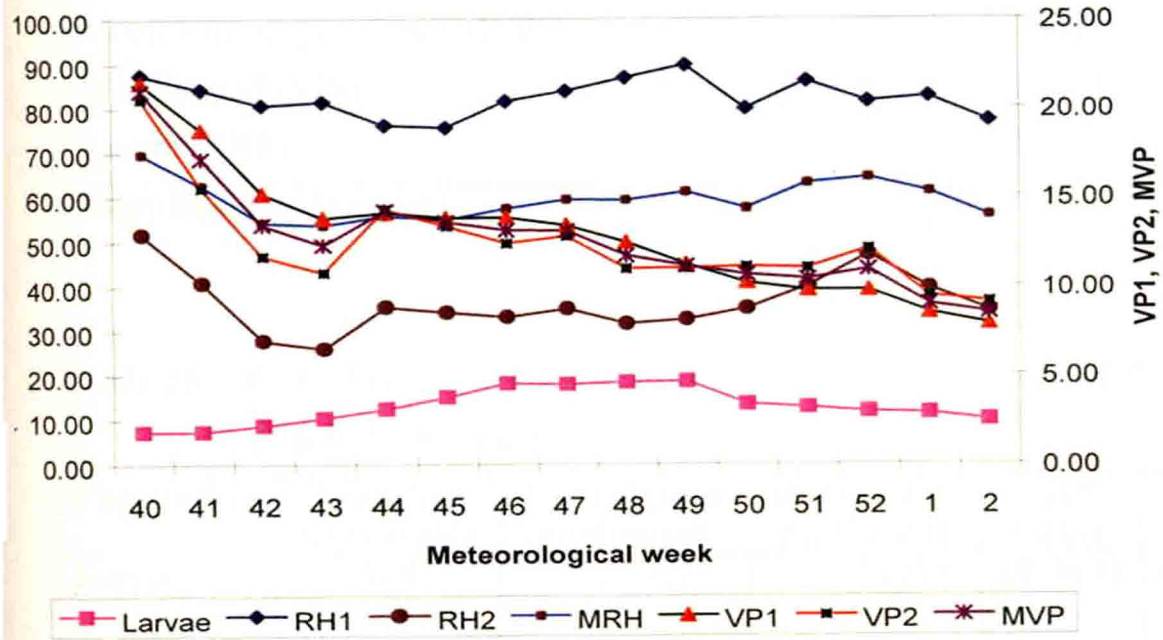


Fig. 5 : Population of *S. litura* larvae in relation to weather parameters

Table 24 : Correlation coefficient of *S. litura* and weather parameters (2003 – 04 and 2004 – 05)

Weather parameters	Larvae / 3 leaves
Bright sunshine hours (BSS)	0.2644
Maximum temperature (Max T)	0.0049
Minimum temperature (Min T)	– 0.2418
Mean temperature (MT)	– 0.0905
Morning relative humidity (RH_1)	0.1884
Evening relative humidity (RH_2)	– 0.3688
Mean relative humidity (MRH)	– 0.1925
Morning vapour pressure (VP_1)	– 0.3351
Evening vapour pressure (VP_2)	– 0.3385
Mean vapour pressure (MVP)	– 0.3463
Wind speed (WS)	– 0.5528*
Rainfall (RF)	– 0.3874

* Significant at 5% level

Table 25 : Correlation coefficient and regression coefficient of *S. litura* population with weather factor

Population	Weather parameter	Correlation coefficient	Regression coefficient	"A" value	R^2
Larvae	WS	– 0.5528*	– 5.7497*	29.7491	0.5762
	VP_1	– 0.3351	– 0.5781		

The regression equation (Table 25) was worked out by taking *S. litura* population (Y) as a dependent variable and meteorological parameters as independent variables the following equation was fitted.

$$Y = 29.749 - 5.750^{*} WS - 0.578 VP_1 \qquad (R^2 = 0.5762)$$

Where,

WS = Wind speed

VP_1 = Morning vapour pressure

The value of coefficient of determination (R^2) was worked out to the tune of 0.5762 indicating 57.62 per cent variation in population was explained due to these weather factors.

4.4 FECUNDITY LIFE TABLES ON DIFFERENT HOST CROPS

The studies on life tables, age specific distribution and life expectancy of *S. litura* was carried out on castor (*Ricinus communis* L.), tobacco (*Nicotiana tabacum* L.), groundnut (*Arachis hypogaea* L.), cabbage (*Brassica oleracea* var. *capitata* L.) and cotton (*Gossypium hirsutum* L.) hosts under laboratory at a constant temperature of 27 ± 1 °C. The results obtained are presented in the subsequent headings.

4.4.1 Castor

An attempt was made to work out the number of individual survived during development of this pest on castor. The results (Table 26) indicated that there was no mortality in egg stage. The number survived

Table 26: Survival of different life stages of *S. litura* during development on castor

No. of eggs	Number survived		
	Egg stage (0 – 3 days)	Larval stage (4 – 21 days)	Pupal stage (22 – 34 days)
10	10	10	9
10	10	8	8
10	10	10	9
10	10	9	8
10	10	8	7
10	10	9	8
10	10	9	9
10	10	9	9
10	10	8	8
10	10	9	8
100	100	89	83

from egg to adults emergence was 83 individuals. The maximum duration of egg, larval and pupa was recorded to be 3, 18 and 13 days, respectively.

Life fecundity tables were constructed to determine the survival of female at different age intervals (lx) and age specific fecundity (mx). A close perusal of the data (Tables 27 and 28 and Fig. 6) indicated that pre-oviposition period ranged from 35th to 36th day of pivotal age. Female started laying eggs after 36th day. The maximum mean progeny production per day (mx = 395.64) was observed on the 42nd day of pivotal age, which declined to 13.62 (mx) on the 47th day. First female died on 45th day (lx = 0.74) and then mortality increased.

The net reproductive potential (Ro) was obtained 1370.74 with the mean length of generation (T) 41.61 days. The intrinsic rate of natural increase in numbers (rm) was worked out to the tune of 0.174 females per female per day. Further, the data indicated that the population would be able to multiply 2.02 times per week. The hypothetical F_2 females were worked out to be 1878928.15. Stable age distribution of *S. litura* was worked out by observing the age schedule of birth rate and death rate (mx and lx). The results (Table 29) revealed that adults contributed only 0.16 per cent to the population of stable age, whereas eggs, larvae and pupae contributed 52.04, 46.08 and 1.71 per cent, respectively. Thus, the table clearly suggested that the maximum contribution towards the stable age distribution was made by the immature stages.

Table 27 : Life table (for female) and age specific fecundity for *S. litura* on castor

Pivotal age in days x	Survival of female at different age interval lx	Age schedule for female births mx	lxmx	xlxmx
0 – 34	0.89	-	-	Immature
35	0.83	-	0.83	29.05
36	0.83	-	0.83	29.88
37	0.83	26.58	22.06	816.22
38	0.83	97.96	81.31	3089.78
39	0.83	168.54	139.89	5455.71
40	0.83	189.90	157.62	6304.80
41	0.83	203.17	168.63	6913.83
42	0.83	395.64	328.38	13791.96
43	0.83	292.60	242.86	10442.98
44	0.80	180.00	144.00	6336.00
45	0.74	85.30	63.12	2840.40
46	0.65	23.00	14.95	687.70
47	0.46	13.62	6.26	294.22
48	0.38	0.00	0.00	0.00
			∑lxmx = 1370.74	**∑xlxmx = 57032.53**

Table 28 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *S. litura* on castor.

Sr. No.	Population growth statistics	Formula	Calculated values
1.	Net reproductive rate	$Ro = \sum lxmx$	1370.74
2.	Mean length of generation	$Tc = \frac{\sum xlxmx}{Ro}$	41.61 days
3.	Innate capacity for increase in numbers	$rm = \frac{\log e^{Ro}}{Tc}$	0.174 Females/female/day
4.	Arbitary 'rm' (rc)	0.17 and 0.18	
5.	Corrected 'rm'	$\sum e^{7 - rmx.\ lxmx}$	0.176 Females/female/day
6.	Corrected generation time	$T = \frac{\log e^{Ro}}{rm}$	41.04 days
7.	Finite rate of increase in numbers	$(\lambda) = \text{antilog } e^{rm}$	1.192 Females/female/day
8.	Weekly multiplication of population	$(\lambda)^7$	2.02 times
9.	Hypothetical F_2 females	$(Ro)^2$	1878928.15

Table 29 : Age specific distribution of *S. litura* on castor (rm = 0.176).

Pivotal age in days 'x'	Lx	$e^{-rm(x+1)}$	Lx . $e^{-rm(x+1)}$	Percentage distribution
0	1.00	0.8386	0.8386	16.6184
1	1.00	0.7033	0.7033	13.9372
2	1.00	0.5898	0.5898	11.6880
3	1.00	0.4946	0.4946	9.8014
				52.045
4	0.98	0.4148	0.4065	8.0556
5	0.98	0.3478	0.3409	6.7556
6	0.96	0.2917	0.2800	5.5487
7	0.96	0.2446	0.2348	4.6530
8	0.96	0.2052	0.1969	3.9019
9	0.92	0.1720	0.1583	3.1370
10	0.92	0.1443	0.1327	2.6297
11	0.90	0.1210	0.1089	2.1580
12	0.90	0.1015	0.0913	1.8093
13	0.90	0.0851	0.0766	1.5180
14	0.90	0.0714	0.0642	1.2722
15	0.90	0.0598	0.0539	1.0681
16	0.89	0.0502	0.0447	0.8858
17	0.89	0.0421	0.0374	0.7412
18	0.89	0.0353	0.0314	0.6222
19	0.89	0.0296	0.0263	0.5212
20	0.89	0.0248	0.0221	0.4380
21	0.89	0.0208	0.0185	0.3666
				46.0821

22	0.89	0.0174	0.0155	0.3072
23	0.89	0.0146	0.0130	0.2576
24	0.89	0.0123	0.0109	0.2160
25	0.89	0.0103	0.0092	0.1823
26	0.89	0.0086	0.0077	0.1526
27	0.89	0.0072	0.0064	0.1268
28	0.89	0.0061	0.0054	0.1070
29	0.89	0.0051	.00045	0.0892
30	0.89	0.0043	0.0038	0.0753
31	0.89	0.0036	0.0032	0.0634
32	0.89	0.0030	0.0027	0.0535
33	0.89	0.0025	0.0022	0.0436
34	0.89	0.0021	0.0019	0.0376
				1.7121
35	0.83	0.0018	0.0015	0.0297
36	0.83	0.0015	0.0012	0.0238
37	0.83	0.0012	0.0010	0.0198
38	0.83	0.0010	0.0009	0.0178
39	0.83	0.0009	0.0007	0.0139
40	0.83	0.0007	0.0006	0.0119
41	0.83	0.0006	0.0005	0.0099
42	0.83	0.0005	0.0004	0.0079
43	0.83	0.0004	0.0004	0.0079
44	0.80	0.0004	0.0003	0.0059
45	0.74	0.0003	0.0002	0.0040
46	0.65	0.0003	0.0002	0.0040
47	0.46	0.0002	0.0001	0.0020
48	0.38	0.0002	0.0001	0.0020
				0.1605

An attempt was also made to work out life expectancy of *S. litura* on castor. The results (Table 30) showed that the life expectancy of newly deposited eggs was only 17.39 days. Further, it has been clearly observed that the mortality rate was comparatively high at the age of 40 to 45 days, when the expectation of further life reduced to 3.57 days from 17.39 days in the beginning.

4.4.2 Tobacco

The results on survival of different stages of *S. litura* on tobacco are summarized in Table 31. It is evident from the data that the maximum duration of egg, larva and pupa were observed 3, 20 and 13 days, respectively. The number that survived from egg to adult emergence was 83 individuals.

The results (Table 32 and Fig. 6) further indicated that pre-oviposition period ranged from 37^{th} to 38^{th} day of pivotal age. Females deposited first batch of eggs on 39^{th} day. The first female mortality was recorded on 9^{th} day (lx = 0.80) after the emergence of adult female and it increased slowly thereafter. The females contributed the highest (mx = 179.32) in the life cycle on 44^{th} day of pivotal age. The net reproductive rate (Ro), representing the total female births was 708.27 with the mean length of generation (T) 43.20 days.

Table 30 : Life table for computing life expectancy of *S. litura* reared on castor.

Pivotal age (Days)	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\left(\frac{dx \cdot 100}{lx}\right)$	Alive between age 'x' and 'x + 1' $\frac{lx + (lx + 1)}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{Tx \times 2}{lx}$
(x)	(lx)	(dx)	(100 qx)	(Lx)	(Tx)	(ex)
0-5	100	2	2.00	99.0	869.5	17.39
5-10	98	6	6.12	95.0	770.5	15.72
10-15	92	2	2.17	91.0	675.5	14.68
15-20	90	1	1.11	89.5	584.5	12.99
20-25	89	0	0.00	89.0	495.0	11.12
25-30	89	0	0.00	89.0	406.0	9.12
30-35	89	6	6.74	86.0	317.0	7.12
35-40	83	0	0.00	83.0	231.0	5.57
40-45	83	9	10.84	78.5	148.0	3.57
45-50	74	36	48.65	69.5	69.5	1.88

Table 31: Survival of different life stages of *S. litura* during development on tobacco.

No. of eggs	Number survived		
	Egg stage (0 – 3 days)	Larval stage (4 – 23 days)	Pupal stage (24 – 36 days)
10	9	9	8
10	10	8	8
10	10	9	9
10	10	9	8
10	9	9	8
10	10	9	9
10	10	8	8
10	10	9	8
10	9	8	8
10	10	9	9
100	97	87	83

Table 32 : Life table (for female) and age specific fecundity for *S. litura* on tobacco.

Pivotal age in days x	Survival of female at different age interval lx	Age schedule for female births mx	lxmx	xlxmx
0 – 36	0.87	-	-	Immature
37	0.83	-	0.83	30.71
38	0.83	-	0.83	31.54
39	0.83	19.10	15.85	618.15
40	0.83	61.20	50.80	2032.00
41	0.83	97.48	80.91	3317.31
42	0.83	127.56	105.87	4446.54
43	0.83	156.92	130.24	5600.32
44	0.83	179.32	148.84	6548.96
45	0.83	97.18	80.66	3629.70
46	0.80	80.75	64.60	2971.60
47	0.72	27.98	20.14	946.58
48	0.60	9.20	5.52	264.58
49	0.46	6.92	3.18	155.82
50	0.42	-	-	-
			$\sum$lxmx = 708.27	$\sum$xlxmx = 30594.19

It is evident from the Table 33 that the innate capacity of increase in numbers (rm) was 0.152 females per female per day with a finite rate of increase (λ) 1.166 females per female per day and population would multiply 2.93 times per week. The values for hypothetical female population in F_2 generation was worked out to the tune of 501646.39.

The contribution of different developmental stages towards the stable age distribution was determined and the results are summarized in Table 34. It has been observed that on reaching the stable age distribution, the population in its various stages *viz.*, eggs, larvae, pupae and adults contributed to the extent of 48.51, 49.22, 2.00 and 0.26 per cent, respectively. Thus, it is clear from the data that immature stages contributed the maximum towards the stable age distributions.

The life expectancy table was constructed and the results are presented in Table 35. The life expectancy (ex) of newly deposited eggs was only 17.44 days. Mortality rate was comparatively high at the age of 35-40 days. The expectation of further life was reduced to 5.74 days from 17.44 days in the beginning.

4.4.3 Groundnut

The data showing survival of different stages of *S. litura* when it was reared on groundnut are summarized in Table 36 and Fig. 6. The data showed that there was only 4 per cent mortality in egg stage. The number that survived from egg to adult emergence was 81 individuals. The maximum duration of egg, larvae and pupa were recorded to be 3, 18 and 12 days, respectively.

Table 33 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *S. litura* on tobacco.

Sr. No.	Population growth statistics	Formula	Calculated values
1.	Net reproductive rate	$Ro = \sum lxmx$	708.27
2.	Mean length of generation	$Tc = \frac{\sum xlxmx}{Ro}$	43.20 days
3.	Innate capacity for increase in numbers	$rm = \frac{\log e^{Ro}}{Tc}$	0.152 Females/female/day
4.	Arbitary 'rm' (rc)	0.15 and 0.16	
5.	Corrected 'rm'	$\sum e^{7 - rmx.\ lxmx}$	0.1535 Females/female/day
6.	Corrected generation time	$T = \frac{\log e^{Ro}}{rm}$	42.75 days
7.	Finite rate of increase in numbers	$(\lambda) = \text{antilog } e^{rm}$	1.166 Females/female/day
8.	Weekly multiplication of population	$(\lambda)^7$	2.93 times
9.	Hypothetical F_2 females	$(Ro)^2$	501646.39

Table 34 : Age specific distribution of *S. litura* on tobacco (rm = 0.1535).

Pivotal age in days 'x'	Lx	$e^{-rm(x+1)}$	Lx . $e^{-rm(x+1)}$	Percentage distribution
0	1.00	0.8577	0.8577	15.1344
1	1.00	0.7356	0.7356	12.9799
2	1.00	0.6310	0.6310	11.1342
3	0.97	0.5412	0.5250	9.2638
				48.5123
4	0.95	0.4642	0.4410	7.7816
5	0.93	0.3981	0.3702	6.5323
6	0.90	0.3415	0.3074.	5.4242
7	0.88	0.2929	0.2578	4.5490
8	0.88	0.2512	0.2210	3.8996
9	0.88	0.2154	0.1896	3.3455
10	0.88	0.1848	0.1626	2.8691
11	0.88	0.1585	0.1395	2.4615
12	0.88	0.1359	0.1196	2.1104
13	0.87	0.1166	0.1014	1.7892
14	0.87	0.1000	0.0870	1.5351
15	0.87	0.0858	0.0746	1.3163
16	0.87	0.0736	0.0640	1.1293
17	0.87	0.0631	0.0549	0.9687
18	0.87	0.0541	0.0471	0.8311
19	0.87	0.0464	0.0404	0.7129
20	0.87	0.0398	0.0346	0.6105
21	0.87	0.0341	0.0297	0.5241
22	0.87	0.0293	0.0255	0.4499
23	0.87	0.0251	0.0218	0.3847
				49.2250

24	0.87	0.0215	0.0187	0.3300
25	0.87	0.0185	0.0161	0.2841
26	0.87	0.0158	0.0137	0.2417
27	0.87	0.0136	0.0118	0.2082
28	0.87	0.0117	0.0102	0.1800
29	0.87	0.0100	0.0087	0.1535
30	0.87	0.0086	0.0075	0.1323
31	0.87	0.0074	0.0064	0.1129
32	0.87	0.0063	0.0055	0.0970
33	0.87	0.0054	0.0047	0.0829
34	0.87	0.0046	0.0040	0.0706
35	0.87	0.0040	0.0035	0.0618
36	0.87	0.0034	0.0030	0.0529
				2.0079
37	0.83	0.0029	0.0024	0.0423
38	0.83	0.0025	0.0021	0.0370
39	0.83	0.0022	0.0018	0.0318
40	0.83	0.0018	0.0015	0.0265
41	0.83	0.0016	0.0013	0.0229
42	0.83	0.0014	0.0012	0.0212
43	0.83	0.0012	0.0010	0.0176
44	0.83	0.0010	0.0008	0.0141
45	0.83	0.0008	0.0007	0.0124
46	0.80	0.0007	0.0006	0.0106
47	0.72	0.0006	0.0004	0.0070
48	0.60	0.0005	0.0003	0.0053
49	0.46	0.0005	0.0002	0.0035
50	0.42	0.0004	0.0002	0.0035
				0.2557

Table 35 : Life table for computing life expectancy of *S. litura* reared on tobacco.

Pivotal age (Days)	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\left(\frac{dx \cdot 100}{lx}\right)$	Alive between age 'x' and 'x + 1' $\frac{lx + (lx + 1)}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{Tx}{lx} \times 2$
(x)	(lx)	(dx)	(100 qx)	(Lx)	(Tx)	(ex)
0-5	100	7	7.00	96.5	872.0	17.44
5-10	93	5	5.38	90.5	775.5	16.68
10-15	88	1	1.14	87.5	685.0	15.57
15-20	87	0	0.00	87.0	597.5	13.74
20-25	87	0	0.00	87.0	510.5	11.74
25-30	87	0	0.00	87.0	423.5	9.74
30-35	87	0	0.00	87.0	336.5	7.74
35-40	87	4	4.60	85.0	249.5	5.74
40-45	83	0	0.00	83.0	164.5	3.96
45-50	83	41	49.40	81.5	81.5	1.96

Table 36: Survival of different life stages of *S. litura* during development on groundnut.

No. of eggs	Number survived		
	Egg stage (0 – 3 days)	Larval stage (4 – 22 days)	Pupal stage (23 – 35 days)
10	10	9	8
10	10	9	8
10	10	8	8
10	10	9	8
10	10	9	8
10	8	7	7
10	10	9	9
10	10	9	8
10	9	8	8
10	9	9	9
100	96	86	81

The results (Table 37) of fecundity life table for females indicated that adult emergence commenced on 36th days of pivotal age. The pre-oviposition period ranged from 36th to 37th day of pivotal age. Females deposited first batch of eggs on the 38th day and it was continued upto 49th day. First female died on 44th day of pivotal age. The maximum mean progeny production per day (mx = 186.25) was observed on the 41st day of pivotal age which declined (mx = 17.25) on 48th day. First female died on 44th day (lx = 0.76) which increased slowly, thereafter. The net reproductive rate (Ro), representing the ratio of total female births in two successive generations was recorded 819.92.

The data on intrinsic rate of natural increase (rm) and generation time are presented in Table 38. It is evident from the data that the intrinsic rate of natural increase in number (rm) was 0.160 females per female per day with finite rate of increase in number 1.176 females per female per day. The population would multiply 3.11 times per week with the hypothetical females population in F_2 generation of 672268.81.

The stable age distribution of *S. litura* was worked out by observing the age schedule of birth rate and death rate (mx and lx). The results (Table 39) revealed that adults contributed only 0.20 per cent to the population of stable age, whereas, eggs, larvae and pupae contributed 50.60, 47.24 and 1.94 per cent, respectively.

Table 37 : Life table (for female) and age specific fecundity for *S. litura* on groundnut.

Pivotal age in days x	Survival of female at different age interval lx	Age schedule for female births mx	lxmx	xlxmx
0 – 35	0.86	-	-	Immature
36	0.81	-	0.81	29.16
37	0.81	-	0.81	29.97
38	0.81	48.90	39.61	1505.18
39	0.81	112.43	91.07	3551.66
40	0.81	157.76	127.78	5111.42
41	0.81	186.25	150.86	6185.36
42	0.81	140.10	113.48	4766.20
43	0.81	119.00	96.39	4144.77
44	0.76	107.13	81.42	3582.43
45	0.58	98.76	57.28	2577.64
46	0.43	76.80	33.02	1519.10
47	0.40	52.96	21.18	995.65
48	0.36	17.25	6.21	298.08
49	0.32	0.00	0.00	0.00
			$\sum$lxmx = 819.92	$\sum$xlxmx = 34296.62

Table 38 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *S. litura* on groundnut.

Sr. No.	Population growth statistics	Formula	Calculated values
1.	Net reproductive rate	$Ro = \sum lxmx$	819.92
2.	Mean length of generation	$Tc = \frac{\sum xlxmx}{Ro}$	41.83 days
3.	Innate capacity for increase in numbers	$rm = \frac{\log e^{Ro}}{Tc}$	0.160 Females/female/day
4.	Arbitary 'rm' (rc)	0.16 and 0.17	
5.	Corrected 'rm'	$\sum e^{7 - rmx.\ lxmx}$	0.162 Females/female/day
6.	Corrected generation time	$T = \frac{\log e^{Ro}}{rm}$	41.41 days
7.	Finite rate of increase in numbers	$(\lambda) = \text{antilog } e^{rm}$	1.176 Females/female/day
8.	Weekly multiplication of population	$(\lambda)^7$	3.11 times
9.	Hypothetical F_2 females	$(Ro)^2$	672268.81

Table 39 : Age specific distribution of *S. litura* on groundnut (rm = 0.162).

Pivotal age in days 'x'	Lx	$e^{-rm(x+1)}$	Lx . $e^{-rm(x+1)}$	Percentage distribution
0	1.00	0.8507	0.8507	15.9913
1	1.00	0.7232	0.7232	13.5993
2	1.00	0.6151	0.6151	11.5666
3	0.96	0.5231	0.5022	9.4436
				50.6008
4	0.92	0.4448	0.4092	7.6948
5	0.90	0.3783	0.3405	6.4029
6	0.88	0.3217	0.2831	5.3235
7	0.88	0.2736	0.2408	4.5281
8	0.88	0.2327	0.2048	3.8511
9	0.88	0.1979	0.1742	3.2757
10	0.88	0.1683	0.1481	2.7849
11	0.88	0.1431	0.1259	2.3675
12	0.87	0.1217	0.1059	1.9914
13	0.87	0.1035	0.0900	1.6924
14	0.87	0.0880	0.0766	1.4404
15	0.87	0.0749	0.0652	1.2260
16	0.86	0.0637	.0548	1.0305
17	0.86	0.0541	0.0465	0.8744
18	0.86	0.0460	0.0396	0.7446
19	0.86	0.0392	0.0337	0.6337
20	0.86	0.0333	0.0286	0.5378
21	0.86	0.0283	0.0243	0.4569
22	0.86	0.0241	0.0207	0.3892
				47.2458

23	0.86	0.0205	0.0176	0.3310
24	0.86	0.0174	0.0150	0.2821
25	0.86	0.0148	0.0127	0.2388
26	0.86	0.0126	0.0108	0.2031
27	0.86	0.0107	0.0092	0.1730
28	0.86	0.0091	0.0078	0.1467
29	0.86	0.0078	0.0067	0.1260
30	0.86	0.0066	0.0057	0.1072
31	0.86	0.0056	0.0048	0.0903
32	0.86	0.0048	0.0041	0.0771
33	0.86	0.0040	0.0034	0.0639
34	0.86	0.0034	0.0029	0.0545
35	0.86	0.0029	0.0025	0.0470
				1.9407
36	0.81	0.0025	0.0020	0.0376
37	0.81	0.0021	0.0017	0.0320
38	0.81	0.0018	0.0014	0.0263
39	0.81	0.0015	0.0012	0.0226
40	0.81	0.0013	0.0010	0.0188
41	0.81	0.0011	0.0009	0.0169
42	0.81	0.0009	0.0007	0.0132
43	0.81	0.0008	0.0006	0.0113
44	0.76	0.0007	0.0005	0.0094
45	0.58	0.0006	0.0003	0.0056
46	0.43	0.0005	0.0002	0.0038
47	0.40	0.0004	0.0002	0.0038
48	0.36	0.0004	0.0001	0.0019
49	0.32	0.0003	0.0001	0.0019
				0.2013

The life expectancy table was constructed and the results are presented in Table 40. The life expectancy (ex) of newly deposited eggs was only 16.39 days. The mortality rate was comparatively high at the age of 35-40 days. There was no mortality between 20 to 35 days of pivotal age.

4.4.4 Cotton

The data on survival of different stages of *S. litura* during development on cotton are presented in Table 41 and Fig. 6. There was only 4 per cent mortality in egg stage. The maximum duration of egg, larva and pupa were 3, 22 and 12 days, respectively. The number survived from egg to adult emergence was 80 individuals.

It is evident from the Table 42 that the immature stage lasted for 38 days. The pre-oviposition period ranged from 39th to 40th day of pivotal age. The first female mortality within the cohort occurred on 10th (lx = 0.63) day after the emergence of adult and than the mortality increased. The females contributed the highest egg production (mx = 292.64) on 46th day of pivotal age. The net reproductive rate (Ro) was 856.72 indicating that the population would be able to multiply 856.72 times at the end of every generation. Data in Table 43 showed that the intrinsic rate of natural increase in number (rm) was 0.148 females per female per day with daily finite rate of increase (λ) 1.161 females per female per day and population would be able to multiply 2.84 times per week. The mean duration of generation (T) was found to be 45.48 days for the cohort.

Table 40 : Life table for computing life expectancy of *S. litura* reared on groundnut.

Pivotal age (Days)	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\left(\frac{dx \cdot 100}{lx}\right)$	Alive between age 'x' and 'x + 1' $\frac{lx + (lx + 1)}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{Tx}{lx} \times 2$
(x)	(lx)	(dx)	(100 qx)	(Lx)	(Tx)	(ex)
0-5	100	10	10.00	95.0	819.5	16.39
5-10	90	2	2.22	89.0	724.5	16.1
10-15	88	1	1.14	87.5	635.5	14.44
15-20	87	1	1.15	86.5	548.0	12.60
20-25	86	0	0.00	86.0	461.5	10.73
25-30	86	0	0.00	86.0	375.5	8.73
30-35	86	0	0.00	86.0	289.5	6.73
35-40	86	5	5.81	83.5	203.5	4.73
40-45	81	23	28.40	69.5	120.0	2.96
45-50	58	28	48.28	50.5	50.5	1.74

Table 41: Survival of different life stages of *S. litura* during development on cotton.

No. of eggs	Number survived		
	Egg stage (0 – 3 days)	Larval stage (4 – 26 days)	Pupal stage (27 – 38 days)
10	10	9	8
10	10	9	8
10	10	8	8
10	9	9	8
10	9	8	8
10	10	9	9
10	9	8	7
10	10	8	8
10	9	8	7
10	10	9	9
100	96	85	80

Table 42 : Life table (for female) and age specific fecundity for *S. litura* on cotton.

Pivotal age in days x	Survival of female at different age interval lx	Age schedule for female births mx	lxmx	xlxmx
0 – 38	0.85	-	-	Immature
39	0.80	-	0.80	31.2
40	0.80	-	0.80	32.0
41	0.80	29.27	23.42	960.22
42	0.80	38.96	31.17	1309.14
43	0.80	97.32	77.86	3347.98
44	0.80	122.03	97.62	4295.28
45	0.80	209.83	167.86	7553.7
46	0.80	292.64	234.11	10769.06
47	0.80	153.32	122.66	5765.02
48	0.63	78.00	49.14	2358.72
49	0.55	62.13	34.17	1674.33
50	0.39	23.00	8.97	448.5
51	0.31	17.95	5.56	283.56
52	0.28	9.20	2.58	134.16
			$\sum$lxmx = 856.72	$\sum$xlxmx = 38962.87

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Table 43 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *S. litura* on cotton.

Sr. No.	Population growth statistics	Formula	Calculated values
1.	Net reproductive rate	$Ro = \sum lxmx$	856.72
2.	Mean length of generation	$Tc = \frac{\sum xlxmx}{Ro}$	45.48 days
3.	Innate capacity for increase in numbers	$rm = \frac{\log e^{Ro}}{Tc}$	0.148 Females/female/day
4.	Arbitary 'rm' (rc)	0.14 and 0.15	
5.	Corrected 'rm'	$\sum e^{7 - rmx.\ lxmx}$	0.1495 Females/female/day
6.	Corrected generation time	$T = \frac{\log e^{Ro}}{rm}$	45.17 days
7.	Finite rate of increase in numbers	$(\lambda) = \text{antilog } e^{rm}$	1.161 Females/female/day
8.	Weekly multiplication of population	$(\lambda)^7$	2.84 times
9.	Hypothetical F_2 females	$(Ro)^2$	733969.16

On reaching the stable age distribution (Table 44) the eggs, larvae, pupae and adults contributed to the tune of 47.80, 50.64, 1.33 and 0.20 per cent, respectively to the population.

The life expectancy data (Table 45) clearly indicated that life expectancy of *S. litura* declined gradually with the advancement of development. The life expectancy of newly deposited eggs was 17.45 days. The mortality rate was comparatively high at the age of 35-40 days, when the expectation of further life was reduced to 6.05 days from 17.45 days in the beginning.

4.4.5 Cabbage

The results on survival of different stages of *S. litura* on cabbage are summarized in Table 46. It is evident from the data that the maximum duration of eggs, larvae and pupae were observed 3, 20 and 12 days, respectively. The number that survived from egg to adult emergence was 80 individuals.

A close perusal of data (Tables 47 & 48 and Fig. 6) indicated that pre-oviposition period ranged from 38th to 39th day of pivotal age. Female started laying eggs after 39th day. The maximum mean progeny production per day (mx) of 215.14 was observed on the 45th day of pivotal age, which declined to 5.0 (mx) on the 51st day. First female died on 46th day (lx 0.76) and mortality increased thereafter. The net reproductive (Ro), was worked out to be 791.39.

Table 44 : Age specific distribution of *S. litura* on cotton (rm = 0.1495).

Pivotal age in days 'x'	Lx	$e^{-rm(x+1)}$	Lx . $e^{-rm(x+1)}$	Percentage distribution
0	1.00	0.8611	0.8611	14.8665
1	1.00	0.7416	0.7416	12.8034
2	1.00	0.6386	0.6386	11.0252
3	0.96	0.5499	0.5279	9.1140
				47.8091
4	0.92	0.4735	0.4356	7.5204
5	0.92	0.4078	0.3752	6.4776
6	0.90	0.3512	0.3161	5.4573
7	0.88	0.3024	0.2661	4.5941
8	0.88	0.2604	0.2292	3.9570
9	0.88	0.2242	0.1973	3.4063
10	0.88	0.1931	0.1699	2.9332
11	0.88	0.1663	0.1463	2.5258
12	0.88	0.1432	0.1260	2.1753
13	0.87	0.1233	0.1073	1.8525
14	0.87	0.1062	0.0924	1.5952
15	0.87	0.0914	0.0795	1.3725
16	0.87	0.0787	0.0685	1.1826
17	0.86	0.0678	0.0583	1.0065
18	0.86	0.0584	0.0502	0.8667
19	0.86	0.0503	0.0432	0.7458
20	0.86	0.0433	0.0372	0.6422
21	0.85	0.0373	0.0317	0.5473
22	0.85	0.0321	0.0273	0.4713
23	0.85	0.0276	0.0235	0.4057
24	0.85	0.0238	0.0202	0.3487

25	0.85	0.0205	0.0174	0.3004
26	0.85	0.0176	0.0150	0.2590
				50.6434
27	0.85	0.0152	0.0129	0.2227
28	0.85	0.0131	0.0111	0.1916
29	0.85	0.0113	0.0096	0.1657
30	0.85	0.0097	0.0082	0.1416
31	0.85	0.0084	0.0071	0.1226
32	0.85	0.0072	0.0061	0.1053
33	0.85	0.0062	0.0053	0.0915
34	0.85	0.0053	0.0045	0.0777
35	0.85	0.0046	0.0039	0.0673
36	0.85	0.0040	0.0034	0.0587
37	0.85	0.0034	0.0029	0.0500
38	0.85	0.0029	0.0025	0.0432
				1.3379
39	0.80	0.0025	0.0020	0.0345
40	0.80	0.0022	0.0018	0.0311
41	0.80	0.0019	0.0015	0.0259
42	0.80	0.0016	0.0013	0.0224
43	0.80	0.0014	0.0011	0.0190
44	0.80	0.0012	0.0010	0.0173
45	0.80	0.0010	0.0008	0.138
46	0.80	0.0009	0.0007	0.0121
47	0.80	0.0008	0.0006	0.0104
48	0.63	0.0006	0.0004	0.0069
49	0.55	0.0006	0.0003	0.0052
50	0.39	0.0005	0.0002	0.0034
51	0.31	0.0004	0.0001	0.0017
52	0.28	0.0004	0.0001	0.0017
				0.2054

Table 45 : Life table for computing life expectancy of *S. litura* reared on cotton.

Pivotal age (Days)	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\left(\frac{dx \cdot 100}{lx}\right)$	Alive between age 'x' and 'x + 1' $\frac{lx + (lx + 1)}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{Tx}{lx} \times 2$
(x)	(lx)	(dx)	(100 qx)	(Lx)	(Tx)	(ex)
0-5	100	8	8.00	96.0	872.5	17.45
5-10	92	4	4.35	90.0	776.5	16.88
10-15	88	1	1.14	87.5	686.5	15.60
15-20	87	1	1.15	86.5	599.0	13.77
20-25	86	1	1.16	85.5	512.5	11.92
25-30	85	0	0.00	85.0	427.0	10.05
30-35	85	0	0.00	85.0	342.0	8.05
35-40	85	5	5.88	82.5	257.0	6.05
40-45	80	0	0.00	80.0	174.5	4.36
45-50	80	41	51.25	59.5	94.5	2.36
50-55	39	11	28.20	35.0	35.0	1.79

Table 46: Survival of different life stages of *S. litura* during development on cabbage.

No. of eggs	Number survived		
	Egg stage (0 – 3 days)	Larval stage (4 – 24 days)	Pupal stage (25 – 37 days)
10	10	9	8
10	10	9	8
10	9	9	8
10	10	8	7
10	10	9	8
10	8	8	8
10	8	8	8
10	10	9	9
10	9	8	8
10	9	9	8
100	96	86	80

Table 47 : Life table (for female) and age specific fecundity for *S. litura* on cabbage.

Pivotal age in days x	Survival of female at different age interval lx	Age schedule for female births mx	lxmx	xlxmx
0 – 37	0.86	-	-	Immature
38	0.80	-	0.80	30.40
39	0.80	-	0.80	31.20
40	0.80	14.26	11.41	456.40
41	0.80	47.24	37.79	1549.39
42	0.80	98.60	78.88	3312.96
43	0.80	119.80	95.84	4121.12
44	0.80	186.00	148.80	6547.20
45	0.80	215.14	172.11	7744.95
46	0.76	156.29	118.78	5463.88
47	0.70	138.50	96.95	4556.65
48	0.68	22.70	15.44	741.12
49	0.62	12.92	8.01	392.49
50	0.56	6.04	3.38	169.00
51	0.48	5.00	2.40	122.40
			$\sum$lxmx = 791.39	$\sum$xlxmx = 35239.16

Table 48 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *S. litura* on cabbage.

Sr. No.	Population growth statistics	Formula	Calculated values
1.	Net reproductive rate	$Ro = \sum lxmx$	791.39
2.	Mean length of generation	$Tc = \frac{\sum xlxmx}{Ro}$	44.53 days
3.	Innate capacity for increase in numbers	$rm = \frac{\log e^{Ro}}{Tc}$	0.15 Females/female/day
4.	Arbitary 'rm' (rc)	0.15 and 0.16	
5.	Corrected 'rm'	$\sum e^{7 - rmx.\ lxmx}$	0.1510 Females/female/day
6.	Corrected generation time	$T = \frac{\log e^{Ro}}{rm}$	44.20 days
7.	Finite rate of increase in numbers	$(\lambda) = \text{antilog } e^{rm}$	1.163 Females/female/day
8.	Weekly multiplication of population	$(\lambda)^7$	2.88 times
9.	Hypothetical F_2 females	$(Ro)^2$	626298.13

The data on intrinsic rate of natural increase (rm) and generation time are presented in Table 48. It is evident from the data that the intrinsic rate of natural increase in number (rm) was 0.15 females per female per day with finite rate of increase in number 1.163 females per female per day. The population would multiply 2.88 time per week with the hypothetical females population in F_2 generation of 626298.13.

The stable age distribution of *S. litura* was worked out by observing the age schedule of birth rate and death rate (mx and lx). It is evident from the results (Table 49) that adults contributed only 0.23 per cent to the population of stable age, whereas eggs, larvae and pupae contributed 48.17, 49.78 and 1.82 per cent, respectively.

The data on life expectancy of *S. litura* (Table 50) clearly indicated that it declined gradually with the development. The life expectancy of newly deposited eggs was 17.98 days. The mortality rate was comparatively high at the age of 35 to 40 days, when the expectation of further life was reduced to 6.58 days from 17.98 days in the beginning.

Table 49: Age specific distribution of *S. litura* on cabbage (rm = 0.1510)

Pivotal age in days 'x'	Lx	$e^{-rm(x+1)}$	Lx . $e^{-rm(x+1)}$	Percentage distribution
0	1.00	0.8598	0.8598	15.0085
1	1.00	0.7393	0.7393	12.9051
2	1.00	0.6357	0.6357	11.0966
3	0.96	0.5466	0.5247	9.1590
				48.1692
4	0.92	0.4700	0.4324	7.5479
5	0.90	0.4041	0.3637	6.3487
6	0.90	0.3475	0.3128	5.4602
7	0.88	0.2988	0.2629	4.5891
8	0.88	0.2569	0.2261	3.9468
9	0.88	0.2209	0.1944	3.3934
10	0.88	0.1899	0.1671	2.9169
11	0.88	0.1633	0.1437	2.5084
12	0.88	0.1404	0.1236	2.1575
13	0.87	0.1208	0.1051	1.8346
14	0.87	0.1038	0.0903	1.5762
15	0.87	0.0893	0.0777	1.3563
16	0.87	0.0768	0.0668	1.1660
17	0.87	0.0660	0.0574	1.0020
18	0.87	0.0568	0.0494	0.8623
19	0.86	0.0488	0.0420	0.7331
20	0.86	0.0420	0.0361	0.6302
21	0.86	0.0361	0.0310	0.5411
22	0.86	0.0310	0.0267	0.4661
23	0.86	0.0267	0.0230	0.4015
24	0.86	0.0229	0.0197	0.3439
				49.7822

25	0.86	0.0197	0.0169	0.2950
26	0.86	0.0170	0.0146	0.2548
27	0.86	0.0146	0.0126	0.2199
28	0.86	0.0125	0.0108	0.1885
29	0.86	0.0108	0.0093	0.1623
30	0.86	0.0093	0.0080	0.1396
31	0.86	0.0080	0.0069	0.1204
32	0.86	0.0068	0.0058	0.1012
33	0.86	0.0059	0.0051	0.0890
34	0.86	0.0051	0.0044	0.0768
35	0.86	0.0044	0.0038	0.0663
36	0.86	0.0037	0.0032	0.0558
37	0.86	0.0032	0.0028	0.0489
				1.8185
38	0.80	0.0028	0.0022	0.0384
39	0.80	0.0024	0.0019	0.0332
40	0.80	0.0020	0.0016	0.0279
41	0.80	0.0018	0.0014	0.0244
42	0.80	0.0015	0.0012	0.0209
43	0.80	0.0013	0.0010	0.0174
44	0.80	0.0011	0.0009	0.0157
45	0.80	0.0010	0.0008	0.0140
46	0.76	0.0008	0.0006	0.0105
47	0.70	0.0007	0.0005	0.0087
48	0.68	0.0006	0.0004	0.0070
49	0.62	0.0005	0.0003	0.0052
50	0.56	0.0004	0.0002	0.0035
51	0.48	0.0004	0.0002	0.0035
				0.2303

Table 50 : Life table for computing life expectancy of *S. litura* reared on cabbage.

Pivotal age (Days)	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\left(\frac{dx \cdot 100}{lx}\right)$	Alive between age 'x' and 'x + 1' $\frac{lx + (lx + 1)}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{Tx}{lx} \times 2$
(x)	(lx)	(dx)	(100 qx)	(Lx)	(Tx)	(ex)
0-5	100	10	10.00	95.0	899.0	17.98
5-10	90	2	2.22	89.0	804.0	17.87
10-15	88	1	1.14	87.5	715.0	16.25
15-20	87	1	1.15	86.5	627.5	14.42
20-25	86	0	0.00	86.0	541.0	12.58
25-30	86	0	0.00	86.0	455.0	10.58
30-35	86	0	0.00	86.0	369.0	8.58
35-40	86	6	6.98	83.0	283.0	6.58
40-45	80	0	0.00	80.0	200.0	5.00
45-50	80	24	30.00	68.0	120.0	3.00
50-55	56	8	14.28	52.0	52.0	1.86

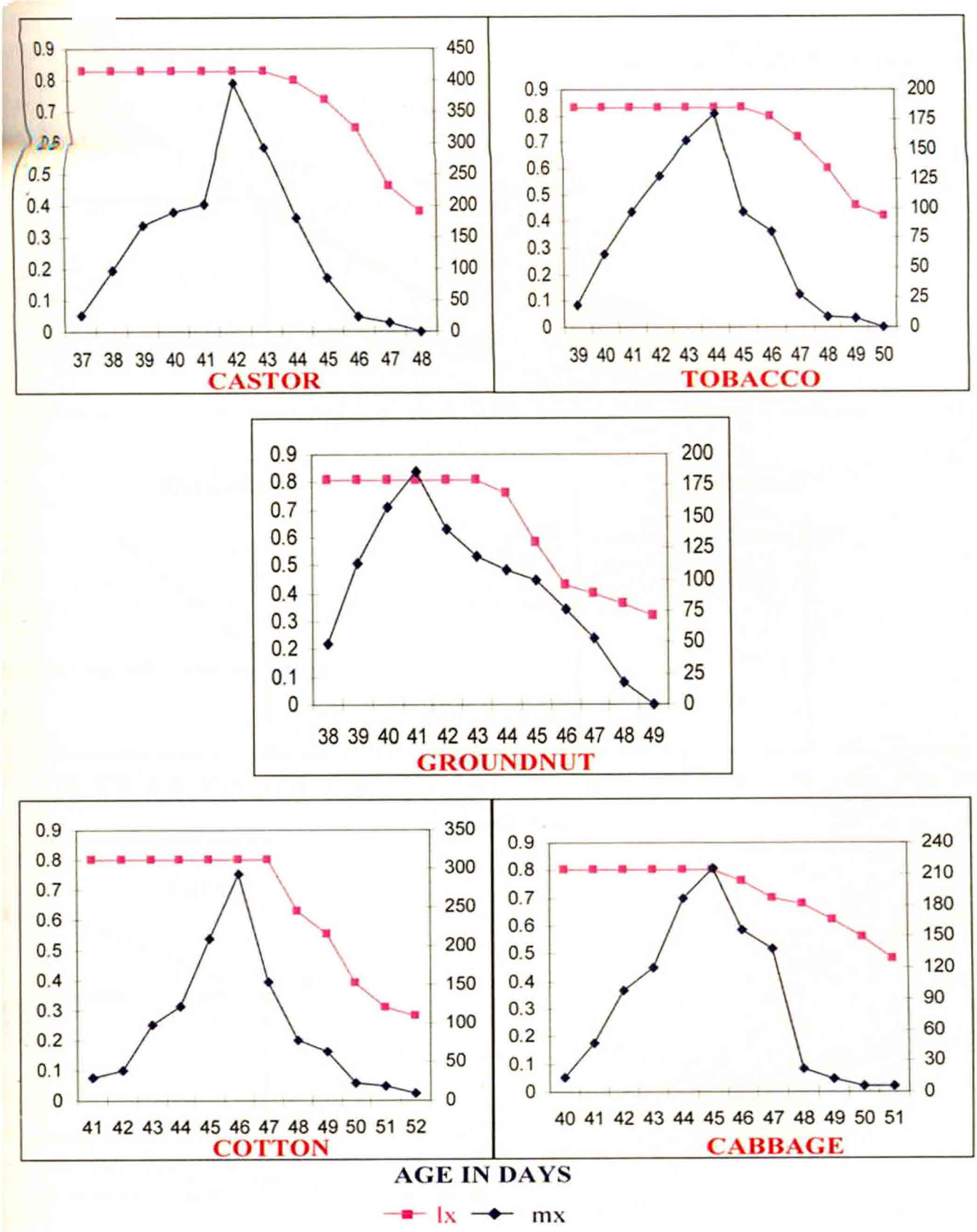
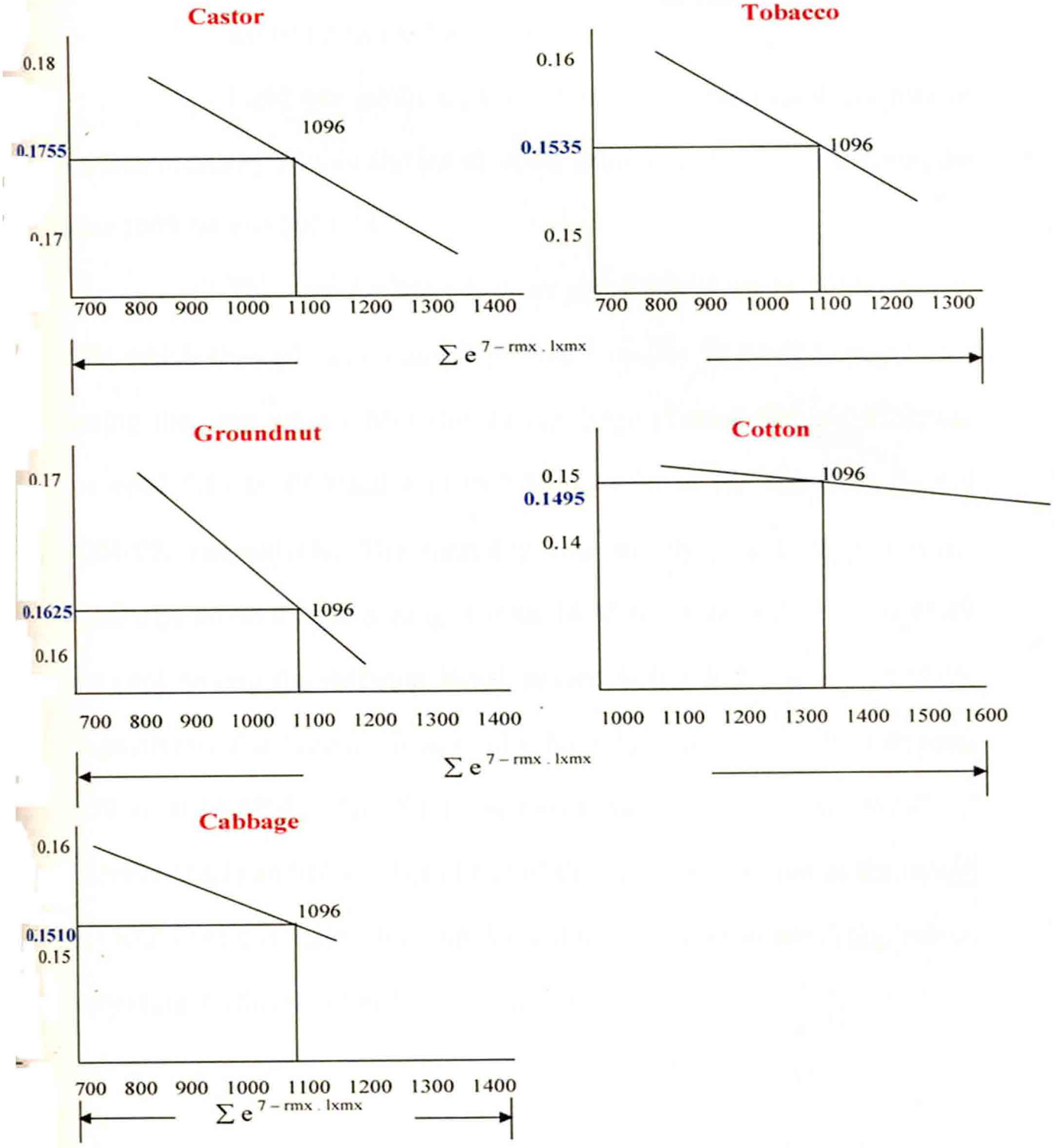


Fig 6 : Daily age-specific survival and fecundity of *S. litura* on different hosts



g. 7 : Determination of the intrinsic rate of increase (rm) of *S. litura* on different hosts

4.5 LIFE TABLE FOR DETERMINATION OF KEY MORTALITY FACTORS

Field life tables were constructed to understand the role of various mortality factors and the seasonal abundance of *S. litura* during the year 2003-04 and 2004-05.

The data for life tables on castor are given in Tables 51a to 53b, which showed natural and sequential mortality in the field population during the crop season. Mortality in egg stage (Tables 51a and 51b) was recorded 5.15 to 8.00 and 4.54 to 7.22 per cent in the year 2003-04 and 2004-05, respectively. The mortality was mainly due to egg sterility. Similarly, larval mortality ranged from 14.83 to 18.44 and 18.89 to 21.49 per cent among the different larval instars during 2003-04 and 2004-05, respectively. The generation survival value ranged from 0.72 (2003-04) and 0.70 to 0.72 (2004-05). The trend index was positive in the month of October (1.01) and November (1.02) of the year 2003-04 and in the month of October (1.08) during 2004-05 while it was negative in remaining period indicating decline trend of *Spodoptera* population.

Table 51a : Life table of *S. litura* eggs (October, 2003)

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	97	Infertility	5	5.15	0.95	1.98677	0.0230
Larva-I (I-II Instar)	92	Unknown causes	8	8.70	0.91	1.96379	0.0395
Larva-II (III-IV Instar)	84	Unknown causes	4	4.76	0.95	1.92428	0.0212
Larva-III (V-VI Instar)	80	Unknown causes	3	3.75	0.96	1.90309	0.0166
Pupae	77	Unknown causes	5	6.49	0.94	1.88649	0.0292
Moths	72	Sex (51.39% female)	2	2.78	0.97	1.85733	0.0122
Female x 2 (N_3)	70	-	-	-	1.00	1.84509	-
Normal female x 2	70	-	-	-	1.00	-	-
Generation total	-	-	27	31.65	-	-	0.1417 K

No. of expected eggs : 1875 x 70/2 = 65625
No. of actual eggs (N_2) : 98
Trend index : N_2 / N_1 = 1.01
Generation survival : N_3 / N_1 = 0.72

November, 2003

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	98	Infertility	6	6.12	0.94	1.9912	0.0274
Larva-I (I-II Instar)	92	Unknown causes	8	8.70	0.91	1.9638	0.0395
Larva-II (III-IV Instar)	84	Unknown causes	3	3.57	0.96	1.9243	0.0158
Larva-III (V-VI Instar)	81	Unknown causes	5	6.17	0.94	1.9085	0.0277
Pupae	76	Unknown causes	3	3.95	0.96	1.8808	0.0175
Moths	73	Sex (52.05% female)	2	2.74	0.97	1.8633	0.0121
Female x 2 (N_3)	71	-	-	-	1.00	1.8512	-
Normal female x 2	71	-	-	-	1.00	-	-
Generation total	-	-	27	31.25	-	-	0.14 K

No. of expected eggs : 1880 x 71/2 = 66,740
No. of actual eggs (N_2) : 100
Trend index : N_2 / N_1 = 1.02
Generation survival : N_3 / N_1 = 0.72

December, 2003

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	100	Infertility	8	8.00	0.92	2.0000	0.0362
Larva-I (I-II Instar)	92	Unknown causes	6	6.52	0.93	1.9638	0.0293
Larva-II (III-IV Instar)	86	Unknown causes	4	4.65	0.95	1.9345	0.0207
Larva-III (V-VI Instar)	82	Unknown causes	3	3.66	0.96	1.9138	0.0162
Pupae	79	Unknown causes	3	3.80	0.96	1.8976	0.0168
Moths	76	Sex (51.32% female)	2	2.63	0.97	1.8808	0.0116
Female x 2 (N_3)	74	-	-	-	1.00	1.8692	-
Normal female x 2	74	-	-	-	1.00	-	-
Generation total	-	-	26	29.26	-	-	0.1308 K

Generation survival : N_3 / N_1 = 0.74

Table 51b : Life table of *S. litura* eggs (October, 2004)

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	90	Infertility	5	5.56	0.94	1.9542	0.0248
Larva-I (I-II Instar)	85	Unknown causes	7	8.24	0.92	1.9294	0.0373
Larva-II (III-IV Instar)	78	Unknown causes	6	7.69	0.92	1.8921	0.0348
Larva-III (V-VI Instar)	72	Unknown causes	4	5.56	0.94	1.8573	0.0248
Pupae	68	Unknown causes	2	2.94	0.97	1.8325	0.0130
Moths	66	Sex (51.51% female)	3	4.54	0.93	1.8195	0.0202
Female x 2 (N_3)	63	-	-	-	1.00	1.7993	-
Normal female x 2	63	-	-	-	1.00	-	-
Generation total	-	-	27	34.53	-	-	0.1549 K

No. of expected eggs : 1795 x 63/2 = 56542
No. of actual eggs (N_2) : 97
Trend index : N_2 / N_1 = 1.08
Generation survival : N_3 / N_1 = 0.70

November, 2004

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	97	Infertility	7	7.22	0.93	1.9868	0.0326
Larva-I (I-II Instar)	90	Unknown causes	8	8.89	0.91	1.9542	0.0404
Larva-II (III-IV Instar)	82	Unknown causes	5	6.10	0.94	1.9138	0.0273
Larva-III (V-VI Instar)	77	Unknown causes	3	3.90	0.96	1.8865	0.0173
Pupae	74	Unknown causes	2	2.70	0.97	1.8692	0.0119
Moths	72	Sex (51.38% female)	3	4.17	0.96	1.8573	0.0185
Female x 2 (N_3)	69	-	-	-	1.00	1.8388	-
Normal female x 2	69	-	-	-	1.00	-	-
Generation total	-	-	28	32.98	-	-	0.148 K

No. of expected eggs : 1670 x 69/2 = 57615
No. of actual eggs (N_2) : 88
Trend index : N_2/N_1 = 0.91
Generation survival : N_3/N_1 = 0.71

December, 2004

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Eggs (N_1)	88	Infertility	4	4.54	0.95	1.9445	0.0202
Larva-I (I-II Instar)	84	Unknown causes	7	8.33	0.92	1.9243	0.0378
Larva-II (III-IV Instar)	77	Unknown causes	5	6.49	0.94	1.8865	0.0292
Larva-III (V-VI Instar)	72	Unknown causes	3	4.17	0.96	1.8573	0.0185
Pupae	69	Unknown causes	2	2.90	0.97	1.8388	0.0127
Moths	67	Sex (52.24% female)	1	1.49	0.98	1.8261	0.0066
Female x 2 (N_3)	66	-	-	-	1.00	1.8195	-
Normal female x 2	66	-	-	-	1.00	-	-
Generation total	-	-	22	27.92	-	-	0.125 K

Generation survival : N_3 / N_1 = 0.75

Mortality during different larval instars (Tables 52a and 52b) were also recorded which ranged from 0.83 to 7.63 (2003-04) and 0.55 to 22.50 (2004-05) per cent. The mortality in different larval groups was mainly due to three factors *viz.*, parasites, disease and unknown factors. During the year 2003-04 high mortality (2.50 to 7.63%) occurred in young group larvae-I (I-II instar) and 1.78 to 3.85 per cent occurred in group-II larvae (III-IV instar) due to unknown cases, whereas 5.56 to 9.38 per cent in group-I larvae and 2.10 to 9.09 per cent in group-II larval population declined due to this factor during 2004-05.

The population of older group larvae was reduced by 1.82 to 6.00 and 1.52 to 22.50 during the year 2003-04 and 2004-05, respectively. Mortality in this group was due to a parasite, *Apanteles beneficus* Viereck (Plate-II), NPV and some unknown factors. Among these factors, 3.64 to 5.56 (2003-04) and 5.71 to 22.50 (2004-05) per cent mortality was recorded due to NPV, whereas mortality due to unknown cases was observed to be 1.82 to 6.00 and 1.52 to 10.00 per cent during the year 2003-04 and 2004-05, respectively. Values of trend index were calculated to the tune of 1.83 (October) and 0.59 (November) during 2003-04 and 1.85 (October) and 0.61 (November) during 2004-05, respectively. The negative value of trend index indicating that the mortality factors operating during the period were effective in causing a decline in pest population.

Plate - 2 : *Apanteles beneficus* larval parasite of *S. litura*

A : Healthy egg of *Apanteles beneficus*

B : Adult male

C : Adult female

Table 52a : Life table of *S. litura* larvae (October, 2003)

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	121	Parasite (*C. formosanus*)	1	0.83	0.97	2.0828	0.0036
	120	Unknown	3	2.50	-	2.0792	0.0011
Larva-II (III-IV Instar)	117	Parasite (*A. beneficus*)	5	4.27	0.94	2.0682	0.019
	112	Unknown	2	1.78	-	2.0492	0.0078
Larva-III (V-VI Instar)	110	Disease (NPV)	4	3.64	0.94	2.0414	0.0161
	106	Unknown	2	1.89	-	2.0253	0.0083
Pupae	104	Unknown	3	2.88	0.97	2.0170	0.0127
Moths	101	Sex (50.49% female)	3	2.97	0.97	2.0043	0.0131
Female x 2 (N_3)	98	-	-	-	1.00	1.9912	-
Normal female x 2	98	-	-	-	1.00	-	-
Generation total	-	-	23	20.76	-	-	0.0916 K

No. of actual larvae (N_2) : 221
Trend index : $N_2 / N_1 = 1.83$
Generation survival : $N_3 / N_1 = 0.81$

November, 2003

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	221	Parasite (*C. formosanus*)	3	1.36	0.49	2.3444	0.2725
	118	Unknown	9	7.63	-	2.0719	0.0345
Larva-II (III-IV Instar)	109	Parasite (*A. beneficus*)	5	4.59	0.92	2.0374	0.0204
	104	Unknown	4	3.85	-	2.0170	0.0170
Larva-III (V-VI Instar)	100	Unknown	6	6.00	0.90	2.0000	0.0269
	94	Disease (NPV)	4	4.26	-	1.9731	0.0189
Pupae	90	Unknown	3	3.33	0.97	1.9542	0.0147
Moths	87	Sex (50.57% female)	2	2.30	0.98	1.9395	0.0101
Female x 2 (N_3)	85	-	-	-	1.00	1.9294	-
Normal female x 2	85	-	-	-	1.00	-	-
Generation total	-	-	36	33.32	-	-	0.415 K

No. of actual larvae (N_2) : 130
Trend index : $N_2 / N_1 = 0.59$
Generation survival : $N_3 / N_1 = 0.38$

December, 2003

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	130	Parasite (*C. formosanus*)	2	1.54	0.92	2.1139	0.0067
	128	Unknown	8	6.25	-	2.1072	0.028
Larva-II (III-IV Instar)	120	Parasite (*A. beneficus*)	6	5.00	0.91	2.0792	0.0223
	114	Unknown	4	3.51	-	2.0569	0.0155
Larva-III (V-VI Instar)	110	Unknown	2	1.82	0.93	2.0414	0.008
	108	Disease (NPV)	6	5.56	-	2.0334	0.0248
Pupae	102	Unknown	5	4.90	0.95	2.0086	0.0218
Moths	97	Sex (50.51% female)	3	3.09	0.97	1.9868	0.0137
Female x 2 (N_3)	94	-	-	-	1.00	1.9731	-
Normal female x 2	94	-	-	-	1.00	-	-
Generation total	-	-	36	31.67	-	-	0.1408 K

Generation survival : $N_3 / N_1 = 0.72$

Table 52b : Life table of *S. litura* larvae (October, 2004)

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	98	Parasite (*C. formosanus*)	2	2.04	0.89	1.9912	0.0089
	96	Unknown	9	9.38	-	1.9823	0.0428
Larva-II (III-IV Instar)	87	Parasite (*A. beneficus*)	12	13.79	0.80	1.9395	0.0644
	75	Unknown	5	6.67	-	1.8751	0.03
Larva-III (V-VI Instar)	70	Disease (NPV)	10	14.28	0.77	1.8451	0.0669
	60	Unknown	6	10.00	-	1.7782	0.0458
Pupae	54	Unknown	4	7.41	0.92	1.7324	0.0334
Moths	50	Sex (50.00% female)	3	6.00	0.94	1.6990	0.0269
Female x 2 (N_3)	47	-	-	-	1.00	1.6721	-
Normal female x 2	47	-	-	-	1.00	-	-
Generation total	-	-	51	69.57	-	-	0.3191 K

No. of actual larvae (N_2) : 181
Trend index : $N_2/N_1 = 1.85$
Generation survival : $N_3/N_1 = 0.48$

November, 2004

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	181	Parasite (*C. formosanus*)	1	0.55	0.94	2.2577	0.0024
	180	Unknown	10	5.56	-	2.2553	0.0249
Larva-II (III-IV Instar)	170	Parasite (*A. beneficus*)	27	15.88	0.82	2.2304	0.0751
	143	Unknown	3	2.10	-	2.1553	0.0092
Larva-III (V-VI Instar)	140	Disease (NPV)	8	5.71	0.93	2.1461	0.0255
	132	Unknown	2	1.52	-	2.1206	0.0067
Pupae	130	Unknown	9	6.92	0.93	2.1139	0.0311
Moths	121	Sex (51.24% female)	11	9.09	0.91	2.0828	0.0414
Female x 2 (N_3)	110	-	-	-	1.00	2.0414	-
Normal female x 2	110	-	-	-	1.00	-	-
Generation total	-	-	71	47.33	-	-	0.2163 K

No. of actual larvae (N_2) : 110
Trend index : $N_2 / N_1 = 0.61$
Generation survival : $N_3 / N_1 = 0.61$

December, 2004

x	lx	dxf	dx	100qx	sx	log (lx)	'k' value
Larva-I (I-II Instar) (N_1)	110	Parasite (*C. formosanus*)	3	2.73	0.89	2.0414	0.012
	107	Unknown	9	8.41	-	2.0294	0.0382
Larva-II (III-IV Instar)	98	Parasite (*A. beneficus*)	10	10.20	0.82	1.9912	0.0467
	88	Unknown	8	9.09	-	1.9445	0.0414
Larva-III (V-VI Instar)	80	Disease (NPV)	18	22.50	0.75	1.9031	0.1107
	62	Unknown	2	3.22	-	1.7924	0.0142
Pupae	60	Unknown	8	13.33	0.87	1.7782	0.0622
Moths	52	Sex (50.00% female)	2	3.85	0.96	1.7160	0.0171
Female x 2 (N_3)	50	-	-	-	1.00	1.6989	-
Normal female x 2	50	-	-	-	1.00	-	-
Generation total	-	-	60	73.33	-	-	0.3425 K

Generation survival : $N_3 / N_1 = 0.45$

Considering 'k' values for younger as well as older groups of larvae (Tables 52a and 52b), the mortality in younger group of larvae was induced by unknown causes, but in older group the maximum population declined due to NPV as the 'k' values were the highest 0.0161 to 0.0248 and 0.0255 to 0.1107 during the year 2003-04 and 2004-05, respectively.

Mortality in pupal stage ranged from 29.17 to 45.24 (2003-04) and 32.06 to 43.08 (2004-05) per cent (Tables 53a and 53b). The mortality was mainly due to some unknown factors, which was the highest (45.24%) in October and 43.08 per cent in December during 2003-04 and 2004-05, respectively. The generation survival values ranged from 0.62 to 0.65 and 0.60 to 0.68 during 2003-04 and 2004-05, respectively. Values of trend index were worked out to be 1.04 during October and 0.88 during November of the year 2003-04 and 1.16 (October) and 0.89 (November) during 2004-05.

Results of key mortality factors analysis clearly showed that among the different stages, 'k' values for pupal stage was higher indicating that maximum mortality was occurred in pupal stage.

Table 53a : Life table of *S. litura* pupae (October, 2003)

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	46	Unknown	6	13.04	0.70	1.6628	0.0608
	40	Unknown	8	20.00	-	1.6020	0.0969
Moths	32	Sex (50.00% female)	2	6.25	0.94	1.5051	0.0280
Female x 2 (N_3)	30	-	-	-	1.00	1.4771	-
Normal female x 2	30	-	-	-	1.00	-	-
Generation total	-	-	16	39.29	-	-	0.1857 K

No. of actual larvae (N_2) : 48

Trend index : $N_2/ N_1 = 1.04$

Generation survival : $N_3/ N_1 = 0.65$

November, 2003

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	48	Unknown	8	16.67	0.73	1.6812	0.0792
	40	Unknown	5	12.50	-	1.6020	0.0579
Moths	35	Sex (54.28% female)	5	14.28	0.86	1.5441	0.0670
Female x 2 (N_3)	30	-	-	-	1.00	1.4771	-
Normal female x 2	30	-	-	-	1.00	-	-
Generation total	-	-	18	43.45	-	-	0.2041 K

No. of actual larvae (N_2) : 42

Trend index : $N_2/ N_1 = 0.88$

Generation survival : $N_3/ N_1 = 0.62$

December, 2003

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	42	Unknown	7	16.67	0.60	1.6232	0.0791
	35	Unknown	10	28.57	-	1.5441	0.1462
Moths	25	Sex (52.00% female)	1	4.00	0.96	1.3979	0.0177
Female x 2 (N_3)	24	-	-	-	1.00	1.3802	-
Normal female x 2	24	-	-	-	1.00	-	-
Generation total	-	-	18	49.24	-	-	0.243 K

Generation survival : $N_3/N_1 = 0.57$

Table 53b : Life table of *S. litura* pupae (October, 2004)

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	38	Unknown	8	21.05	0.66	1.5798	0.1027
	30	Unknown	5	16.67	-	1.4771	0.0792
Moths	25	Sex (52.00% female)	2	8.00	0.92	1.3979	0.0362
Female x 2 (N_3)	23	-	-	-	1.00	1.3617	-
Normal female x 2	23	-	-	-	1.00	-	-
Generation total	-	-	15	45.72	-	-	0.2181 K

No. of actual larvae (N_2) : 44

Trend index : $N_2/N_1 = 1.16$

Generation survival : $N_3/N_1 = 0.60$

November, 2004

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	44	Unknown	6	13.64	0.70	1.6434	0.0636
	38	Unknown	7	18.42	-	1.5798	0.0884
Moths	31	Sex (54.83% female)	1	3.22	0.97	1.4914	0.0143
Female x 2 (N_3)	30	-	-	-	1.00	1.4771	-
Normal female x 2	30	-	-	-	1.00	-	-
Generation total	-	-	14	35.28	-	-	0.1663 K

No. of actual larvae (N_2) : 39

Trend index : $N_2/ N_1 = 0.89$

Generation survival : $N_3/ N_1 = 0.68$

December, 2004

x	lx	dxf	dx	100 qx	sx	log (lx)	'k' value
Pupae (N_1)	39	Unknown	9	23.08	0.62	1.5911	0.114
	30	Unknown	6	20.00	-	1.4771	0.0969
Moths	24	Sex (50.00% female)	2	8.33	0.92	1.3802	0.0378
Female x 2 (N_3)	22	-	-	-	1.00	1.3424	-
Normal female x 2	22	-	-	-	1.00	-	-
Generation total	-	-	17	51.41	-	-	0.2487 K

Generation survival : $N_3 / N_1 = 0.56$

4.6 EVALUATION OF NEWER INSECTICIDES AND BIOPESTICIDES AGAINST *S. litura*

Experiments were conducted under field conditions to determine the effectiveness of certain new insecticides and biopesticides against *S. litura* on castor during 2003-04 and 2004-05. Treatments were applied twice, (first at ETL and second after 15 days of first spray). The data on per cent mortality obtained after each spraying were pooled and summarized in Tables 54 and 55.

4.6.1 Effect of insecticides

First spray

The pooled data on per cent mortality of *S. litura* larvae (Table 54) recorded three days after application of different insecticidal treatments revealed that indoxacarb 0.015 per cent caused the highest mortality (52.92%) and found significantly superior to the rest of the treatments in minimizing the larval population. Among the remaining treatments, alphamethrin 0.0075 per cent showed good control by registering 39.66 per cent mortality of the pest followed by quinalphos 0.05 per cent (29.96%). Among the biopesticides, *B. thuringiensis* (Bt) gave the highest per cent mortality (24.57%) of the pest and it was remained at par with chemical insecticides acephate 0.075 and profenophos 0.05 per cent. The lowest mortality (18.58%) was recorded in the treatment of NSKS 2 per cent and proved to be the least effective.

Table 54 : Efficacy of different insecticides against *S. litura* on castor

Treatment			Mean percentage larval mortality at different interval after first spray								
			3 days			5 days			7 days		
			2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	Quinalphos	0.05%	31.39* (28.29)	34.20 (31.64)	32.80 (29.96)	42.74 (46.21)	45.98 (51.75)	44.36 (48.98)	52.62 (63.09)	51.14 (60.67)	51.88 (61.88)
T2	Alphamethrin	0.0075%	36.04 (34.87)	41.78 (44.45)	38.91 (39.66)	46.15 (51.98)	51.06 (60.52)	48.60 (56.25)	62.22 (78.01)	58.82 (73.20)	60.52 (75.61)
T3	Lufenuron	0.005%	22.99 (15.83)	28.26 (22.54)	25.62 (19.18)	32.07 (28.34)	38.76 (39.25)	35.42 (33.79)	41.07 (43.22)	46.64 (52.88)	43.85 (48.05)
T4	Acephate	0.075%	29.30 (24.17)	31.78 (27.87)	30.54 (26.02)	40.28 (41.89)	42.86 (46.29)	41.57 (44.09)	48.51 (56.13)	47.88 (55.05)	48.20 (55.59)
T5	Profenophos	0.05%	26.84 (21.05)	32.19 (28.68)	29.51 (24.86)	39.66 (40.89)	43.46 (47.36)	41.56 (44.12)	50.38 (59.19)	48.65 (56.37)	49.52 (57.78)
T6	Indoxacarb	0.015%	45.92 (51.61)	47.41 (54.24)	46.67 (52.92)	52.58 (62.93)	59.32 (73.97)	55.95 (68.45)	66.62 (84.18)	65.15 (82.02)	65.88 (83.10)
T7	NSKS	2%	23.47 (16.17)	27.25 (21.00)	25.36 (18.58)	31.41 (27.27)	37.38 (36.91)	34.40 (32.09)	40.97 (43.02)	41.96 (44.73)	41.46 (43.88)
T8	Bt (Biolep)	1 kg/ha	27.63 (21.72)	31.55 (27.42)	29.59 (24.57)	36.50 (35.45)	46.04 (51.85)	41.27 (43.65)	49.34 (57.57)	51.69 (61.61)	50.52 (59.59)
T9	Azadirachtin	0.03%	23.37 (15.98)	28.19 (22.35)	25.78 (19.17)	34.94 (32.92)	39.35 (40.27)	37.15 (36.60)	42.82 (46.27)	45.83 (51.49)	44.33 (48.88)
	S.Em. ±	T	2.11	1.32	1.16	1.72	0.98	1.01	1.38	1.54	1.12
		Y x T	-	-	1.76	-	-	1.40	-	-	1.46
	C.D. at 5%	T	6.33	3.96	3.32	5.15	2.94	2.88	4.13	4.61	3.20
		Y x T	-	-	NS	-	-	NS	-	-	NS
	C.V.%		12.33	6.81	9.64	7.51	3.78	5.73	4.72	5.24	4.99

* Arcsin √percentage transformation

Figures in parentheses are retransformed values

Mortality data recorded on fifth day after spraying followed the same trend and indicated that indoxacarb 0.015 per cent proved to be significantly superior over rest of the treatments by registering the highest mortality (68.45%) which was closely followed by alphamethrin 0.0075 (56.25%) and quinalphos 0.05 per cent (48.98%). The treatment with Bt @ 1 kg per hectare recorded the highest mortality (43.65%) and was statistically at par with the chemical insecticides acephate 0.075 and profenophos 0.05 per cent. However, NSKS 2 per cent showed the lowest mortality (32.09%) and proved to be comparatively less effective.

The data on per cent larval mortality obtained seven days after spraying revealed that indoxacarb 0.015 per cent was significantly superior over rest of the treatments by causing the highest mortality (83.10%) which followed by alphamethrin 0.0075 per cent (75.61%). Among the remaining treatment, quinalphos 0.05 per cent, Bt @ 1 kg a.i./ha, profenophos 0.05 and acephate 0.075 per cent emerged out to be the next best group of treatment by causing 61.88, 59.59, 57.78 and 55.59 per cent mortality of the pest, respectively. Treatment with NSKS 2 per cent could not cause satisfactory control and proved to be the least effective against this pest even seven days after application.

Second spray

The pooled data on per cent mortality recorded after three days of second application are given in Table 55. The data revealed that indoxacarb 0.015 and alphamethrin 0.0075 per cent found significantly superior to rest of the treatments. Among the remaining treatments profenophos 0.05 per cent showed 32.71 per cent mortality and was pat par with quinalphos 0.05 per cent. Bt found superior over rest of the treatments with other bio-pesticides under study by giving 26.84 per cent mortality of the pest which was statistically at par with acephate 0.075 per cent. However, NSKS 2 per cent caused 19.29 per cent mortality which remained at par with lufenuron 0.005 and azadirachtin 0.03 per cent.

A close perusal of the data recorded five days after spraying indicated that indoxacarb 0.015 per cent caused the highest mortality (70.04%) followed by alphamethrin 0.0075 per cent (60.73%). Quinalphos 0.05 per cent gave 48.73 per cent mortality, which remained at par with profenophos 0.05 per cent. Treatments with Bt and acephate 0.075 per cent were also proved effective as they registered 40.72 and 40.52 per cent mortality, respectively. NSKS 2 per cent proved almost ineffective (31.28 % mortality) even after five days of spraying.

The data on larval mortality recorded at seven days after the application of treatments indicated that the mortality increased with time in all the treatments, however, indoxacarb 0.015 per cent registered maximum

Table 55 : Efficacy of different insecticides against *S. litura* on castor

Treatment			Mean percentage larval mortality at different interval after second spray								
			3 days			5 days			7 days		
			2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	Quinalphos	0.05%	32.44* (29.36)	34.96 (33.14)	33.70 (31.25)	44.30 (48.82)	44.21 (48.65)	44.26 (48.73)	53.21 (64.16)	52.21 (62.40)	52.71 (63.28)
T2	Alphamethrin	0.0075%	41.91 (44.65)	37.92 (37.92)	39.91 (41.28)	53.89 (65.30)	48.53 (56.17)	51.21 (60.73)	59.78 (74.69)	59.55 (74.35)	59.66 (74.52)
T3	Lufenuron	0.005%	24.40 (17.67)	26.84 (20.91)	25.62 (19.29)	33.14 (29.96)	35.93 (34.56)	34.53 (32.26)	42.29 (45.32)	44.10 (48.46)	43.19 (46.89)
T4	Acephate	0.075%	31.27 (27.10)	29.67 (25.18)	30.46 (26.14)	39.28 (40.15)	39.72 (40.90)	39.50 (40.52)	47.24 (53.93)	47.82 (54.92)	47.52 (54.42)
T5	Profenophos	0.05%	44.33 (36.82)	32.18 (28.59)	34.73 (32.71)	44.05 (48.39)	41.09 (43.26)	42.57 (45.83)	50.76 (60.00)	49.42 (57.72)	50.09 (58.86)
T6	Indoxacarb	0.015%	23.67 (48.86)	44.14 (48.54)	44.23 (48.70)	57.50 (71.15)	56.14 (68.93)	56.82 (70.04)	68.08 (85.97)	66.11 (83.40)	67.09 (84.69)
T7	NSKS	2%	29.41 (16.56)	27.56 (22.14)	25.61 (19.35)	31.01 (26.62)	36.73 (35.94)	33.87 (31.28)	40.15 (41.61)	43.96 (48.22)	42.06 (44.92)
T8	Bt (Biolep)	1 kg/ha	27.88 (25.43)	31.85 (28.26)	30.63 (26.84)	39.42 (40.62)	39.68 (40.82)	39.55 (40.72)	52.01 (62.10)	50.99 (60.40)	51.50 (61.25)
T9	Azadirachtin	0.03%	32.51 (21.98)	27.56 (21.92)	27.72 (21.95)	34.82 (32.64)	37.35 (36.90)	36.09 (34.77)	44.51 (49.18)	43.82 (47.97)	44.16 (48.57)
	S.Em. ±	T	2.21	1.84	1.46	1.70	1.14	1.64	0.90	1.06	0.74
		Y x T	-	-	2.03	-	-	1.45	-	-	0.98
	C.D. at 5%	T	6.61	5.51	4.18	5.11	3.41	5.06	2.68	3.19	2.12
		Y x T	-	-	NS	-	-	NS	-	-	NS
	C.V.%		11.76	9.78	10.81	7.03	4.67	5.96	3.05	3.62	3.34

* Arcsin $\sqrt{\text{percentage}}$ transformation

Figures in parentheses are retransformed values

larval mortality (84.69%) and it was followed by alphamethrin 0.0075 per

cent (74.52%). The remaining insecticidal treatments found comparatively less effective as they registered 46.89 to 63.28 per cent mortality, whereas treatment with NSKS 2 per cent found to be the lest effective.

Thus, pooled results of two years showed that among the different chemical insecticidal treatments, indoxacarb 0.015, alphamethrin 0.0075, quinalphos 0.05 and profenophos 0.05 per cent proved to be the most effective for the control of this pest under field conditions, however, among the biopesticides Bt was the superior against this pest, whereas NSKS 2 per cent found less effective.

4.6.2 Effect of different insecticidal treatments on yield of castor

The seed yield of castor recorded from plots treated with different insecticides are included in Table 56. The pooled data revealed that all the insecticidal treatments proved significantly superior in increasing the seed yield of castor over control. Among the various treatments under test, the plots treated with indoxacarb 0.015 per cent found significantly superior and gave the highest yield (2199.07 kg ha^{-1}) followed by alphamethrin 0.0075 (1907.58 kg ha^{-1}) and quinalphos 0.05 per cent (1620.37 kg ha^{-1}). Among the remaining treatments the plots treated with profenophos 0.05 per cent registered 1251.72 kg ha^{-1} and was at par with acephate 0.075 (1140.26 kg ha^{-1}) and lufenuron 0.005 per cent

Table 56: Efficacy of various insecticidal treatments on castor yield

Sr. No.	Treatment		Yield (kg/ha)		
			2003-04	2004-05	Pooled
1	Quinalphos	0.05%	1628.94	1611.80	1620.37
2	Alphamethrin	0.0075%	1920.44	1894.72	1907.58
3	Lefnuron	0.005%	1088.82	1054.53	1071.67
4	Acephate	0.075%	1148.83	1131.69	1140.26
5	Profenophos	0.05%	1260.29	1243.14	1251.72
6	Indoxacarb	0.015%	2220.51	2177.64	2199.07
7	NSKS	2%	771.60	745.88	758.74
8	Bt (Biolep)	1 kg/ha	1003.09	1020.23	1011.66
9	Azadirachtin	0.03%	917.35	891.63	904.49
10	Control		591.56	557.27	574.42
	S.Em. ±	T	109.83	107.36	68.78
		Y x T	-	-	108.60
	C.D. at 5%	T	326.32	318.98	198.58
		Y x T	-	-	NS
	C.V.%		15.16	15.08	15.12

(1071.67 kg ha^{-1}). The treatment with NSKS 2 per cent showed minimum yield 758.74 kg ha^{-1} and proved to be the least effective as the yield was at par with control.

4.6.3 Economics of insecticides

The economics of these treatments were also worked out and summarized in Table 57.

Considering the economics of the treatments, alphamethrin 0.0075 per cent gave the highest incremental cost benefit ratio (ICBR) (1:23.15) which was followed by quinalphos 0.05 (1:16.37) per cent whereas the lowest ICBR (1:3.58) was recorded in the treatment of NSKS 2 per cent. The other treatments were in order of indoxacarb 0.015 > profenophos 0.05 > acephate 0.07 > azadirachtin 0.03 > lufenuron 0.005 > Bt.

Considering the effectiveness of the insecticides, alphamethrin 0.0075 and quinalphos 0.05 per cent were found most effective for the control of this pest. The treatments gave the higher net profit over control, which was worked out to the tune of Rs. 25559.20 and 19715.00 per hectare, respectively. Thus, considering economics of the treatments, alphamethrin 0.0075 and quinalphos 0.05 per cent can be recommended for the control of *S. litura* in castor.

Table 57 : Economics of different treatments for control of *S. litura* on castor

Insecticides	Quantity (l/ha)*	Total cost of treatment including labour charge for two application (Rs/ha)	Yield (kg/ha)	Gross realization (Rs/ha)	Net profit (Rs/ha)	Profit over control	ICBR
T1 Quinalphos 0.05%	2.0	1204.00	1620.37	32407.40	31203.40	19715.00	1:16.37
T2 Alphamethrin 0.0075%	1.0	1104.00	1907.58	38151.60	37047.60	25559.20	1:23.15
T3 Lufenuron 0.005%	2.0	1504.00	1071.67	21433.40	19929.40	8441.00	1:5.61
T4 Acephate 0.075%	2.0	1504.00	1140.26	22805.20	21301.20	9812.80	1:6.52
T5 Profenophos 0.05%	1.8	1584.00	1251.72	25034.40	23450.40	11962.00	1:7.55
T6 Indoxacarb 0.015%	1.0	3104.00	2199.07	43981.40	40877.40	29389.00	1:9.47
T7 NSKS 2%	6.0	804.00	758.74	15174.40	14370.40	2882.00	1:3.58
T8 Bt (Biolep) 1 kg/ha	1 kg/ha	1604.00	1011.66	20233.20	18629.20	7140.80	1:4.45
T9 Azadirachtin 0.03%	1.8	954.00	904.49	18089.80	17135.80	5647.40	1:5.92
T10 Control	-	-	574.42	11488.40	11488.40	-	-

* For two spray

Cost of Insecticidal application

Quinalphos	350 Rs/lit	Indoxacarb	2600 Rs/lit	Market price of castor	20 Rs/kg
Alphamethrin	600 Rs/lit	NSKS	5 Rs/kg	Labour charge @ 84 Rs./ day/ labour	
Lufenuron	500 Rs/lit	Bt	1100 Rs/kg	Three labours / hectare for each spray	
Acephate	500 Rs/kg	Azadirachtin	250 Rs/lit		
Profenophos	600 Rs/lit				

Discussion

V. DISCUSSION

Spodoptera litura Fabricius is one of the important polyphagous pests having worldwide distribution. It feeds on majority of crops including castor, tobacco, groundnut, cotton and cabbage and causes economic damage to these crops. The food plants play an important role in the survival and reproductive potential of insects. Published information on different aspects like biometry and intrinsic rate of increase of this pest on different hosts are very scanty. With a view to fill up the lacuna in present investigations were carried out on the following aspects. The results obtained through present investigations are discussed in the light of the available literature in this chapter.

5.1 BIOMETRICAL ANALYSIS

Attempts were made to study the applicability of Dyar's principle to the larval stage of *S. litura*, when the larvae were reared on different host. Dyar (1890) while working with twenty eight species of Lepidoptera concluded that the rate of growth in successive instars, as measured by increasing size of the head capsule was in regular geometrical progression in successive instars by a ratio of about 1.4 and this has been called the Dyar's Law. Fisher's work on *Tortrix pronubana* Hb. (1924) confirmed this conclusion. Miles (1931) found that width of head capsule in

successive instars of four species of Tenthredinidae family follows a regular geometrical progression in initial stage of growth, in the later instars the growth becomes irregular owing to sex differentiation and the occurrence of the pre-pupal stadium.

The results of present studies revealed that the head capsule width of the larvae fall into six distinct groups each indicating an instar, when larvae were reared on castor, tobacco, groundnut, cotton and cabbage. The width of head capsule within an instar did not vary much and there was also no overlapping of size from the first to last instar. Further, the data also indicated that up to the third instar, there was not much variation in the observed head width. However, it was slightly more in the fifth and the sixth instars. Peterson and Haeussler (1928) opined that in case of oriental fruit moth, the measurements of head width of the larvae fall into different groups, which evidently characterize a specific instar. The results of the present study also showed that the estimated head width is almost close to the observed one which suggesting that the head width of successive instars was more or less in geometrical progression as stated in Dyar's Law. The growth ratio of the mean head width of each instar and that of the preceeding one shows the development of larvae during each instar according to the growth ratio.

In the present experiment (Table 58) the mean value of the observed and calculated head width and progression factors are close to

each other which indicated that the width of head capsule of *S. litura* is more or less constant for that particular instar. The observed and estimated progression factors were sufficiently close to indicate the increase in head width follows Dyar's Law. Slight variations in ratios might be due to small number of measurements taken in each instar.

Table 58: Comparison of mean observed values (mm) of larval head capsule width of *S. litura* on different hosts

Host	Instars						Progression factors	
	1st	2nd	3rd	4th	5th	6th	Observed	Estimated
Castor	0.29	0.52	0.79	1.28	1.97	2.99	1.598	1.588
Tobacco	0.27	0.49	0.78	1.28	1.95	2.88	1.608	1.601
Groundnut	0.27	0.47	0.77	1.27	1.96	2.87	1.604	1.606
Cotton	0.23	0.42	0.73	1.22	1.93	2.83	1.660	1.658
Cabbage	0.27	0.45	0.75	1.26	1.94	2.85	1.610	1.615

Almost straight line relationships were obtained in case of all the hosts under study, when the head capsule widths were plotted against the different instars. Thus, it is concluded that there is close approximately between the observed and estimated head widths. The increase in head width of different instars is in a geometrical progression indicating the applicability of Dyar's Law to the larvae of *S. litura* on different hosts. Patel *et al.* (1986), Patel and Chari (1987) and Kharub *et al.* (1993) also reported six larval instars of this pest on cotton, tobacco and groundnut, respectively. However, Mann *et al.* (1995) and Devinder *et al.* (1996) recorded five larval instars on cotton and sunflower, respectively.

Log measurements of larval body length and larval body width in different instars were considered to test the applicability of Prazibran's and Megusar (1912) Rule. They stated that at each moult, all linear dimensions increased by a ratio of 1.26.

The mean body length (mm) ranged from 1.86 to 2.46 (first instar), 3.19 to 3.96 (second instar), 4.98 to 10.32 (third instar), 8.02 to 19.59 (fourth instar), 22.01 to 27.88 (fifth instar) and 34.30 to 43.58 (sixth instar) on different hosts under present study (Table 59). The observed and estimated progression factors for the larvae passed through six instars ranged from 1.774 to 1.912 and 1.775 to 1.854, respectively.

The observed mean progression factors of larval body width when larvae undergone different instars ranged from 1.698 to 1.780 and those of the estimated values varied from 1.660 to 1.697 on different hosts under study (Table 60). These values have shown a deviation from the value of 1.26 as required by Prazibran's rule. Harries and Handerson (1938) concluded that the variation shown in the value of progression factors is too great to provide any support for the theory that the constant has the same value (1.26) for different species. Thus, the data obtained from the present investigation for body length and body width do not support Prazibran's and Megusar's theory.

Table 59 : Comparison of mean observed values (mm) of larval body length of *S. litura* on different hosts

Host	Instars						Progression factors	
	1st	2nd	3rd	4th	5th	6th	Observed	Estimated
Castor	1.86	3.89	10.32	19.59	27.88	37.80	1.884	1.854
Tobacco	2.46	3.96	5.35	8.64	22.74	43.56	1.824	1.775
Groundnut	2.23	3.19	5.19	8.38	22.30	34.30	1.774	1.769
Cotton	1.93	3.43	4.98	8.02	22.01	43.27	1.912	1.854
Cabbage	2.35	3.84	5.14	8.55	22.18	43.58	1.838	1.790

Table 60 : Comparison of mean observed values (mm) of larval body width of *S. litura* on different hosts

Host	Instars						Progression factors	
	1st	2nd	3rd	4th	5th	6th	Observed	Estimated
Castor	0.39	0.79	1.38	2.01	3.02	6.51	1.780	1.695
Tobacco	0.48	0.74	1.26	1.75	3.15	6.51	1.698	1.660
Groundnut	0.42	0.69	1.26	1.69	3.08	6.51	1.748	1.697
Cotton	0.44	0.65	1.21	1.65	3.08	6.13	1.712	1.680
Cabbage	0.44	0.76	1.15	1.68	3.12	6.47	1.726	1.674

The multiple correlation and partial regression analysis were carried out to understand the strength of association between the larval body length (X_1), larval body width (X_2) and head capsule width (Y) of larvae, when passed through six instars on different hosts. The values of coefficient of determination (R^2) ranged from 0.9435 to 0.9967 on these hosts which indicated a very high predictability of head capsule width through larval body length and larval body width.

The investigations on the biometrical analysis of *S. litura* on castor, tobacco, groundnut, cotton and cabbage are carried out for the first time in the present studies, since no published information on these crops are available and therefore, the results could not be discussed in light of published literature.

5.2 BIOLOGY

Observations on the incubation period reveled that the period was not different significantly on different hosts, however, the maximum period was recorded on cotton (3.53 days) followed by on cabbage (3.43 days). The minimum periods of 3.23 and 3.27 days were found on castor and groundnut, respectively. Similar observations were also reported by Balasubramanian *et al.* (1984) for castor and cotton and on groundnut (Kharub *et al.*, 1993 and Arora, 1993).

Larval duration on different hosts ranged from 18.00 (castor) to 23.63 (cotton) days. This period was almost similar on tobacco, groundnut and cabbage. Similar observation of the shortest larval period on castor followed by tobacco, cotton and cabbage was also reported by Sing and Hoi (1972); Singh and Byas (1976); Bhalani and Talati (1984); Patel *et al.* (1987); Matholiya (1997) and Baloliya (2001). Thus, the results obtained through present study are in agreement of the earlier reports.

Data on mean percentage larvae survived on different hosts significantly differed from each other. The maximum percentage larval

survival was obtained on castor (86.67%) followed by tobacco and other hosts. Similarly, the results further indicated that the highest number of pupae were observed on castor and the lowest on cotton, whereas it was more or less equal on groundnut and cabbage. Considering the growth index values, the growth was faster on castor followed by on tobacco. The lower growth index values on cotton and cabbage indicated relatively poor growth on these hosts. Thus on the basis of growth index values, the hosts could be arranged in descending order as: castor > tobacco > groundnut > cabbage > cotton.

The pupal period was also affected, when the larvae were fed on different hosts and it varied from 9.10 (castor) to 9.47 (cotton) but did not differ significantly on tobacco, groundnut and cabbage. Thomas *et al.* (1969) and Balasubramanian *et al.* (1984) reported the pupal period of 9 to 11 and 9.2 days at 25 to 30 °C and 26 to 31 °C temperatures, respectively on castor.

According to Mann *et al.* (1995) the duration of pupal stage on cotton was 7.73 to 10.86 days during June to October and 22.66 days during October in Punjab. Kharub *et al.* (1993) reported the male and female pupal period of 8.6 and 8.4 days, respectively on groundnut, whereas it was 8.06 $\pm$ 0.63 days on cotton (Arora, 1993). Thus the variation in pupal period may be due to sex. However, the pupal period reported by Baloliya (2001) on castor was in close agreement with the present findings.

In the present investigation, the mean oviposition period was longer on castor (7.58 days) followed by on tobacco (7.33 days), while it did not differ significantly on groundnut (6.42 days), cotton (6.75 days) and cabbage (6.50 days). This variability in oviposition duration may be either due to dietary differences or genetically programmed to deposit the eggs for a certain period of time. The differences in oviposition duration were reported 5.6 and 5.0 days on castor and cotton, respectively at 26 to 30 °C temperatures by Balasubramanian *et al.* (1984). This period was extended up to 7.60 days on cotton as observe by Patel *et al.* (1986). Based on the number of eggs laid by the female, the host could be arranged in the following order: castor (2269), tobacco (1819), groundnut (1591), cabbage (1669) and cotton (1592). Kuarub *et al.* (1993) reported 1618.8 eggs on groundnut, while it was 938 $\pm$ 12.2 eggs on cotton as observed by Arora (1993). Almost similar observations were also reported by Baloliya (2001) on castor followed by tobacco and cabbage. Results of the present investigations showed almost similar trend, however, slight variation may be existed due to rearing conditions.

In general, life span from egg to death of adult varied from 39.67 to 45.67 days. This period was almost similar on groundnut (44.88 days), cotton (45.67 days) and cabbage (44.79 days). Considering the total life span of male and females, the hosts can be arranged in descending order as : cotton > cabbage > groundnut > tobacco > castor.

5.3 POPULATION DYNAMICS OF *S. litura* ON CASTOR

In nature the distribution and abundance of animals are determined by combined effect of different components of environment. Weather factors influence the most for build up of the population (Andrewartha and Birch, 1954). Among the various weather factors, temperature, humidity, rainfall, intensity of light and other physical factors play a vital role in population fluctuation of any pest species and have a direct influence on their abundance (Atwal and Bains, 1974). The present studies were carried out to determine the fluctuation of population of *S. litura* during 2003-04 and 2004-05 at Anand Campus, Anand. The results obtained are discussed in light of published literature in this chapter.

5.3.1 Larval population

5.3.1.1 Population trend

The results revealed that the pest infestation commenced from 1st week of October in castor crop. The population showed peak during 2nd week of November and 1st week of December but remained static and then gradually decreased upto 1st week of January. Thanki (1999) also recorded similar trend for the pest activity. Thus, the findings of present study are in conformity of the earliest report.

5.3.1.2 Effect of weather parameters

The population of the pest showed significantly negative correlation with wind speed (WS), whereas positive relationship with

morning relative humidity (RH_1). Further it is evident from the data that minimum temperature (Min. T.), morning and evening vapour pressure and evening relative humidity showed negative correlation with the pest population. On the basis of regression study following equation was derived :

$$Y = 29.749 - 5.750^{*}WS - 0.578\ VP_1 \qquad (R^2 = 0.5762)$$

Earlier, Zaz and Kushwaha (1983) observed the positive correlation between the pest population and mean temperature and relative humidity on cabbage, whereas it was found positive with maximum and minimum temperature and negative with relative humidity on turnip by Malik and Parihar (1996). Thanki (1999) also reported significant negative relationship with minimum temperature, morning and evening vapour pressure and evening relative humidity. Thus, the results of present findings are in agreement with the earlier reports.

5.4 LIFE FECUNDITY TABLE

Life tables are the most useful tools to make quantitative and qualitative evaluation of different host plants. It is also useful to analyze contribution of different life stages during its life cycle in buildup of the pest population. Birch (1948) stated that the life table can be successfully used to determine the growth statistics and to estimate the potential increase of insects reared on different hosts. In present investigations, the rate of increase of *S. litura* on five different hosts *viz.*, castor, tobacco, groundnut,

cotton and cabbage were computed by adopting the method described by Birch (1948) and elaborated by Howe (1953) and Atwal and Bains (1974). Results obtained through the studies are discussed in the light of available literature on *S. litura*.

The results on the basis of survivalship values (lx) of immature stages of *S. litura* showed that the highest survival of immature stages was on castor. The survival on tobacco, groundnut, cotton and cabbage was almost equal. The 'lx' values for these hosts varied from 0.85 to 0.87. The net reproductive rate (Ro) of *S. litura* on castor, tobacco, groundnut, cotton and cabbage were worked out to be 1370.74, 708.27, 819.92, 856.72 and 791.39 females per female, respectively at the end of each generation. Considering the net reproductive rate, the host can be categorized as castor > cotton > groundnut > cabbage > tobacco. The pattern of female birth (mx) was almost similar on all the five hosts under study. The birth of female increased slowly reached a peak, which gradually decreased. Looking to the net reproductive rate castor and cotton were proved to be the most suitable for the multiplication of this pest. More or less similar observations were also recorded by Balasubramanian *et al.* (1988).

The mean length of generation differed considerably on different hosts. It was maximum on cotton (45.48 days). The generation period was 41.61 days on castor, 43.20 days on tobacco, 41.83 days on

groundnut and 44.53 days on cabbage. The mean length of generation on cotton differed slightly from that reported by Dhandapani *et al.* (1989). This difference in mean length of generation might be due to nutritional quality of plant, which was provided as food to be pest during larval development.

The innate capacity for increase in number (rm) ranged from 0.148 to 0.174. On the basis of innate capacity for increase in numbers (rm) descending order of food plant was: castor (0.174), groundnut (0.160), tobacco (0.152), cabbage (0.150) and cotton (0.148). Balasubramanian *et al.* (1988) reported the innate capacity for increase in number (rm) as 0.1935 and 0.1465 females per female per day on castor and cotton, respectively. The slight variation among the findings might be due to difference in nutritional status of food and conditions under which the pest has been reared.

The results of present investigations also showed that on the basis of net reproductive rate (Ro) castor, cotton, groundnut and cabbage occupied first, second, third and fourth rank, respectively, whereas tobacco ranked fifth. This might be due to relatively higher values of generation time, which reduced the value of innate capacity of increase (rm). Birch (1948) suggested that the comparison of two or more population by means of their net reproductive rates may be quite misleading, unless the mean length of generations is same. Further, they suggested that two or more

population may have the same reproductive rate but their intrinsic rates of increase may be quite different because of different length of generation.

The finite rate of increase in numbers (λ) was calculated to be 1.192, 1.166, 1.176, 1.161 and 1.163 on castor, tobacco, groundnut, cotton and cabbage, respectively. Almost similar observations were also recorded on cotton (1.191) and groundnut (1.14) by Dhandapani *et al.* (1989) and Kulkarni and Lingappa (1993), respectively.

The data on stable age distribution of different life stages revealed that the age distribution pattern was more or less similar on cotton, tobacco and cabbage. The stable age distribution of eggs was recorded to be 47.80, 48.51 and 48.17 per cent on cotton, tobacco and cabbage, respectively, whereas it was 50.60 and 52.04 per cent on groundnut and castor, respectively. The maximum contribution of larval stage to the stable age distribution was on cotton (50.64%) followed by cabbage (49.78%), tobacco (49.22%), groundnut (47.24%) and castor (46.08%). The contribution of pupae and adults were negligible as it ranged from 1.33 to 2.00 and 0.16 to 0.25 per cent, respectively. Thus, it was concluded that the population on reaching to the stable age distribution, the immature stages *viz.*, eggs and larvae contributed the highest, whereas it was the lowest by pupae and adult. Similar observations were also reported by Balasubramanian *et al.* (1988) on castor and cotton and by Kulkarni and Lingappa (1993) on groundnut.

The life expectancy of newly deposited eggs was reported to be the lowest on groundnut (16.39 days) and the highest on cabbage (17.98 days) while 17.39, 17.44 and 17.45 days on castor, tobacco and cotton, respectively. The mortality rate in larval stage was comparatively high between 5 to 10 days of pivotal age on all the five crops. Thus, the results obtained from the present study are in close conformity of the earlier findings reported by Balasubramanian *et al.* (1988) on castor and cotton.

The results on survival of immature stages, net reproductive rate (Ro), mean length of generation (Tc), innate capacity for increase in numbers (rm) and finite rate of increase (λ) on tobacco and cabbage could not be discussed and compared with other similar studies due to lack of such information in published literature.

5.5 LIFE TABLES FOR KEY MORTALITY FACTORS

The life tables were constructed on castor to identify the key mortality factors operating under field conditions during 2003–04 and 2004-05. The life table studies indicated that mortality factors operating during the crop season were larval parasite, NPV and unknown factors.

Mortality in egg stage was recorded to be 5.15 to 8.00 (2003-04) and 4.54 to 7.22 (2004-05) was mainly due to egg sterility. Larval mortality ranged from 14.83 to 18.44 and 18.89 to 21.49 per cent of which 2.50 to 7.63 and 1.78 to 3.85 per cent younger larvae were reduced by unknown causes, during 2003-04 and 2004-05, respectively. Further, it

was observed that mortality in older group larvae was recorded mainly due to NPV and unknown causes. The NPV caused 3.64 to 5.56 and 5.71 to 22.50 per cent mortality, whereas 1.82 to 6.00 and 1.52 to 10.00 per cent was due to unknown causes during the year 2003-04 and 2004-05, respectively.

The results further indicated that there were 29.17 to 45.24 and 32.06 to 43.08 per cent mortality during pupal stage, of which highest (45.24 %) was in October and 43.08 per cent in December. The pupae were died due to some unknown factors during 2003-04 and 2004-05, respectively.

Thus, it can be concluded that the larval parasite, *Apanteles beneficus* and NPV, was effective in reducing the population of this pest in castor crop. Thanki (1999) also reported similar results from Gujarat. However, published information on this aspect is very scanty.

5.6 EVALUATION OF NEWER INSECTICIDES AGAINST *S. litura*

Effectiveness of different new insecticides and biopesticides were evaluated against *S. litura* during 2003-04 and 2004-05 under field conditions.

5.6.1 Efficacy against *S. litura*

The insecticidal treatments were applied two times during crop season. Observations on mortality were recorded at 3,5 and 7 days

after each spraying revealed that indoxacarb 0.015, alphamethrin 0.0075, quinalphos 0.05 and profenophos 0.05 per cent proved to be the most effective for the control of this pest, however, among the biopesticides, *Bacillus thuringiensis* (Bt) proved to be the best against this pest as compared to other biopesticides, whereas NSKS 2 per cent found to be the least effective.

Similar results for the efficacy of Polytrin-C 44 0.088 per cent and Bt was also reported by Babu and Subramanian (1973); Grewal *et al.* 1982; Natesan and Balasubramanian (1979) and Venkateswarlu *et al.* (1992). However, information on bio-efficacy of newer insecticides is very scanty and therefore present investigation could not be compared with published literature.

5.6.2 Seed yield

Seed yield data recorded from the plots treated with different insecticides and biopesticides revealed that the highest seed yield (2199.07 kg ha^{-1}) was obtained from plot treated with indoxacarb 0.015 per cent, which was followed by alphamethrin 0.0075 (1907.58 kg ha^{-1}) and quinalphos 0.05 (1620.37 kg ha^{-1}) per cent. The lowest yield was recorded from the plots treated with NSKS 2 per cent (758.74 kg ha^{-1}). Considering the effectiveness and economics of treatments alphamethrin 0.0075 per cent gave highest incremental cost benefit ratio (ICBR) which was followed by quinalphos 0.05 per cent.

Summary and Conclusion

VI. SUMMARY AND CONCLUSION

Investigations were carried out under laboratory as well as field conditions on biometrical analysis, biology, population dynamics, life-tables of *Spodoptera litura* Fabricius on different hosts, ecological life-table of *S. litura* and management of *S. litura* on castor at Anand Agricultural University, Anand during 2003-04 and 2004-05. The main findings of these investigations are summarized herein this chapter.

Biometrical analysis was carried out to test the applicability of Dyar's principle to *Spodoptera* larvae, when they were reared on different hosts. The measurements of head capsule width (mm) of the larvae fall in to six well defined groups, when larvae were reared on castor, tobacco, groundnut, cotton and cabbage. These groups evidently indicated an instar. Further, the observed and estimated head widths were in close approximity and also found to be in more or less geometrical progression. The progression factors (observed and estimated) revealed that the increase in head width during successive instar follows the Dyar's law, when the larvae were reared separately on the five different hosts under study.

Larval body length ranged from 1.86 to 43.58 mm for first to sixth instar, when they were provided with plant parts of castor, tobacco, groundnut, cotton and cabbage. Similarly, the measurements of larval body width ranged from 0.39 to 6.51 mm for one to six instar groups, respectively. The progression factors determined from the body length and

body width indicated the great deviation to provide any support for the theory suggested by Prazibran and Megusar (1912).

Observations on various biological parameters indicated that the incubation period did not differ significantly when this pest was reared on different hosts. However, the maximum period was recorded on tobacco and cotton (3.53 days) followed by on cabbage (3.43 days), groundnut (3.27 days) and castor (3.23 days).

The larval period ranged from 18.00 (castor) to 23.63 days (cotton), but the period did not differ significantly on groundnut and cabbage, respectively. Similarly, the mean percentage survival of larvae on different hosts ranged from 73.33 to 86.67 per cent with highest percentage survival on castor followed by tobacco and groundnut. The pre-pupal period was almost equal on five different hosts. However, the longest period (2.33 days) was observed on cotton and the shortest (2.07 days) on castor. The results on per cent pupae formed on different hosts revealed that the highest percentage of pupae (87.50 %) was formed on castor and the lowest (72.50 %) on cotton, whereas it did not differ significantly, when larvae were fed on groundnut and cabbage. The growth index values indicated that the growth was faster on castor followed by on tobacco. On the basis of the growth index values, the suitability of hosts can be grouped as: castor > tobacco > groundnut > cabbage > cotton.

The pupal period varied from 9.10 (castor) to 9.47 (cotton) days and did not differ significantly, when the larvae were reared on all the

five different hosts. The general life span (irrespective to male and female) from egg to death of adult varied from 39.67 to 45.67 days.

Studies on oviposition period revealed that the mean oviposition period was longer (7.58 days) on castor followed by on tobacco (7.33 days). However, it did not differ significantly, when the adults developed from the larvae fed on groundnut, cotton and cabbage.

Results of mean fecundity per female showed significant difference, when the adults developed from the larvae reared on different hosts. The maximum number of eggs was recorded on castor (2269.25), whereas it was the lowest on groundnut (1591.58).

A study on population dynamics of *S. litura* on castor indicated that the pest infestation commenced from first week of October and its population was almost static from 2nd week of November and attained a peak during 1st week of December but then it showed decreasing trend upto 2nd week of January.

Study on correlation regression for the effect of different weather factors (WF) in fluctuation of the population showed significant negative correlation with wind speed (WS) indicating that increase in the magnitude of this factor resulted in reduction of numbers of *S. litura* larvae.

Among the different weather factors, minimum temperature (MinT), mean temperature (MT), morning and evening vapour pressure and evening relative humidity (RH_2) showed negative correlation with the population.

Investigations on life fecundity tables and age specific distribution revealed that the maximum expectancy of newly deposited eggs was on cabbage followed by castor, tobacco, cotton and groundnut. On the basis of 'lx' value, the highest survival of egg stage was observed on castor followed by tobacco, groundnut, cotton and cabbage.

The highest reproductive rate (Ro) of this pest was recorded on castor, whereas it was the lowest on tobacco. Thus, on the basis of values of reproductive rate, the host can be arranged in descending order as castor > cotton > groundnut > cabbage > tobacco.

Mean length of generation was the lowest on castor (41.61 days), whereas it was recorded 41.83 days on groundnut, 43.20 days on tobacco, 44.53 days on cabbage and 45.48 days on cotton.

The intrinsic rate of natural increase in numbers (rm) ranged from 0.148 to 0.174 females per female per day on different hosts. Considering the values of 'rm' the host can be categorized as: castor > groundnut > tobacco > cabbage > cotton. Similarly, the finite rate of increase in number (λ) ranged from 1.161 to 1.192 females per female per day on different hosts.

Studies on age specific distribution of the pest on different hosts revealed that the eggs and larvae contributed the highest to the population, whereas the contribution of pupae and adults was negligible.

Life tables of *S. litura* were constructed under field conditions to determine the key mortality factor operating in castor crop. The data

indicated that among various factors a larval parasite, *Apanteles beneficus* Viereck was found to be effective in causing reduction in pest population. The extent of parasitism ranged from 4.27 to 5.00 and 10.20 to 15.88 per cent during the year 2003-04 and 2004-05, respectively. Further, it was found that mortality in older group larvae was mainly due to Nuclear Polyhedrosis Virus (NPV) with 3.64 to 5.56 and 5.71 to 22.50 per cent mortality during the year 2003-04 and 2004-05, respectively.

A study on effectiveness of newer insecticides against *S. litura* indicated that among the different insecticidal treatments, indoxacarb 0.015, alphamethrin 0.0075, quinalphos 0.05 and profenophos 0.05 per cent proved to be the most effective in controlling *S. litura* population under field conditions, whereas NSKS 2 per cent found to be the least effective. It has been further observed that among the biopesticides, *Bt* was found to be the best treatment for managing this pest.

Pooled data on grain yield revealed that among the different treatments, the plots treated with indoxacarb 0.015 per cent registered the highest yield (2199.07 kg ha^{-1}) followed by alphamethrin 0.0075 (1907.05 kg ha^{-1}) and quinalphos 0.05 (1620.37 kg ha^{-1}) per cent. The lowest yield was recorded from the plots treated with NSKS 2 per cent (758.74 kg ha^{-1}). Considering the economics of the treatments alphamethrin 0.0075 per cent gave the highest incremental cost benefit ratio (ICBR = 1: 23.15) followed by quinalphos 0.05 (1: 16.37) per cent. Thus, these insecticides can be recommended for the management of *S. litura* in castor.

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Appendices

Appendix I : Trial and error method for the calculation of infinite rate of natural increase (rm) of *S. litura* on castor.

Pivotal age in days x	lxmx	rm = 0.17		rm = 0.18	
		$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$	$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$
0 – 34	-	-	-	-	-
35	0.83	2.86	2.37	2.01	1.67
36	0.83	2.41	2.00	1.68	1.39
37	22.06	2.03	44.78	1.40	30.88
38	81.31	1.72	139.78	1.17	95.13
39	139.89	1.45	202.84	0.98	137.09
40	157.62	1.22	192.30	0.82	129.25
41	168.63	1.03	173.69	0.68	114.67
42	328.38	0.87	285.69	0.57	187.18
43	242.86	0.73	177.29	0.48	116.57
44	144.00	0.62	89.28	0.40	57.60
45	63.12	0.52	32.82	0.33	20.83
46	14.95	0.44	6.58	0.28	4.19
47	6.26	0.37	2.32	0.23	1.44
48	0.00	-	-	-	-
			$\sum e^{(7 - rmx) . (lxmx)}$ = 1351.81		$\sum e^{(7 - rmx) . (lxmx)}$ = 897.89

Appendix II : Trial and error method for the calculation of infinite rate of natural increase (rm) of *S. litura* on tobacco.

Pivotal age in days x	lxmx	rm = 0.15		rm = 0.16	
		$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$	$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$
0 – 36	-	-	-	-	-
37	0.83	4.26	3.54	2.94	2.44
38	0.83	3.67	3.05	2.51	2.08
39	15.85	3.16	50.09	2.14	33.20
40	50.80	2.72	138.18	1.82	92.46
41	80.91	2.34	189.33	1.55	125.41
42	105.87	2.01	212.80	1.32	139.74
43	130.24	1.73	225.32	1.13	147.17
44	148.84	1.49	221.77	0.96	142.89
45	80.66	1.28	103.24	0.82	66.14
46	64.60	1.10	71.06	0.70	45.22
47	20.14	0.95	19.13	0.59	11.88
48	5.52	0.82	4.53	0.51	2.82
49	3.18	0.70	2.23	0.43	1.37
50	0.00	-	-	-	-
			$\sum e^{(7 - rmx) . (lxmx)}$ = 1244.25		$\sum e^{(7 - rmx) . (lxmx)}$ = 813.54

Appendix III : Trial and error method for the calculation of infinite rate of natural increase (rm) of *S. litura* on groundnut.

Pivotal age in days x	lxmx	rm = 0.16		rm = 0.17	
		$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$	$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$
0 – 35	-	-	-	-	-
36	0.81	3.46	2.80	2.41	1.95
37	0.81	2.94	2.38	2.03	1.64
38	39.61	2.51	99.42	1.72	68.13
39	91.07	2.14	194.89	1.45	132.05
40	127.78	1.82	232.56	1.22	155.89
41	150.86	1.55	233.83	1.03	155.38
42	113.48	1.32	149.79	0.87	98.73
43	96.39	1.13	108.92	0.73	70.36
44	81.42	0.96	78.16	0.62	50.48
45	57.28	0.82	46.97	0.52	29.78
46	33.02	0.70	23.11	0.44	14.53
47	21.18	0.59	12.50	0.37	7.84
48	6.21	0.51	3.17	0.31	1.92
49	0.00	-	-	-	-
			$\sum e^{(7 - rmx) . (lxmx)}$ = 1188.50		$\sum e^{(7 - rmx) . (lxmx)}$ = 788.68

Appendix IV : Trial and error method for the calculation of infinite rate of natural increase (rm) of *S. litura* on cotton.

Pivotal age in days x	lxmx	rm = 0.14		rm = 0.15	
		e^{7-rmx}	$e^{(7-rmx).(lxmx)}$	e^{7-rmx}	$e^{(7-rmx).(lxmx)}$
0 – 38	-	-	-	-	-
39	0.80	4.66	3.73	3.16	2.53
40	0.80	4.06	3.25	2.72	2.18
41	23.42	3.52	82.44	2.34	54.80
42	31.17	3.06	95.38	2.01	62.80
43	77.86	2.66	207.11	1.73	134.70
44	97.62	2.32	226.48	1.49	145.45
45	167.86	2.01	337.40	1.28	214.86
46	234.11	1.75	409.69	1.10	257.52
47	122.66	1.52	186.44	0.95	116.53
48	49.14	1.32	64.86	0.82	40.29
49	34.17	1.15	39.30	0.70	23.92
50	8.97	1.00	8.97	0.61	5.47
51	5.56	0.87	4.84	0.52	2.89
52	2.58	0.76	1.96	0.45	1.16
			$\sum e^{(7-rmx).(lxmx)}$ = 1671.84		$\sum e^{(7-rmx).(lxmx)}$ = 1064.96

Appendix V : Trial and error method for the calculation of infinite rate of natural increase (rm) of *S. litura* on cabbage.

Pivotal age in days x	lxmx	rm = 0.15		rm = 0.16	
		$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$	$e^{7 - rmx}$	$e^{(7 - rmx) . (lxmx)}$
0 – 37	-	-	-	-	-
38	0.80	3.67	2.94	2.51	2.01
39	0.80	3.16	2.53	2.14	1.71
40	11.41	2.72	31.04	1.82	20.77
41	37.79	2.34	88.43	1.55	58.57
42	78.88	2.01	158.55	1.32	104.12
43	95.84	1.73	165.80	1.13	108.30
44	148.80	1.49	221.71	0.96	142.85
45	172.11	1.28	220.30	0.82	141.13
46	118.78	1.10	130.66	0.70	83.15
47	96.95	0.95	92.10	0.59	57.20
48	15.44	0.82	12.66	0.51	7.87
49	8.01	0.70	5.61	0.43	3.44
50	3.38	0.61	2.06	0.37	1.25
51	2.40	0.52	1.25	0.31	0.74
			$\sum e^{(7 - rmx) . (lxmx)}$ = 1135.63		$\sum e^{(7 - rmx) . (lxmx)}$ = 733.12

Appendix VI : Weekly meteorological data recorded at Observatory of College Farm (October to January, 2003-04 and 2004-05)

Std. week	Temperature °C			Relative humidity (%)			Vapour pressure			Wind speed (kmph)	Rainfall (mm)	Bright sunshine (hrs.)
	Max.	Min.	Mean	RH_1	RH_2	MRH	VP_1	VP_2	MVP			
						2003-04						
40	35.46	23.17	29.32	84.85	43.19	64.02	19.99	18.25	19.12	1.43	0	9.20
41	35.79	22.01	28.90	84.67	33.40	59.04	18.85	14.41	16.63	1.99	0	9.93
42	35.89	18.67	27.28	77.19	29.11	53.15	14.96	12.47	13.72	1.59	0	9.96
43	35.21	16.14	25.68	83.05	30.40	56.73	13.24	12.46	12.85	1.19	0	9.71
44	35.34	19.31	27.33	78.44	37.44	57.94	14.84	15.89	15.37	2.10	0	9.91
45	35.23	19.70	27.47	85.50	31.92	58.71	15.83	12.93	14.38	1.50	0	9.56
46	33.37	16.59	24.98	88.88	30.14	59.51	13.40	10.83	12.12	1.23	0	9.44
47	32.33	18.01	25.17	77.20	40.72	58.96	13.52	14.48	14.00	1.73	0	8.53
48	32.14	16.40	24.27	85.75	33.05	59.40	12.80	11.45	12.13	1.43	0	9.34
49	32.50	13.40	22.95	93.24	31.03	62.14	11.48	11.04	11.26	0.99	0	9.36
50	30.87	14.46	22.67	80.66	37.16	58.91	11.08	11.67	11.38	1.71	0	8.91
51	26.90	11.63	19.27	79.61	42.74	61.18	9.14	11.24	10.19	2.99	0	9.21
52	26.34	10.61	18.48	81.12	37.03	59.08	8.54	9.26	8.90	2.35	0	8.88
1	26.30	10.80	18.55	82.90	42.10	62.50	9.10	10.00	9.55	3.20	0	8.70
2	28.30	11.00	19.65	82.60	33.40	58.00	8.60	9.70	9.15	2.50	0	9.00
						2004-05						
40	33.50	25.40	29.50	90.30	60.00	75.15	22.90	22.80	22.85	1.80	1	6.80
41	33.30	21.90	27.60	83.90	48.20	66.05	18.70	16.60	17.65	2.30	0	8.00
42	35.10	18.60	26.90	84.20	26.40	55.30	15.40	10.90	13.15	1.00	0	9.60
43	35.80	18.10	27.00	79.80	21.50	50.65	14.40	9.10	11.75	1.10	0	9.70
44	34.40	18.70	26.60	73.80	33.20	53.50	13.40	12.70	13.05	1.40	0	8.90
45	33.30	18.90	26.10	65.70	36.40	51.05	11.80	13.80	12.80	1.80	0	9.30
46	34.80	19.80	27.30	74.30	36.10	55.20	14.30	14.00	14.15	1.20	0	9.10
47	34.10	15.90	25.00	90.50	29.10	59.80	13.30	11.10	12.20	0.60	0	8.90
48	32.70	15.10	23.90	87.90	30.10	59.00	12.10	10.50	11.30	0.80	0	9.40
49	31.10	14.00	22.60	86.10	33.90	60.00	11.00	11.00	11.00	1.10	0	9.40
50	30.70	12.60	21.70	78.90	32.70	55.80	9.30	10.50	9.90	1.50	0	9.50
51	30.00	12.30	21.20	92.50	37.10	64.80	10.40	10.80	10.60	1.10	0	9.00
52	27.80	14.80	21.30	81.70	57.00	69.35	11.00	14.90	12.95	1.40	0	7.00
1	26.50	9.80	18.15	82.20	36.90	59.55	7.90	8.90	8.40	2.10	0	7.80
2	25.80	10.00	17.90	71.40	35.50	53.45	7.10	8.50	7.80	2.10	0	8.80